NCCARF
National
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Research Facility

Synthesis and Integrative Research
Final report

Supporting evidence-based adaptation decision-making in the Australian Capital Territory: A synthesis of climate change adaptation research

AECOM

SUPPORTING EVIDENCE-BASED ADAPTATION DECISION-MAKING IN THE AUSTRALIAN CAPITAL TERRITORY

A synthesis of climate change adaptation research

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The role of NCCARF is to lead the research community in a national interdisciplinary effort to generate the information needed by decision-makers in government, business and in vulnerable sectors and communities to manage the risk of climate change impacts.

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Shortened forms

ACR	Australian Capital Region
ACT	Australian Capital Territory
ACTPLA	ACT Planning and Land Authority
AEP	Annual Exceedance Probability
BCA	Building Code of Australia
BoM	Bureau of Meteorology
CALD	Culturally and Linguistically Diverse
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSO	Community Service Organisation
DCCEE	Australian Department of Climate Change and Energy Efficiency
DECCW	(NSW) Department of Environment, Climate Change and Water
DEFRA	(UK) Department for Environment, Food and Rural Affairs
DoHA	Australian Department of Health and Ageing
DRR	Disaster Risk Reduction
DPI	(NSW) Department of Primary Industries
FORNSAT	Forum for NCCARF Interaction with States and Territories
GIS	Geographical Information System
ILM	Integrated Land Management
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
NCCARF	National Climate Change Adaptation Research Facility
NDRRA	Natural Disaster Recovery Relief Arrangements
NGO	Non-governmental Organisation
NSW	New South Wales
NT	Northern Territory
OEH	Office of Environment and Heritage
PCF	Policy Choice Framework
QLD	Queensland
QUT	Queensland University of Technology
SA	South Australia
SAFECOM	South Australian Fire and Emergency Services Commission
SME	Small to Medium Sized Enterprise
VCAT	Victorian Civil and Administrative Tribunal
VIC	Victoria
WA	Western Australia

EXECUTIVE SUMMARY

Project background

A growing recognition of inevitable global climate change has led to significant research investment aimed at understanding the impacts of climate change and how to best adapt to these changes. As part of this, the Australian Government established the National Climate Change Adaptation Research Facility (NCCARF) in 2008 to harness Australian research capabilities to support adaptation decision-making.

What is adaptation?

This project utilises the Intergovernmental Panel on Climate Change (IPCC) definition of adaptation to determine research for inclusion in this synthesis. The IPCC defines adaptation as "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 WG2 2007).

In 2012, NCCARF commissioned this project, a synthesis of the research for each Australian state and territory, to answer a fundamental question: "What are the common emerging adaptation research lessons that can be used by state and territory decision-makers, particularly with regards to policy-setting?"

This report for the ACT is one of seven reports produced by AECOM for this project. A report was created for each state and territory with the exception of Tasmania. A Tasmanian report was produced separately by the University of Tasmania.

Current and future climate in the ACT

- Long-term temperature increases have been observed for the ACT, particularly in the last ten years. This is modelled to continue and result in a significant increase in the number of extreme heat days as well as an increase in the frequency and intensity of bush fires.
- Average yearly rainfall is predicted to remain stable, although a higher proportion is expected to fall in summer and autumn. The frequency and intensity of storm and extreme rainfall events is expected to increase.
- Snow in the alpine regions of the ACT has declined by 30 percent since 1954.

Climate change impacts

- Health and wellbeing impacts of these changes may include physical injury due to bushfire, extreme weather and heat-related illness. Impacts on the health services sector are expected due to increased demand, resource constraints and damage to supporting infrastructure.
- Primary production is expected to be impacted by reduced rainfall, increased temperatures and physical damage to assets and infrastructure.
- The natural environment in the ACT is vulnerable to climate change impacts, particularly in alpine and wet forest areas, and where existing ecosystem fragmentation has occurred.
- Infrastructure and settlements will be impacted by increases in extreme weather including flooding, as well as bushfire activity. Water security is an existing issue for the ACT and is predicted to be made worse by reduced rainfall to catchment, and increases in flooding resulting in reduced water quality.
- Tourism in alpine and wine growing areas is likely to be impacted by climate change.

State/territory government's role in adaptation

The purpose of this project is to synthesise adaptation lessons relevant to decision-makers in state and territory government. State/territory Governments have an essential role to play in supporting adaptation to climate change. States and territories have direct involvement in managing a range of assets and government services, and as a result have a significant role in direct adaptation actions. The ACT's *Weathering the Change* action plans outline priority actions to enable Government agencies to respond to climate change effectively.

States and territories also play a role in creating an institutional, market and regulatory environment that supports and promotes adaptation to climate change. The *Weathering the Change* action plans also include vulnerability assessments for the territory and recommend changes to urban development and public space development guidance to respond to climate change impacts

Research collected for synthesis

The project has drawn on a broad range of published research, including draft NCCARF research reports not yet publicly available. The majority of research utilised for the synthesis was funded by NCCARF. However, over 450 research reports were gathered in total from Australian journals and publications and then included in the database that accompanies this project. Up to 15 pieces of research specific to each state/territory but not part of the NCCARF-funded research pool were selected and reviewed for synthesis in addition to the NCCARF reports. This research was selected based on its relevance to state/territory government policy.

The figure below maps the study locations and regions within the ACT examined in the research included in this synthesis. This map demonstrates that research was conducted in Canberra and Canberra Nature Park. Research also occurred within the regions of the Australian Alps and the Murray-Darling Basin, of which the ACT is part. Most of this research focused on adaptation issues related to natural resource management. Some research examined also covered the entire territory.

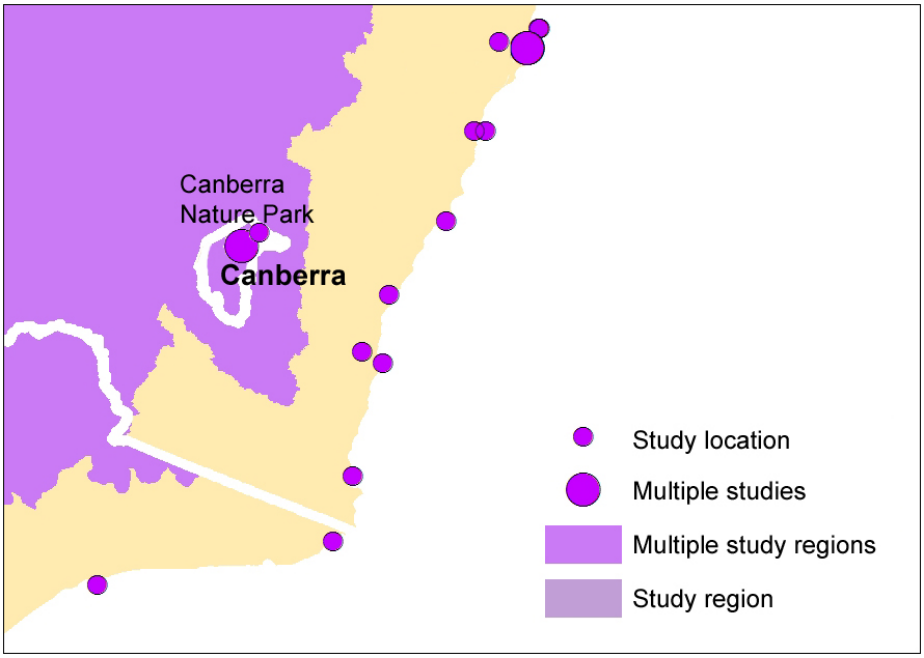


Figure ES: Case study locations of synthesis research in ACT

Synthesis of findings by theme

The role of a synthesis is to value add to existing research by breaking down individual research reports and aggregating findings to form a new whole based on common threads or themes of learning. The main themes utilised in this synthesis are: increasing resilience and adaptive capacity; learning from experience; costing, financing and funding adaptation; limits and barriers to adaptation; maladaptation; and the timing and scale of adaptation. It should also be noted that, due to the nature of the research reviewed, this synthesis largely presents broader findings rarely specific to an individual state/territory. The primary research findings are summarised below under these key themes.

Increasing resilience and adaptive capacity

Adaptation actions are largely centred on increasing a community or system's adaptive capacity and resilience and thereby reducing its vulnerability. However, as the research indicates, determining an effective method by which to increase resilience can be challenging.

Adaptation responses and emergency assistance need to take into account a community's short- and long term challenges, including broader socio-economic issues. It is also important that preparedness is holistic and tested for robustness (Kiem et al. 2010a, Boon et al. 2012D[1]; Sherval and Askew 2012, Black et al. 2013D). At the community level, government disaster assistance can deter residents from securing insurance and can in some instances facilitate departure from a community post-disaster (Boon et al. 2012D). Limited assistance from government or insurers for pre-disaster preparation has been trialled. It is also important to remember that some communities are inherently more vulnerable than others and that community and system vulnerability may change over time (Kiem et al. 2010a, Hanson-Easey et al. 2013D, Boulter 2012).

Community connectedness and the presence of local networks were found to be strong contributors to community resilience and recovery (Boon et al. 2012D). State/territory government can help guide local efforts and initiatives and support community service organisations in their efforts to assist communities (Boon et al. 2012D, Mallon et al. 2013D). A useful starting place for collaboration for adaptation is disaster risk management, as these arrangements are historically and currently formed around interagency and intergovernmental approaches (Howes et al. 2013D).

Building resilience and adaptive capacity also relies on the need to better consider messaging and communication. Engagement can help increase community preparedness, create ownership of and buy-in for adaptation options, improve social cohesion, and can increase confidence in governance processes. Clearly articulating adaptation goals (together with options) and using shared terminology are seen as key to engaging the community (Kiem et al. 2010b, Hadwen et al. 2011, Howes et al. 2013D, Johnston et al. 2013D). In addition, it is important to use bespoke, tailored messaging to reach intended audiences and to distribute information through multiple, diverse channels (Boon et al. 2012D, Hanson-Easey et al. 2013D, Reser et al. 2012).

For natural systems, current efforts to improve habitat protection are considered the optimal action for assisting the majority of species adapt to climate change within the budgetary limitations. However policy and management needs to transition to ecosystem-based approaches which seek to maintain function. Adaptive management and the maintenance and improvement of natural systems are increasingly recognised as the most effective approaches. Focusing on facilitating change rather than resisting impacts, assists in maximising the inherent adaptive capacity of ecosystems (Doerr et al 2011). This approach also recognises the impact of existing, non-climatic changes on ecosystems rather than viewing climatic changes in isolation.

In primary production systems, adaptation will largely be driven by the private sector, however, government still has a key role to play in helping set the right policy conditions and through the provision of appropriate incentives. Implementation of market-based instruments, such as water trading, needs to better consider broader social and economic impacts including the capacity of participants to engage in change.

Learning from experience

Adaptation planning will be informed by lessons learned from past events. Recent events (drought, bushfire, floods and storms) have resulted in various policy responses across the country, enabling rapid mobilisation of resources across all levels of government (Howes et al. 2013D).

However, prior experience with natural disasters can be unpredictable in its influence on community resilience. Communities with a collective memory of a crisis may be able to respond with adaptive change more easily than those with lack of experience; however, despite past experience, many communities still do not take steps to prepare for the next event (Kiem et al. 2010a, King et al. 2012D).

Preparedness for one disaster, such as drought, can also make residents and agencies less concerned or prepared for other potential risks, such as floods (Bird et al. 2011, QUT 2010).

Basing decisions on past experiences will become increasingly risky. There is a tendency to stay within known parameters and uncertainties, yet there is a growing need to understand system-wide properties at scales and within timeframes beyond the normal comfort zone of most decision-makers (Albrecht et al. 2010). Furthermore, because of the urgency to re-build quickly, adaptation measures implemented after extreme events may not take

[1] Note that references ending in capital 'D' are draft NCCARF research reports; the date shows the year they were made available for incorporation into this synthesis report.

adaptation opportunities into account or be fit for purpose with continued climate change and may increase vulnerability in the longer-term (Kiem et al. 2010a; Albrecht et al. 2010).

Extreme events can also provide an impetus for overdue and unpopular adaptation actions (Kiem et al. 2010a) and can enable governments to mandate change, making implementation of actions progressively more affordable (Mason and Haynes 2010). However, the opposite can also be true. For some disasters, attitudinal barriers, such as the common belief that excessive heat is not a threat in a warm country, can prohibit planning and action. Public education campaigns are recommended (QUT 2010).

Costing, financing and funding adaptation

Adaptation options entail varying costs, both in terms of time and resources involved in their implementation and maintenance as well as with respect to the risks involved (Hadwen et al. 2011). Robust costing must take into account a wide range of direct and indirect impacts of both climate change itself and the responses put in place. The effectiveness of some options may decrease as climate change continues or as other factors modify the impacts. The return on adaptation needs to be considered beyond the short term and in relation to the distribution of costs and benefits to the broader community.

Disaster relief funding is considered by some to be over-generous and untargeted, and its ability to increase resilience to disaster under current arrangements is questioned (Wenger et al. 2012D). It also frequently does not provide assistance that takes into consideration a local government's capacity to commence emergency works or the longer-term cost impacts of the extreme event (Verdon-Kidd et al. 2010).

Consideration of who pays for adaptation is also an ongoing issue for many decision-makers. Economic tools that estimate specific costs and potential benefits throughout the community can help inform sensible choices about which adaptations, or suite of adaptations, are likely to yield more benefits than they cost to implement (Fletcher et al. 2013D). Currently there is limited research testing how adaptation costs and benefits might be distributed through the community.

Insurance is generally considered an important adaptation tool to help defer climate change risks, particularly in the private sector. However, there are limitations associated with insurance arrangements, individual behaviours and government responses to natural disasters. There is also limited practice by insurers to promote or encourage actions that reduce or avoid future risks associated with climate change (Bird et al. 2011). Ultimately, in the case of a disaster when people are not insured it is the government that bears the risk.

Apart from water trading, there are few tested market-based mechanisms for adaptation. Market-based approaches to adaptation are particularly important to encourage financing of physical assets and infrastructure.

Limits and barriers to adaptation

Understanding the limits and potential barriers to adaptation can help decision-makers determine more practical and legitimate responses to climate change and better engage with stakeholders (Morrison and Pickering 2011). The primary limitations identified in the research are as follows:

- *Lack of community support.* Public opposition and poor communication with stakeholders can derail adaptation implementation (Haynes et al. 2011, Poloczanska et al. 2012, Petheram et al. 2010). Varying perceptions of adaptation interventions among stakeholders can also be a major source of conflict (Gross et al. 2011, Evans et al. 2011).
- *Current institutional and legislative frameworks.* Practical management strategies at the local or state/territory level can be constrained by higher level government legislation, which may not take into account local conditions (Hadwen et al. 2011, Robson et al. 2013D).

  Institutional arrangements can also create barriers for effective collaboration, such as the relatively little transfer of expert personnel between the planning, building and insurance professions (King et al. 2012D).
- *Capacity and resource constraints.* Resource and capacity constraints can relate to financial or human capital limitations.
- Local governments, in particular, find long-term, large adaptation projects are beyond their capabilities (Mukheibir et al. 2012). There is also often an issue of split incentives, where the person able to fund an adaptation intervention is not the one who benefits in terms of avoided costs.
- *Lack of system understanding.* Unknown thresholds of ecological resilience and lack of understanding about the interconnectivity within ecosystems limit the identification of effective adaptation options (Hadwen et al. 2011).

- *Lack of accessibility to-up-to-date and relevant information.* There is a distinct lack of coordination of existing databases and data-sharing arrangements between relevant authorities (Hadwen et al. 2011).

Maladaptation

Adaptation-related decisions intended to reduce climate change impacts may instead increase vulnerability. This problem of increasing risks from adaptation is often termed 'maladaptation'. Maladaptation can occur when the connections and interdependencies of systems are underestimated, particularly in the context of natural ecosystems (Hadwen et al. 2011). Therefore, it is critical to the success of adaptation activities that the connectivity between ecosystem and human systems is considered within the decision-making process. A number of climate change adaptation and mitigation policies also have the potential to negatively affect the most vulnerable sectors of society due to the inequitable distribution of economic impacts (Mallon et al. 2013D).

Timing and scale of adaptation

The timing for and scale at which adaptation is best delivered remain fundamental questions. Adaptation will continue to be a series of reactions to environmental and social changes – some quickly executed in response to emergencies, others more autonomously in response to slowly changing social and economic conditions (Gross et al. 2011).

Government and communities have tended to favour short-term and responsive approaches; this can make adaptation more difficult to initiate and more expensive (Stanley et al. 2013D). Adaptation actions need to take a long term view to be effective (Hadwen et al. 2011). Having more flexible and dynamic policy and planning that looks beyond political cycles is needed for this forward thinking approach.

At the same time, the windows for adaptation opportunity following extreme events are relatively short, largely due to current funding arrangements and community expectations. Rapid recovery may hinder adaptation, as new knowledge can take time to incorporate into existing regulations and guidelines (e.g. revised building codes). However, there is a need to act quickly, while the issue remains within community memory and before complacency sets in (Helman et al. 2010).

Triggers need to be considered for extreme events as the increasing frequency of climate-related events is changing the perception of what is an extreme and what is 'normal climate' (Kiem et al. 2010a). This is typified by changes in drought policy responses in Australia over the past 20 years which now see drought as part of normal climate, not as an extreme event. In light of this, disaster management arrangements need to be reviewed.

Finally, it is important to recognise that doing nothing may be an appropriate adaptation response if and only if (Garnett et al. 2012D):

- full consideration of the potential consequences has been given;
- there is ongoing monitoring of climate change risks; and
- there is flexibility to recognise and respond to changed circumstances in a timely manner.

Synthesis of findings by sector

A primary purpose of this synthesis was to look across sectors and to integrate and aggregate findings into common threads or themes of learning. This is particularly important in adaptation as responding to climate change largely requires a holistic, systems approach to avoid maladaptation and to manage risks (including non-climatic threats) over the long-term. However, this report also contains lessons relevant to specific sectors, particularly for natural resource management, primary production and land use planning. It is also important to note that in no way did the research reviewed comprehensively cover any individual sector. A few of these findings are also specifically relevant to the ACT. The table below provides a summary of the key findings by sector.

Key findings for the ACT by sector

	Key findings related to adaptation and natural resource management: - Existing management strategies will lessen the impacts on ecosystems, but the objectives of conservation and management plans will need to be reconsidered in the context of longer-term climate change. AECOM sees this as being particularly relevant for monitoring and review of the Nature Conservation Strategy. - Habitat protection is currently considered the optimal action for assisting most species adapt to climate change within budgetary limitations. However, adaptation also needs to take an ecosystem-based approach where resources are directed towards a suite of actions. Effective adaptation requires adaptive management, meaning actively experimenting with actions and learning from past activities. - There are conflicting conclusions regarding whether water pricing reduces water demand.
	Key findings related to agriculture, fisheries and forestry: - Diversification is the effective strategy for mitigating climate-induced variability. - Adaptation will be primarily driven by private sector responses, but government needs to play a supporting role to ensure the effectiveness of adaptation responses. - Individual farms have coped with periodic events through a range of management and behavioural changes. The effectiveness of these options in the long term needs to be considered.
	Key findings related to infrastructure, communities and land use planning: - There are issues of continued expansion of populations into at-risk areas particularly with regard to bushfire and flash flooding risk. - Regulatory instruments in land use planning need to have a precautionary approach, including greater flexibility to support adaptation. - Climate change adaptation programs targeted to Indigenous communities should focus on empowering communities to identify and implement their own responses.
	Key findings related to health and wellbeing: - There is need for a consistent heatwave policy for the management of aged care facilities. - Territory government should ensure adequate health services are available, both during and for the longer-term after disaster events
	Key findings related to business and industry: - Adaptation action within small and medium businesses may be resource constrained.

Conclusions

The complexity of climate change adaptation cannot be underestimated. A wide range of issues, including federal and state/territory policy contexts, local institutional constraints, short and long term climate variability, local community needs and environmental conditions play a role. As pointed out by Gross et al. (2011) “adaptation to climate change should be considered as one aspect in a complex, ever changing set of environmental, social and economic circumstances.” (p. 77). There are also clear challenges associated with the scale of adaptation required, the timing of when to introduce interventions and how interventions are best delivered. Improvements in climate change science can only partially reduce this uncertainty and adaptation planning must accept this fact.

These uncertainties highlight the need for flexibility, both as new information emerges and as society evolves. Climate change uncertainties are not the only constraints, however. Changes within society and the environment – both in response to climate change and other forces and their influence on adaptive capacity and vulnerability – remain some of the greatest limits to effective adaptation. From these changes, values and priorities will also adjust and will need to be captured in adaptation objectives and actions.

Responses to recent extreme events have been examined to identify potential adaptation lessons, particularly with regards to floods, bushfires and drought. While it is critical that we learn from and address the many issues that arise from these events, the potential influence of further climate change has not been considered in order to identify where responses beyond ‘business as usual’ may be necessary. Further opportunities are lost by the rush to restore communities and meet shorter-term needs. The question of whether experience with disaster events improves community resilience also remains inconclusively answered – it appears that it depends on a range of factors, unique to each location, each event and each point in time. However experience from extreme events also brings hope. Stories of autonomous self- organisation and neighbourhood support highlight the need to continue efforts that strengthen a sense of community and ultimately improve adaptive capacity. Local knowledge provides considerable assets in the form of social capital and natural capital, demonstrating innovation in the face of adversity. Recognition and promotion of these behaviours needs to be considered in community and targeted by support programs.

Key lessons for state and territory government decision makers

Monitor and evaluate existing adaptation practices for ongoing adaptation. Monitoring is essential to evaluate the effectiveness of current adaptation options, but it also critical for continuous improvement, to build trust with stakeholders, and to effectively implement adaptive management.

Increase effort in identifying adaptation opportunities and promoting positive change. While there is a need to continue to prioritise adaptation aimed at reducing the risk of harm and in evaluating the limits and barriers of adaptation, potential opportunities also need to be identified.

Clearly define specific adaptation objectives. Decision-making, implementation and evaluation require an understanding of the government’s appetite for risk and what outcomes are expected. Objectives also need to be defined in consultation with stakeholders.

Ensure structures and institutions are flexible and can react to emerging issues and unforeseen events. The research reviewed for this synthesis frequently reiterated the need to ensure governance systems are flexible in order to respond to unforeseen events as well as incremental changes. Flexibility will also allow for continuous learning, which is essential for adaptive management.

Continue efforts to build community cohesion. Building a sense of community is important to increase adaptive capacity and resilience and will have a range of benefits beyond climate change adaptation.

Avoid calm weather planning. Taking a risk-based approach that factors in both experience from past extreme events and future potential climate change is a more robust approach for adaptation planning.

Create opportunities for greater engagement with researchers. To take advantage of research and to support better adaptation planning, government decision-makers need early and frequent engagement with the research community.

1. Introduction

1.1 Project background

Over the past two decades, climate change activities by governments around the world have largely focused on reducing atmospheric greenhouse gas concentrations in an attempt to avoid dangerous climate change. However, a growing recognition of the inevitable impacts of climate change has led to significant research investment aimed at understanding the impacts of climate change and how to best adapt to these changes.

In response to climate change, the Australian Government established the National Climate Change Adaptation Research Facility (NCCARF) in 2008 to harness Australian research capabilities to support adaptation decision-making. The NCCARF program, together with research outcomes from other Australian research institutions, constitutes an important part of the growing body of climate change adaptation knowledge for Australia's states and territories. Emerging from nine research plans for key sectors of Australian society, more than 100 research projects have been funded to support decision-makers in climate change adaptation.

NCCARF has commissioned a synthesis of research outputs to date for each Australian state and territory. The intent of this report is to inform policymakers and other interested parties of relevant research for Australian Capital Territory (ACT) and identify what strategic implications and lessons can be learned from this research. At the same time, this synthesis is intended to identify transferable lessons between regions and sectors while also identifying emerging research gaps at both the state/territory and national level. It also seeks to present findings and analysis in a way that will enhance adaptation understanding of decision-makers in state/territory government.

This report draws together and presents key findings and lessons from individual NCCARF research reports, and a selection of other supporting studies identified through a literature review. This report has been shaped by the needs identified by state and territory government representatives participating on NCCARF's forum for engagement with state and territory government, FORNSAT.

Adapting to climate change

This project utilises the Intergovernmental Panel on Climate Change (IPCC) definition of adaptation to determine research for inclusion in this synthesis. The IPCC defines adaptation as "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 WG2 2007). As such, the literature gathered and synthesised for this project is *not* focused on climate change science, climate change modelling, climate change risk or vulnerability assessments, although it is acknowledged that these often form a critical element of adaptation planning. It is focused on research that tests or discusses *responses* to climate change that is how natural or human systems can adjust to unavoidable climate impacts and the effectiveness of these adjustments in reducing vulnerability and adverse effects.

1.2 Report structure

This report consists of seven sections and four Appendices. Table 1 displays the main objectives and content of each section.

Table 1: Objectives and content of report sections

Report section	Objectives	Content
1.0 Introduction	To introduce the project background and purpose; to place the project in the context of the roles and challenges for territory government.	Project background; scope and methodology; description of the role of government in adaptation; discussion of the adaptation challenge for government and research.
2.0 The ACT climate challenge	To describe the climatic challenge faced by the ACT and the ACT's existing adaptation priorities and actions.	Description of current and future climate conditions; key climate change impacts facing ACT; discussion of the ACT's current adaptation priorities and activities.
3.0 Research relevant to the ACT	To provide an overview of the research collected for the synthesis and its geographical relevance.	Total number of research studies gathered; list and map of research reports with the ACT-specific case studies.
4.0 Research findings	To synthesise research reviewed based on common themes of learning for territory government policy and decision-making.	Key findings and supporting research by identified themes and sectors. Also includes a list of practical adaptation options identified in the research.
5.0 Policy and research engagement	To capture lessons regarding how the intersection of and interactions between policy and research may be improved.	Key findings from the research regarding improving researcher and decision-maker engagement; research gaps regarding the application of the research findings for specific end users.
6.0 Conclusions	To summarise the fundamental challenges facing territory government decision-makers and the key lessons.	Description of the adaptation challenges and potential policy implications; summary of identified lessons for decision-makers.
Appendix A	Appendix A provides an overview of early consultation with FORNSAT representatives about their needs for this project.	
Appendix B	Appendix B provides a list of the nationally relevant NCCARF research projects. This list of projects does not contain case studies specific to an Australian state or territory.	
Appendix C	Appendix C provides summaries of all NCCARF-funded research that contains a case study within the ACT.	
Appendix D	Appendix D provides a list of all NCCARF-funded research reports excluded from the synthesis and reason for exclusion.	
7.0 Bibliography	To capture a full list of research reports reviewed for this project.	The bibliography includes all research reviewed for the synthesis, as well as cited research. Research reviewed but not cited also informed the thinking of this project.

Icon key	
	Natural environment
	Agriculture, fisheries and forestry
	Infrastructure and communities
	Health and well being
	Business and industry
	Emergency management
	Government and governance
	Tools

Sector icons

Icons are presented throughout this document to represent the sectors, or themes, the information relates to or to indicate whether it provides a tool or framework to assist the end-user.

1.3 Scope and methodology

This project sought to identify relevant climate change adaptation research for each state and territory government while considering the transferability of research findings between jurisdictions. In addition to research commissioned by NCCARF, a scan of relevant scientific journals and Australian government websites was undertaken. The research reports collected during this scan are included in a database that accompanies this report, and a subset of this research is included in this synthesis report. The database is a searchable tool outlining NCCARF and non-NCCARF adaptation research in Australia.

The project has taken a broad view of published research: it has not been limited to peer-reviewed literature and it incorporates findings from NCCARF's draft research reports some of which may not yet be in the public domain. The literature gathered and synthesised for this project is also *not* focused on climate change science, climate change modelling, climate change risk or vulnerability assessments, although it is acknowledged that these often form a critical element of adaptation planning. The research scan instead focused on research that tests or discusses *responses* to climate change, that is, how natural or human systems can adjust to unavoidable climate impacts and the effectiveness of these adjustments in reducing vulnerability and adverse effects. In addition, the report focuses on research that can inform directed and planned adaptation, particularly in relation to the roles and responsibilities of state and territory governments.

A summary of the methodology is outlined in Figure 1. Broader adaptation research occurring at other Australian locations is considered where it has been deemed that this research is relevant to the ACT. There is a growing body of international research which may also provide insights for adaptation planning and implementation in the ACT, but this information was beyond the scope of this project.

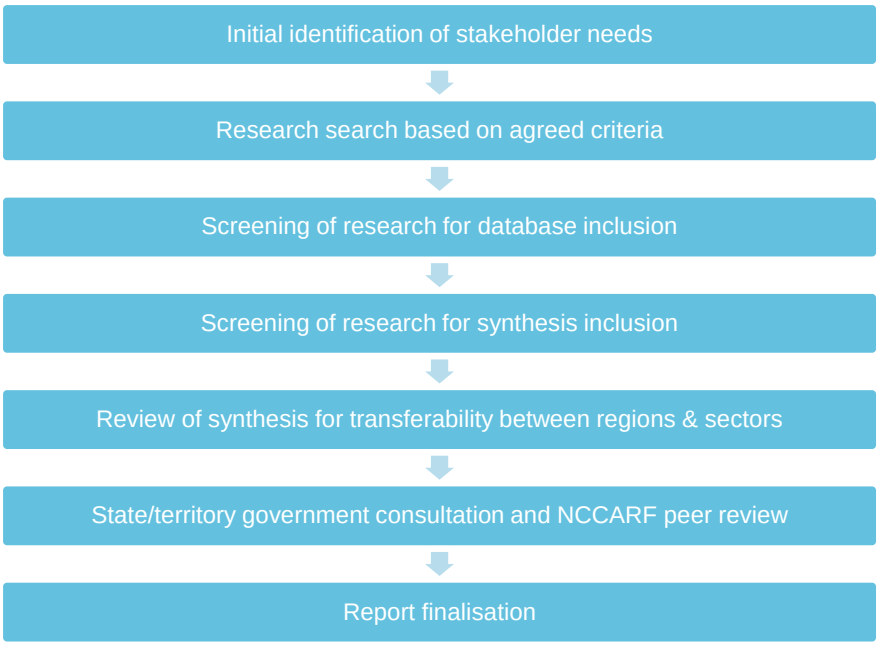


Figure 1:Summary of project methodology

Initial identification of stakeholder needs

At the beginning of this project, all FORNSAT representatives and, when requested, additional state/territory government employees were interviewed by phone to:

- better understand what they would most like to get out of this synthesis
- discuss identified or articulated priority climate change risks or adaptation priorities
- clarify where research has been used so far to inform policy and program development.

A summary of the interview results is included in Appendix A.

Research pool (NCCARF and non-NCCARF research)

This synthesis draws upon climate change adaptation research commissioned by NCCARF and research gathered through Australian sources. The primary sources for research gathered were:

1. Published and peer reviewed literature using relevant databases and key search terms.
    a. The databases utilised for the scan were Science Direct, APAIS, SciVerse Scopus, ANR index, ANR research, EVA, FAMILY, and CSIRO Publishing.
    b. Search terms included adaptation, adaptive capacity, climate change, climate impact, climate proofing, climate risk, climate variability, future proofing, resilience, and vulnerability.
2. Scan of state/territory and Commonwealth websites for relevant research reports. Websites were scanned by entering the search terms into the search bar on territory and commonwealth department websites. The websites of ACT departments searched included the Office of the Environment, Climate Change, Energy and Water and ACT Territory and Municipal Services.
3. Engagement with FORNSAT representatives to nominate research. After the database search and website scan was complete, a full list of over 610 pieces of research was sent to each FORNSAT representative. FORNSAT representatives were then given two weeks to review the research relevant to their state/territory and provide feedback on inclusion or exclusion.

Screening of research for database inclusion

Prior to submitting the research list to FORNSAT representatives, AECOM assessed the research for inclusion in the project database that accompanies this report based on criteria agreed upon by FORNSAT representatives and NCCARF. This criteria list was also to be used by FORNSAT representatives to guide their research nomination process.

- primary research reports (mainstream media reports and peripheral research outputs were included)

- research published since 2001
- publicly available (confidential government reports or reports pending government approval were not included. An exception to this is NCCARF research.)
- consistency with the IPCC definition of adaptation
- of relevance/significant to the responsibilities and interests of Australian states and territories
- specifically considering responses to future climate change.

Screening of research for synthesis inclusion

All research reports included in the database were then considered for inclusion in the synthesis using the following criteria:

- relevance to state/territory government roles and responsibilities
- ability to influence state/territory government policy and decision-making
- robustness of research methodology to 'scale up' findings and lessons to sectors and regions
- provision of policy analysis or policy recommendations relevant to state and territory government roles and responsibilities.

The purpose of these criteria was to have the synthesis informed by research that is the most appropriate and relevant to a state and territory government audience.

The second purpose of these criteria and the inclusion/exclusion process was to allow AECOM capacity to review non-NCCARF research. Our initial scope of work allowed for a total of 150 reports to be reviewed for the synthesis. This was based on the synthesis being informed by NCCARF research only.

AECOM identified 454 non-NCCARF funded adaptation research articles that met the above four criteria. To consider all of these for the synthesis report in addition to the identified NCCARF research was beyond the scope of the project.

To resolve this issue, AECOM proposed that:

- all research that meets the above four criteria were included in the database
- the synthesis was based predominately on findings from the identified NCCARF research but supplemented by the inclusion of up to 15 of the most relevant research papers for each state/territory as identified by AECOM. NCCARF and FORNSAT were also invited to nominate research that they identified as being most relevant and influential.

Any NCCARF research reports provided to AECOM after close of business on 14 January 2013 were also unable to be included in the synthesis due to project time constraints.

Review of synthesis for transferability between regions and sectors

The research identified for each state/territory was initially reviewed and captured separately in order to draw out state/territory-specific lessons. However, as a stated interest from FORNSAT was identifying transferable lessons and comparisons across regions, states/territories and sectors, the full body of research reviewed was considered for each synthesis report. As discussed under 1.3.1 Project limitations, there turned out to be limited consideration of geographical distinctions within the research examined, as only a limited number of research pieces considered the current policy frameworks for state/territory government. As a result, the majority of research reports reviewed were determined to have elements of transferability between regions and/or sectors.

State/territory government consultation and NCCARF peer review

Draft reports were submitted to FORNSAT representatives and NCCARF in March 2013 for review. In March and April, AECOM also conducted a workshop in each state/territory (with the exception of the NT who were not interested in a workshop at this time) to further discuss the project and gather feedback. All workshop attendees were also encouraged to thoroughly review the draft report for their state/territory and provide written feedback during the month-long review period.

Draft reports were also submitted for a peer review by a qualified science reviewer identified by NCCARF.

Report finalisation

Feedback provided during consultation workshops along with written comments provided by FORNSAT representatives and NCCARF science reviewers were incorporated into the final versions of the reports. Each FORNSAT representative was also sent a draft version of their report with changes incorporated for a final review prior to submission to NCCARF for publishing.

1.3.1 Project limitations

The role of a synthesis is to value add to existing research by breaking down individual research reports and aggregating findings to form a new whole based on common threads or themes of learning. Within this approach, bias is inherent and the authors of this report acknowledge that bias. This bias was also inevitably further compounded by the interests and experiences of the individual authors of this report.

In compiling this synthesis, an interpretative approach was used and the research was approached subjectively – first to identify research findings relevant specifically to the responsibilities of state and territory, secondly to focus on research findings developed or currently being developed under the NCCARF's program of research.

While this synthesis was also initially intended to draw out themes of learning specific to each individual state and territory, review of the literature indicated that:

- There is limited consideration of geographical distinctions within the research examined – largely as a result of only a limited number of research pieces giving consideration to current policy frameworks for this particular level of government;
- Research findings that targeted to a location are often very specific and at a level of detail not necessarily relevant to a synthesis approach; and
- Research findings were generally based on a specific climate hazard (such as flooding, heatwaves, bushfires etc.), which are largely common risks faced by all states and territories but with different levels of likelihood and underlying vulnerability.

As a result, the roles and objectives of state/territory government (when defined) are discussed to place the research in the context of each state/territory's needs and activities. However, this synthesis largely presents broader themes and findings occasionally specific to a sector but rarely specific to an individual state/territory. This can be considered an advantage as it creates a larger pool of potential knowledge but it could also be a disadvantage as it presents few distinct and specific directions to further the adaptation policy creation and implementation at a geographical scale.

The synthesis and project database are also not intended to be comprehensive collections of all research on adaptation relevant to states/territories in Australia. As a result, the following limitations should also be noted:

- international adaptation research was not included unless it was specific to Australia.
- journal articles relating to climate change impact studies were not included unless they specifically mentioned adaptation in the abstract.
- some modelling articles (such as those discussing the pros and cons of various models on impacts) have not been included, despite possibly falling within the adaptation spectrum.
- research connected to adaptation (disaster management, planning, etc.) was probably not captured unless it directly mentioned climate change.
- neither NCCARF nor FORNSAT received a list of research that was determined not to meet the criteria. As a result, there is a risk that eliminated research would have been considered relevant by NCCARF or FORNSAT representatives. This risk was mitigated by asking FORNSAT representatives to nominate additional research.

A final limitation of this work is project timing. Literature was gathered between August and October 2012; research completed after October and research not publicly available during this time was not included unless nominated by NCCARF or FORNSAT. However, in order to incorporate the majority of NCCARF research, draft reports commissioned by NCCARF were considered. Many of these reports are still undergoing peer review and are not yet available publicly. Draft research incorporated into this synthesis is denoted as such in the reference (e.g. Smith, 2013D).

Completed first drafts of some NCCARF commissioned research were also not yet available for inclusion in the synthesis. In order to include these projects in the database, the researchers were asked specific questions

about the relevance of the project to government decision-makers and about the project's likely policy implications; their answers were used to populate the relevant database fields.

AECOM recognises that the inclusion of incomplete NCCARF research but not research in progress from other agencies, universities, government bodies and institutions (e.g. CSIRO) is an inconsistency and a limitation of this project.

1.4 The role of government in adaptation

Government and private parties both have an essential part to play in supporting adaptation to climate change. Government is responsible for managing risks to public goods and assets (including the natural environment) and to government service delivery. Businesses and individuals are best placed to manage the risks to their own private assets and income. However, government is also responsible for creating an institutional, market and regulatory environment that supports and promotes private adaptation to climate change (DCCEE 2012).

The three levels of government in Australia have different roles to play in climate change adaptation. In some cases, adaptation will be best managed by an individual state or territory, whereas in other cases it will require collaboration across tiers of government and jurisdictions (DCCEE 2012). The Commonwealth will need to take a leadership role in climate change adaptation, driving and coordinating national reform efforts while managing the key assets under its control (DCCEE 2012).State/territory government, the primary audience for this report, delivers a wide range of services, administers a significant body of legislation, and manages important assets and infrastructure – all of which are likely to be directly impacted by climate change (DCCEE 2012). To assist with adaptation and encourage climate resilience and adaptive capacity, state/territory government's primary roles are to:

- collaborate with Commonwealth and other states/territories to provide local and regional science and information
- manage risks and impacts to public assets, infrastructure and services
- through planning, policy and legislation, encourage effective adaptation by asset and infrastructure owners and managers (both public and private)
- collaborate with other jurisdictions when necessary to manage risks and provide emergency services
- work with the Commonwealth and other jurisdictions to establish and implement national adaptation priorities, to improve adaptive capacity, to strengthen climate resilience in vulnerable communities, to establish a consistent approach to regulation and education, and to implement monitoring and evaluation of adaptation responses
- promote risk management responses by government and the private sector through appropriate forums and communication channels
- ensure regulatory frameworks promote effective adaptation by private parties, utilising market mechanisms when most likely to be effective
- support efforts to build resilience and adaptive capacity in the local community and in creating and implementing policies and regulations consistent with state/territory government adaptation approaches.

(DCCEE 2012)

Adaptive responses to climate change are often localised, meaning responses and their benefits depend on location and local circumstances. A decentralised approach that strongly emphasises local or regional action is often most effective and efficient (Cimato and Mullan 2010). For this reason, local governments are vital to addressing the impacts to climate change, and the coordination between state/territory and local government is especially important. Local government is best positioned to inform state government and the commonwealth of local and regional needs, to communicate with their communities directly, and to respond to local changes in an appropriate and timely manner (DCCEE 2012). However, the ACT Government has responsibility for state/territory functions as well as local government functions.

Table 2 presents the key functions of the ACT government and the potential climate change impacts that are likely to affect each department's areas of responsibility.

An understanding of the duties of different departments and how climate change will affect them and their constituents can help determine the role each part of state or territory government can play, or their sphere of influence, in adaptation planning and action.

Table 2: Key functions of the ACT government & potential climate change impacts

Chief Minister and Treasury Directorate	**Key functions**
	Provides direction and coordination across the ACT Public Service on policy and strategy
	Provides policy advice and financial management services including asset and liability management, taxes, insurance and superannuation
	Provides strategic planning and direction on public sector standards, such as employment, industrial relations and work safety
	Implements sound financial policies
	Provides strategic financial and economic advice and services to the ACT Government with the aim of improving the Territory's financial position and economic management
	Potential climate change impacts
	Negative impacts of climate change on territory and national economies
	Increasing cost of providing and maintaining government assets and services
Community Services Directorate	**Key functions**
	Responsibility for human services functions , including multicultural affairs, community services, older people, women, public and community housing services and policy, children, youth and family support services and policy, disability policy and services, therapy services, Child and Family Centres, the ACT Government Concessions Program, homelessness, community engagement, Aboriginal and Torres Strait Islander Affairs, and community disaster recovery
	Potential climate change impacts
	Impacts on housing and service provision
	Increase in the number and severity of natural disasters
	Impacts on vulnerable members of the community
Economic Development Directorate	**Key functions**
	Provide high quality proactive and responsive advice on economic development issues
	Support the growth and diversification of the ACT private sector through the delivery of business innovation and commercialisation programs
	Developing and maintaining infrastructure and programs for recreation and sport
	Planning, designing and delivering the land release capital works program.
	Providing gaming and racing policy advice and legislative support
	Potential climate change impacts
	Broader transitional impacts on the territory economy Impacts on land use planning and residential development
Education and Training Directorate	**Key functions**
	Provision of strategic advice to the Minister and the Directorate
	Provide vocational education and training
	Deployment of information and communication technology (ICT) into learning environments
	Provision of advice on school planning and development
	Provision of legal advice to schools and other internal stakeholders
	Potential climate change impacts
	Increased need for climate change related science and knowledge
	Need to support innovation and to assist in the development of new technologies Realignment of training and development programs to support emerging industries driven by climate change
Environment and Sustainable Development Directorate	**Key functions**
	Strengthens the Territory's response to climate change Develops and implements targeted policies and programs that address environment protection and sustainability, nature conservation, heritage, water and energy security, sustainable urban design, and sustainable transport and spatial planning
	Provides a planning and land use system that contributes to the sustainable development of the ACT

Environment and Sustainable Development Directorate cont.	**Potential climate change impacts**
	Decline in rainfall and reduction in both run-off to surface water storages and recharge to aquifers
	Changes to energy demands and increased energy costs
	Changes in ecosystem and land use management needs.
	Increased costs and risks to business
	Increased incidence of more severe rainfall events and flooding
Health Directorate	**Key functions**
	Delivers healthcare and health-related services in the ACT, through its public hospitals
	Potential climate change impacts
	Increasing physical and mental impacts on health from extreme weather events, including heatwaves and bushfire
	Increasing prevalence of some vector-borne and respiratory diseases
Justice and Community Safety Directorate	**Key functions**
	Seeks to maintain a fair, safe and peaceful community
	Implement and enforce legislation covering regulatory functions of Government
	Provide effective and cohesive emergency response and management
	Potential climate change impacts
	Legal disputes, particularly regarding land use planning issues
	Increased demand for emergency services during extreme weather events
Territory and Municipal Services Directorate	**Key functions**
	Delivers municipal services, operates municipal facilities and maintains municipal infrastructure (e.g. roads, footpaths, public transport)
	Manages ACT's parks and reserves
	Potential climate change impacts
	Increased maintenance requirements Increasing stress on parks and reserves, including extreme heat, bush fire and flooding
	Increasing cost of providing and maintaining government assets and services
	Disruption to transport networks

1.5 The adaptation challenge for government and the role of research

Climate change is one of the most pressing issues of our time and one of the most challenging to address. It exceeds the capacity of any one actor – be that government or the private sector – to understand and respond to. In fact, the motivation and actions of all individuals and all levels of government are critical and interactive components of the solution. Mitigation efforts to reduce greenhouse gas emissions are important, but some level of climate change has occurred and further change is inevitable. There is considerable uncertainty related to future climate change, but sufficient evidence exists to start planning adaptation action. Increasingly frequent and extreme weather events combined with continued economic growth suggest that action to adapt to climate change is increasingly urgent. Pre-emptive adaptation action is also likely to be the most efficient, effective, equitable and sustainable approach to managing the risks associated with climate change (Department for Environment, Food and Rural Affairs, 2010).

Adaptation to climate change clearly presents new challenges and opportunities for decision-makers. While decision-makers may aim to make sensible decisions that take into account current and future climate change, they frequently lack a clear understanding of their own vulnerability to climate variability (Preston and Stafford Smith, 2009). Furthermore, as climate change and adaptation are complex topics, policy-makers may feel the need to wait for science to provide clear answers before taking action. This creates a fundamental challenge, as there are a number of areas of public policy and management directly related to climate change that still have critical unanswered questions (Morton et al. 2009). Decision-makers are being asked to use their partial knowledge and the current state of scientific knowledge to implement specific policies and measures; they are finding this a difficult undertaking (Preston and Stafford-Smith 2009 and Morton et al. 2009).

According to the DCCEE (2011), governments face numerous barriers to adaptation-related decisions, including:

- limits to the availability of, or access to, information as well as the understanding, funds, expertise and other capacity necessary to make appropriate decisions and implement the actions that flow from these decisions;

- a misunderstanding of the nature and timing of climate change, especially the perception that it will occur in a slow and linear manner; and
- emerging awareness of a range of institutional, regulatory and other factors which act to constrain action to prepare for the impacts of climate change.

To address some of these challenges, Australian state and territory governments frequently fund or undertake research activities to support their direct needs. However, state and territory government decision-makers are also reliant on independent research. Utilising this research effectively is challenged by a number of factors, including its discoverability, accessibility, direct relevance to the context (physical, socio-economic, ecological or geographical), clarity, internal processes and capacity of decision-makers (Preston and Stafford Smith 2009 and Morton et al. 2009). In its attempt to make a large portion of Australian adaptation research easily accessible to state and territory decision-makers, this synthesis aims to help reduce this barrier.

2. THE AUSTRALIAN CAPITAL TERRITORY'S CLIMATE CHALLENGES

In order to plan for climate change and prioritise adaptation activities, it is important to understand what climatic challenges are occurring now and what changes will be faced in the future. This section of the report highlights the current state of the climate, potential climatic changes, and how these changes are expected to affect the ACT. Recognising that considerable activity has already occurred in the Territory to address these climatic challenges, it also highlights the ACT's current adaptation priorities and current and past activities.

2.1 Current and future climate

The ACT's climate sees significant spatial and temporal variation. Data gathered at the official weather recording stations at Canberra Airport, Mount Ginini and Tuggeranong (Isabella Plains) demonstrate this variability and across the year there are four distinct seasons (Australian Bureau of Meteorology 2012a). Historically, average rainfall for Canberra is 614.4 mm, the long term average maximum temperature is 20.9^{o}C, the long term average minimum temperature is 6.1^{o}C and there is an average of 32 days a year that exceed 30^{o}C (Australian Bureau of Meteorology 2012a). However, to some extent, these relatively mild averages mask a climate that can experience periods of extreme heat and cold, extremes that are likely to be exacerbated under projected climate change scenarios.

Highlighting the climatic variety across the geography of the ACT, the average maximum temperature for Mount Ginini in 2011, which reaches 1762 metres above sea level, was 10.8^{o}C and average minimum was 3.2^{o}C. In higher altitude areas such as the tablelands, frosts can occur at any time of the year (Australian Bureau of Statistics 2012) as well as seasonal snow in the Australian Alps; however, the alpine region has seen a decline in snow of 30 per cent since 1954 (Morrison and Pickering 2011).

Recent data shows Canberra's rainfall as being below the long term average but distributed across an above average number of rainy days (Australian Bureau of Meteorology 2012a). Average maximum and minimum temperatures were very close to long term averages, however the warmest winter on record was observed in 2011 (Australian Bureau of Meteorology 2012a).

The ACT experiences wind storm events fairly regularly, particularly over spring and summer between September and February, and experiences dust storms and thunderstorms (Commissioner for Sustainability and the Environment 2011). Flooding is not a frequent event in the ACT currently, though major flooding events in the territory have occurred causing loss of life and property (Commissioner for Sustainability and the Environment 2011).

Warming is projected to intensify in the ACT with an increase in average temperatures and a decrease in cooler nights (ACT Government 2007a, DCCEE 2012). Under high emission scenarios, a 2^{o}C warming by the mid-21st Century is projected by CSIRO (AECOM 2010). In addition to increased average temperatures, temperature extremities also are expected to change. The annual average number of days over 35°C in Canberra could increase from 5 days currently to as high as 26 days by 2070 without global action to reduce emissions (DCCEE 2012).

Average yearly rainfall is likely to stay fairly stable in the ACT, however there is uncertainty regarding rainfall projections. Under some modelling, rainfall is expected to increase in summer and autumn, and decrease in winter and spring to roughly the same extent (ACT Government 2007a). Droughts are likely to become more frequent and severe for region (ACT Government 2007a), with increased evaporation and changes to rainfall likely leading to reduced soil moisture (Commissioner for Sustainability and the Environment 2011). Alternative modelling suggests a minor decrease in average yearly rainfall is expected, due to stable rainfall in summer and autumn and reduced rainfall in winter and spring (CSIRO 2007).

Due to the projected overall increase in temperatures, days of extreme heat and drier conditions, the risk of high fire danger days and bushfire is projected to increase (Lucas et al. 2007 in Webb 2011). The increase in days of high to extreme fire danger could increase from the current average of 23 days per year to between 26 and 29 days by 2020 and up to 38 days by 2050 (DCCEE 2012). The fire season is also projected to start earlier and end slightly later, and be generally more intense, based on CSIRO climate simulations (SGS 2010).

Despite average yearly rainfall remaining relatively stable, extreme rainfall events are projected to increase (AECOM 2012), storm events are likely to become more intense, and wind speeds are likely to increase in the region).

Surface water flows in the Murray-Darling Basin are expected to decrease (Albrecht et al. 2010), though the greater impact is likely to occur outside the ACT in the southern Murray-Darling Basin region (Loch et al. 2012D). The increase in extreme rainfall events may cause increased frequency and intensity of flooding events that have the potential to increase damage to natural and manmade infrastructure and systems (Loch et al. 2012D).

2.2 Climate change impacts for the ACT

The expected changes in climate for the ACT will result in a range of physical, social, economic and environmental impacts. Impacts will be related to direct changes to climate and extreme weather events, and also flow on effects influencing infrastructure, social and economic systems and the natural environment. Local, regional and national circumstances and responses will also influence the nature of these impacts.

The ACT has experienced long periods of drought over the past decade and faced significant losses to life, property and infrastructure due to bushfires (DCCEE 2012, Commissioner for Sustainability and the Environment 2011). Without adaptation, risks to the ACT community and environment are likely to increase as a result of both climate change and population growth.

While it is beyond the scope of this report to detail the range of potential climate change impacts anticipated for the ACT, a summary of potential sectoral vulnerabilities is described below.

Health and wellbeing

The likely increase in heat wave duration and intensity will have significant impacts on human health both directly through dehydration and heat stroke, and indirectly through a number of other health conditions including cardiovascular collapse and respiratory distress. The number of heat related illnesses and fatalities is likely to increase with the number of days over 35^{o}C (DCCEE 2012). Existing vulnerabilities are likely to impact on the resilience and adaptive capacity of ACT residents, with the infirm, elderly and those on a lower income facing the greatest impacts (DCCEE 2012). Other potential human health and wellbeing impacts include an increase in respiratory diseases from increased pollution, the impact of social disruptions and emergencies on mental health and the increase in vector-borne disease from changes to the populations and locations of mosquitoes and other disease-carrying species (ACT Government 2007a).

A positive impact of continued warming in the ACT is the potential reduction in the proportion of cold related fatalities for the region, currently accounting for 3 fatalities a year. Although the proportion is likely to decrease, the overall number of lives lost to cold a year is projected to increase to between 4 and 9 by 2050 (DCCEE 2012).

Emergency management

Bushfires are likely to increasingly impact the ACT, with many residents living in areas close to bushland susceptible to fire (AECOM 2010). The 2003 bushfires, which resulted in the loss of four lives, highlight this risk (DCCEE 2012). This is likely to impact emergency and disaster services, increasing demand, stretching capacity and directly impacting infrastructure. Positively, volunteering for emergency services, such as the ACT Fire Brigade Community Fire Units and support services, has mostly grown since 2007. This demonstrates community engagement and willingness to contribute and take on responsibility for emergency service challenges (Commissioner for Sustainability and the Environment 2011).

Fisheries, forestry and agriculture

Primary industries, and in particular agricultural and related industries, are sensitive to changes in temperature, water availability and quality. Much vulnerability for these industries already exist in the ACT due to the Territory's topography, soil types and condition, and water availability (Commissioner for Sustainability and the Environment 2011). Projected climate changes for the ACT could directly impact on the productivity of the regions agriculture and viticulture industries (DCCEE 2012), putting at risk a component of the ACT economy worth $14.2 million in 2010-2011 (Australian Bureau of Statistics 2012b). The Canberra region also hosts more than 140 cool climate vineyards, which are highly sensitive to climate conditions (Commissioner for Sustainability and the Environment 2011).

The primary production sector will also be sensitive to changes in climate extremes – including droughts, floods, bushfires and heatwaves. An example of this is the almost complete destruction of commercial forests from the 2003 bushfires, creating a $60 million loss (DCCEE 2012).

Climate change is likely to affect the incidence and severity of pest and disease outbreaks for both primary production and natural resource management. This includes changes in average or extreme values of climate variables which affect the life cycles of pest populations, the severity of disease, geographic distribution of pests and disease, and vulnerability of hosts. Increased summer temperatures are likely to accelerate the development rate and reproductive potential of insect pests, while warmer winters will increase over-winter survival (Old and Stone 2005 in DPI 2012; Cannon 1998 in DPI 2012).

There are potential benefits to agriculture from climate change - with low to moderate increases in warming potentially increasing plant growth (particularly cold sensitive crops such as wheat) though the increased number of very hot days, heatwaves and a reduction in water availability will most likely reduce yields (ACT Government 2007a).

Natural environment

Direct and indirect effects of climate change are expected to affect the natural environment in the ACT. The function, composition and structure of aquatic and land based ecosystems are expected to be affected. Specialist species in the ACT which rely on a particular climate, habitat or other environmental factor (such as the corroboree frog and many alpine and sub-alpine species) are likely to suffer the most, and may eventually become extinct (ACT Government 2007a). The lack of connectivity of ecosystems in the ACT presents challenges for both specialist and generalist organisms in responding and adapting through moving to new suitable habitats (Commissioner for Sustainability and the Environment 2011). Species and ecosystems that are stressed by non-climatic factors are less likely to be resilient to climate change impacts.

Stresses to alpine and subalpine ecosystems can be due to direct factors such as reduced snow cover as well as indirect effects such as reduction in water quality and quantity (in the ecosystem and down-gradient), all of which can lead to species decline (ACT Government 2007a). Increased fire risk will likely have multiple negative impacts the region's biodiversity through ecosystem destruction, changes to species distribution and populations (Webb 2011), through changes to phenology, and through the establishment of invasive species after a fire.

Climate change will also result in changes to the distribution and prevalence of pest and disease which is expected to have direct effects on the biodiversity of the ACT. Many Australian ecosystems and species have evolved in highly variable climates, and consequently are likely to have some capacity to resist or adapt to expected climate changes over time. However, many ecological communities and species in the ACT have already declined significantly because of land clearing, water extraction, and habitat fragmentation, grazing and introduced pests, limiting their adaptive capacity.

Water security is a major issue for the ACT. The network is predominantly supplied by four catchment areas which face growing pressure with increased water demand, changed rainfall patterns and decreased surface runoff (DCCEE 2012).

Climate change is likely to exacerbate these pressures with reduction in rainfall and runoff to catchment areas projected (ACT Government 2007a). Extreme rainfall events may also lead to

runoff in quantities too high for the catchment to absorb, leading to potential impacts on river water quality (ACT Government 2007a).

Community and infrastructure

Climate change will have direct and indirect impacts for the ACT's built environment as a consequence of increasing temperatures, and changing rainfall patterns which will exacerbate and extend current climate risks. Changed rates of deterioration may occur for roads, pavement and concrete infrastructure through changes to atmospheric CO2, increased temperature and increased runoff; capacity may become an issue for stormwater infrastructure after extreme rainfall events; loss of building amenity and increased operational costs may occur after extreme events, including flash flooding, fire and through wind damage (AECOM 2012, ACT Government 2007a). Additionally, increases in potable water and electricity consumption during extreme heat events will place additional pressure on water and energy distribution infrastructure (DCCEE 2012).

Fire vulnerability is a concern for the ACT, especially for peri-urban areas (SGS 2010), with the territory experiencing nine large severe fires since the beginning of the 20th Century (ACTPLA 2010 in Commissioner for Sustainability and the Environment 2011). Significant losses have been experienced in previous bushfire events. For example, 500 homes were destroyed and approximately $350 million of damage was inflicted by the 2003 Canberra bushfires (DCCEE 2012). Fire risk is expected to increase significantly with climate change, with a longer fire season and an increase in extreme fire risk days (DCCEE 2012).

Extreme weather events can also significantly damage the built environment, including wind, rain and hail damage. This risk has been highlighted by recent events, including damaging winds in September 2008, heavy hail-fall event in east Tuggeranong in 2007 and a tornado in Gungahlin in 2009 (Commissioner for Sustainability and the Environment 2011). Though flood events are not frequent, damages - such as the $15 million experienced in the December 2005 - and stresses to emergency and disaster services and available resources can be significant (Commissioner for Sustainability and the Environment 2011).

Business and industry

Climate change is likely to affect different business and industry sectors in different ways. The region's tourism industry is likely to be affected by changes to seasonal snow, changes to grape growing for the wine region, and changes to climate for outdoor and sporting activities. Other industries and businesses will also be impacted through damage to infrastructure, loss of worker capacity and increased insurance costs (AECOM 2012). This includes the agricultural and primary production industries, as detailed above.

Cool climate vineyards in the ACT region provide an important contribution to both tourism and the primary production economy. As many of these vineyards rely on very specific temperature ranges and adequate water availability, climate change has the potential to have a major impact on the industry and the tourism it creates (Commissioner for Sustainability and the Environment 2011).

Changes to climate could have beneficial impacts for outdoor and wilderness tourism activities including bushwalking/ trekking, camping, wildlife watching, fishing and climbing with warmer and drier conditions and longer summer peak season (Commissioner for Sustainability and the Environment 2011). However, significant risks to the tourism industry also exist due to extreme weather events such as heatwaves, storms and fire, and subsequent impacts on infrastructure and demand.

2.3 The Australian Capital Territory's adaptation priorities and activities

In 2007, the Government of the Australian Capital Territory (ACT) released, *Weathering the Change, the ACT Climate Change Strategy for 2007 through 2025*. This strategy includes a target of zero net emissions by 2060 and a 40 per cent reduction in greenhouse gas emissions from 1990 levels by 2020. The strategy recognises that the ACT needs to prepare for and manage the risks of climate change in addition to reducing greenhouse gas emissions. To achieve these targets and allow the ACT to properly prepare, detailed action plans have (and will continue) to be developed at regular intervals (ACT Government, 2007a).

The first of these plans, *Weathering the Change – Action Plan 1 2007-2011*, included 10 actions which aim to assist adaptation to climate change in the ACT (ACT Government 2007b, pp. 24). These include a focus on:

- helping vulnerable communities to adapt;
- improving the preparedness of ACT Government Agencies to respond to climate change;
- regional planning and vulnerability assessment;
- participation in regional and national initiatives (e.g. National Adaptation Framework); and
- preparing new urban development and public spaces for climate change, and better understanding climate change impacts across urban and natural environments.

The second action plan, *AP2: A new climate change strategy and action plan for the Australian Capital Territory* outlines the updated pathways that are planned for 2012 – 2020, with opportunity for the government to review the plan at intervals following status reports (in 2014, 2017 and 2020) and government responses (in 2015 and 2018) (ACT Government 2012a). As stated in the plan, ACT's objective is to embed climate change risks into standard risk management frameworks so adaptation is core business for the ACT. The AP2 includes actions to address adaptation that build on those contained in AP1 (ACT Government, 2012a).

The ACT Government has also partnered with the NSW Government to address adaptation. In 2008, the governments agreed to cooperate in analysis of climate change vulnerability and adaptation for the ACT and south-eastern NSW. This has resulted in a series of papers that assist the two governments towards the next steps in climate change adaptation (Office of the Commissioner for Sustainability and the Environment 2011). ACT is also partnering with NSW to develop new, fine-scale climate projections using a regional climate model called the NSW and ACT Regional Climate Model or NARCliM (Office of Environment and Heritage 2012).

Finally, the ACT Government has conducted a number of vulnerability assessments, including studies on human settlement and infrastructure (AECOM 2010 and AECOM 2012). The ACT Natural Disaster Resilience Program is also about to undertake a Territory-wide prioritised natural disaster risk assessment (ACT Emergency Services Agency 2012).

3. RESEARCH RELEVANT TO THE AUSTRALIAN CAPITAL TERRITORY

This project primarily draws upon NCCARF research. However, the synthesis findings (Section 4) also utilise a selection of policy-relevant research gathered through other Australian sources. This section of the report provides further information on the research collected and synthesised for this project and, in particular, highlights which research studies occurred in the ACT.

3.1 Identified adaptation research

Over 450 research reports (including NCCARF-funded research) were gathered in total and included in the database that accompanies this project. Figure 2 displays the number of research reports collected by the state/territory in which the research occurred (meaning that state/territory was stated as the study area). A large portion of the research collected had national relevance as it did not contain case studies specific to a state/territory. For the location-specific research, Queensland and Victoria were most commonly studied, followed by New South Wales.

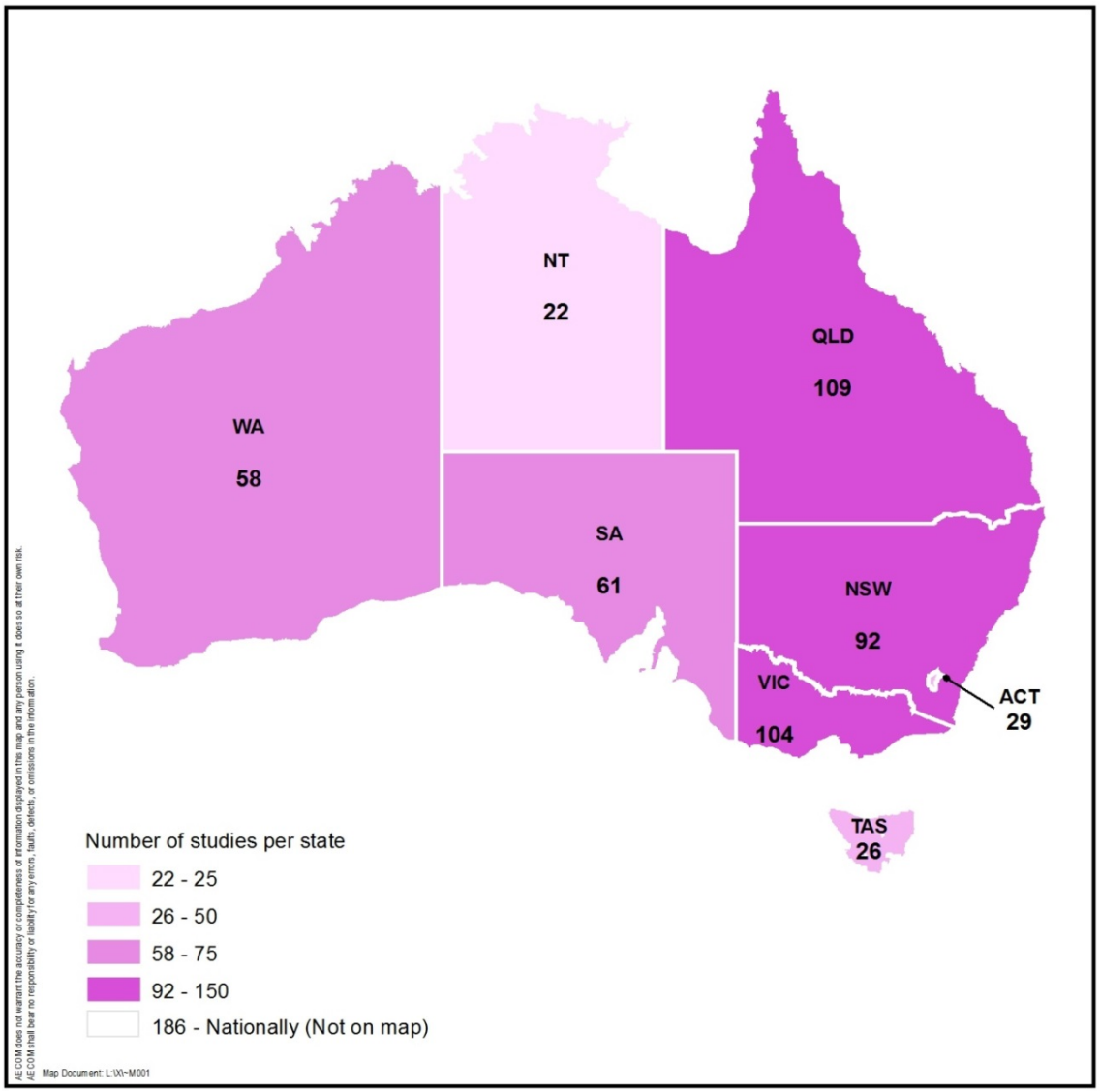


Figure 2: NCCARF and non-NCCARF research by state/territory

A selection of the research gathered for the database was included in the synthesis (Section 4). Some NCCARF reports were unable to be included as research drafts were not available at the time of synthesis drafting. Others were excluded as their content was not directly relevant to state or territory government policy- and decision-

makers. A full list of excluded projects is included in Appendix D. Up to 15 pieces of research specific to each state or territory but not part of the NCCARF-funded research pool were selected and reviewed for synthesis in addition to the NCCARF reports. The research was selected based on its relevance to state or territory government policy.

3.2 ACT-specific research

Research projects used to inform and shape this synthesis occurred across Australia, as many lessons were transferrable to multiple geographies. The bibliography lists all research projects reviewed for this report. However, multiple research projects used as the foundation for this synthesis consider adaptation within the ACT and are listed in Table 3**.** Projects were chosen on the basis that their research included at least one ACT-specific location or case study, although not all projects were delivered by ACT-based research organisations. The purpose of this table is to assist readers locate a particular report in the ACT that they may wish to find and read further. Note that Table 3 does not include the research reports reviewed that only covered climate change impacts and the ACT government activities and priorities, referenced in Section 2.0. These reports are listed in the bibliography.

Table 3: ACT-specific research

Lead Author	Status	Year	Title	Sectors
AECOM Australia Pty Ltd,	Final	2010	Human settlement vulnerability and adaptive capacity assessment - spatial plan evaluation	.gov.au
AECOM Australia Pty Ltd,	Final	2012	Climate change vulnerability assessment framework for infrastructure - discussion paper	.gov.au
A. Aldous	Final	2011	Droughts, floods and freshwater ecosystems: evaluating climate change impacts and developing adaptation strategies	
V. Doerr	Final	2011	From climate change challenges to adaptation solutions	.gov.au
K. Hobson	Final	2011	Public responses to climate change: The role of deliberation in building capacity for adaptive action	.gov.au
Q. Jiang	Final	2012	Economic effects of climate change in the Murray-Darling Basin, Australia	
A. S. Kiem	Final	2012	Limits and barriers to climate change adaptation for small inland communities affected by drought	
A. Loch	Draft	2012	The role of water markets in climate change adaptation	.gov.au
C. Morrison	Final	2011	Climate change adaptation in the Australian Alps: impacts, strategies, limits and management	
G. Newton	Final	2009	Australia's environmental climate change challenge: overview with reference to water resources.	.gov.au

Lead Author	Status	Year	Title	Sectors
C.M. Pickering	Draft	2013	Determining high risk vegetation communities and plants species in relation to climate change in the Australian alpine region.	
J. Pittock	Final	2011	Australia's Murray-Darling Basin: Freshwater ecosystem conservation options in an era of climate change	
N. Saintilan	Final	2011	Matching research and policy tools to scales of climate-change adaptation in the Murray-Darling, a large Australian river basin: a review	
SGS Economics and Planning Pty Ltd	Final	2010	Spatial Plan Evaluation - Urban Form Scenarios – Adaptation and Mitigation Interventions; Part 1 - Report	
R. Slayter	Final	2010	Climate change impacts on Australia's alpine ecosystems	
W. Steele	Draft	2013	Learning from Cross-Border Mechanisms to Support Climate Change Adaptation in Australia: Every state for themselves? Learning from cross-border regulatory instruments to support and promote climate change adaptation in Australia	
B. Webb	Final	2011	Impacts of Climate on the Canberra Nature Park : Risks and Responses - Report for the ACT Office of the Commissioner for Sustainability and the Environment	

3.3 Australian Capital Territory locations of synthesis research

Figure 3 maps the study locations and study regions within the ACT for the research utilised in this synthesis. The purpose of this map is to highlight the cities, towns and regions where research has occurred, as this information may be relevant to the ACT government's work and emphasises locations where additional research may need to occur.

This map demonstrates that research was conducted in Canberra and Canberra Nature Park. Research also occurred within the regions of the Australian Alps and the Murray-Darling Basin, of which the ACT is part. Most of this research focused on adaptation issues related to natural resource management. Some research examined also covered the entire territory.

Appendix C includes summaries of the NCCARF-funded research that occurred in the ACT.

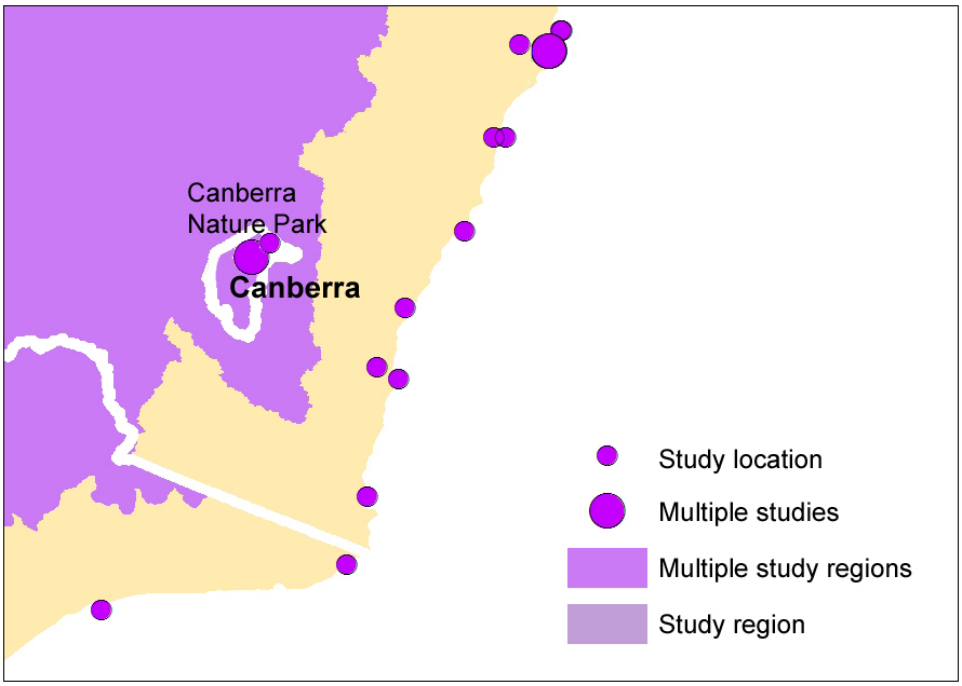


Figure 3: Case study locations of synthesis research in the ACT

4. RESEARCH FINDINGS

The role of a synthesis is to value add to existing research by breaking down individual research reports and aggregating findings to form a new whole based on common threads or themes of learning. A synthesis of research is also usually formulated in an attempt to find answers to a specific question or a series of questions. For this synthesis, that question was: *"What are the common emerging adaptation research lessons that can be used by state and territory decision-makers, particularly with regards to policy-setting?"*

This section of the report presents the main findings of the synthesis by the identified themes. It is important to note, however, that though findings have been categorised into one theme, there are overlapping and cross-theme relationships between the lessons described.

The findings described are the opinions and conclusions of the researchers and are not necessarily the professional opinion of AECOM. It is also important to recognise that, despite best efforts to aggregate findings across multiple research reports, the distinct focus of some of the research has not enabled some findings to be supported by more than one research study.

4.1 Increasing resilience and adaptive capacity

Vulnerability (be that biophysical or socio-economic) is intrinsically linked with adaptation through the consideration of resiliency and adaptive capacity. The IPCC WG2 (2007) defines 'vulnerability' as "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" (p. 883). This concept is important as many adaptation actions focus on increasing a community's or system's ability to handle exposure to climate change, that is, increasing its adaptive capacity, and thereby reducing its vulnerability. Increasing adaptive capacity can relate to changes in resources (e.g. financial or human capital) and institutional or governance arrangements.

'Resilience' is a related term that can create confusion as it could be interpreted to mean returning to a prior state after a disturbance, while 'adaptation' usually refers to a fundamental shift or transformation in state (Preston and Stafford-Smith 2009). However, often resilience simply refers to a community or system's robustness or its ability to undergo change while maintaining its integrity. This confusion in terminology is discussed further in Section 4.1.3.

This section outlines the emerging themes identified in the research that are relevant to increasing the resilience and adaptive capacity of communities, systems or individuals. It includes a discussion of pre/post-extreme event support, lessons regarding building and maintaining community resilience, messaging and communication about climate change and adaptation, and community expectations for government.

4.1.1 Pre- and post-extreme event support

The findings in this section are particularly relevant for emergency management.

Many of the findings presented below and in Section 4.2, Learning from Experience, deal with disaster risk reduction (DRR); DRR is the practice of reducing the disaster risks from extreme events through the reduction of underlying factors that contribute to vulnerability. While technically separate practices, DRR and climate change adaptation converge on the common goals of risk and vulnerability reduction. They differ in multiple ways; two key distinctions are that DRR addresses broader risks, beyond climate, including volcanic eruptions and earthquakes, which adaptation does not: and that adaptation considers longer-term changes to climate while DRR is mainly interested in extremes. However, at the local level, many communities also do not see a separation between the two (Gero et al. 2010). Therefore, the historical experiences of DRR can contribute greatly to climate change adaptation, and the integration of the two is often recommended (Gero et al. 2010).

Key findings for increasing resilience and adaptive capacity pre- and post extreme events:

- Government financial support post-disaster is complex and could lead to moral hazard and reduced resilience.
- Targeted preparation investment, including subsidising community emergency supplies and SME support, is critical to community economy and wellbeing.
- Adaptation and emergency assistance need to take into account a community's short- and long-term challenges, including broader socio-economic issues.
- Planning for extreme events is important, yet preparedness also needs to be holistic and tested for robustness.

Government financial support post-disaster is complex and could lead to moral hazard and reduced resilience. Provision of government assistance post-disaster is a complicated issue given the complexity and cost of insurance arrangements and limited capacity of the uninsured to make changes to their homes due to lack of funds (Bird et al. 2011D). Nonetheless, some research suggests there is a real risk that this type of financial support could deter some residents from covering their own risk and instil expectations that may be detrimental to a community's long term resilience (Bird et al. 2011D). As stated by Macintosh et al. (2013D),

"if there is an expectation that governments will manage the risks, and cover private losses when risks materialise, the incentive to avoid at-risk areas, and to take appropriate preventative action, will be reduced. In a liberal democracy like Australia, where there is a significant social safety net and governments provide extensive emergency assistance, eliminating this expectation would be difficult and could involve considerable political cost" (p. 28).

This may be particularly problematic if people are reluctant to donate to the sources of these funds, such as the Premiers Flood Appeal, as the frequency of extreme events increases, and governments are unable to afford continued assistance (Bird et al. 2011D). In addition, Boon et al. (2012D) found that, in some cases, providing financial support from state or federal agencies and NGOs to residents faced with the adverse impacts of floods, bushfires and cyclones does not support resilience and can facilitate a departure from the community, thereby potentially reducing the resilience of the community as a whole.

The temporary lifting of water restrictions during a major ACT heatwave in 2004 resulted in a surge in water use and a 26 per cent increase in electricity use. Immediate actions to reduce impact of the heat resulted in the Territory's water and electricity infrastructure being placed under significant additional strain, including already-low water reserves (AECOM 2010).

Targeted preparation investment, including subsidising community emergency supplies and SME support, is critical to community economy and wellbeing. Being financially able to prepare for a disaster is critical for resilience. Boon et al. (2012D) suggest that emergency supplies, preparation kits and other items encouraging a proactive response to extreme weather events should be subsidised. Similar issues for small-to-medium-sized enterprises (SMEs) were also noted in Victorian bushfire and flooding case studies by Kuruppu et al. (2013D). Historical disaster response initiatives supporting the economic recovery of SMEs were found to be generally reactive and to fail to specifically address underlying vulnerabilities, such as limited access to financial and human resources, under-insurance and operational location challenges. The effectiveness of these assistance measures was perceived by SMEs to be further limited as a result of:

- the short term duration of business recovery programs (generally only up to three years following an event)
- the limited support available to SMEs indirectly impacted by climate hazards and in preparing disaster response and recovery. This sentiment has also been raised as an issue between farmers and non-farmers in relation to drought assistance in Victoria (Sherval and Askew 2012)
- lack of consideration of the psychological impacts for SMEs
- difficulties in accessing recovery funds.

These identified shortfalls suggested the importance of ensuring that business continuity for SMEs under climate change is integrated into existing processes and networks (Kuruppu et al. 2013D).

This type of approach was undertaken with SMEs in Western Australia in response to drought, where counsellors were assigned to support local businesses with more strategic business planning processes to improve resilience. Given the importance of SMEs to local economies and to community resilience, further consideration needs to be given to more proactive adaptation support to this sector.

Adaptation and emergency assistance needs to take into account a community's short- and long term challenges, including broader socio-economic issues. Adaptation and response to extreme events cannot be considered in isolation. As noted by Kiem et al. (2010b), the social and economic issues facing many communities (inland, rural) are not just the product of a climate hazard, and to understand them as such underestimates the extent of the problem and reduces the effectiveness of intervention. While the type of disaster, its intensity and length of its impact will influence resilience, responses need to take into account short- and long term issues affecting both individuals and the community as a whole.

Planning for multiple levels of preparedness is needed for catastrophic and less severe events and for the onset of rapid and slow events (Boon et al. 2012D). The first step towards enhancing community resilience requires an understanding of the community's strengths and vulnerabilities, its physical characteristics (e.g. local infrastructure), local governance (e.g. disaster policies and plans) and social characteristics (e.g. level of community cohesion) (Boon et al. 2012D). For example, lack of provision within funding contracts (particularly within government contracts) for community service organisations to act in response to and recovery from extreme events, as well as lack of government adaptation policy and guidelines were identified as barriers for these organisations to adapt and act as adaptation enablers for the disadvantaged (Mallon et al. 2013D).

Many adaptation lessons can be learned from decades of drought policy which help illustrate how other external factors, such as the introduction of water trading, commodity prices and aging communities, affect the effectiveness and the equity of interventions. According to Sherval and Askew (2012), local experiences of Victoria's recent drought, particularly in rural towns whose local economies rely on agriculture, are not well understood as a result of the combination of rapidly evolving changes in water market reforms, the drought itself and non climate-related simultaneous changes (in this case, the changes to the Australian Wheat Board). While many of these challenges have been financial, health impacts have also resulted due to the important social and emotional connections with water for the community. The ongoing resilience and adaptive capacity of these towns is severely challenged by multiple drivers of changes, not just climate change (Sherval and Askew: 2012, Kiem et al. 2010b). Therefore, support needs to take into account underlying vulnerability and support for longer-term adaptation within the broader community. For example Exceptional Circumstances payments for farmers can work against communities trying to adapt and transition (Kiem et al. 2010b).

Finally, post-event assistance needs to consider projected future events and the resilience of the community as a whole. This includes changes in frequency and intensity of the same hazard, as well as others where adaptation measures against one risk may introduce new risks from other events – for example, buildings built with lighter, more comfortable materials to handle hot, tropical weather can be maladaptive during a cyclone, increasing the risk of damage from flying debris.

Planning for extreme events is important, yet preparedness also needs to be holistic and tested for robustness. In some Australian states/territories, heatwave plans for aged care facilities are directed by the government. For example, heatwave planning is a major focus of health and safety departments in South Australia. Ninety-three per cent of aged care facilities surveyed by Black et al. (2013D) in South Australia had heatwave plans. In Queensland, 41 per cent of facilities had a dedicated heatwave plan, while dedicated plans were uncommon among NSW aged care facilities.

Only about half of the facilities in South Australia surveyed had back-up generators, though this was more than the aged care facilities in both NSW and Queensland. Many facilities in South Australia also suggested back-up cooling methods that rely on electricity. This indicates that many aged care facilities have not considered the risk of increased power outages during periods of extreme heat, a necessary consideration for planning to be considered robust and holistic. A number of adaptation options are available to reduce risk which could be incorporated into asset renewal and maintenance plans. These include provision of water coolers, tinted windows, window awnings and shutters, reflective roof paint, and air conditioning upgrades (Black et al. 2013D).

Black et al. (2013D) also found variable and inconsistent results across the states/territories regarding staff knowledge of the health effects of extreme heat and the best ways to care for the elderly during very hot weather. Clinical care staff needs to be aware of the importance of caring for the elderly in periods of extreme heat, even if air conditioning is available and functioning.

4.1.2 Building and maintaining community resilience

Key findings for building and maintaining community resilience:

- Community connectedness and local networks are strong contributors to community resilience and recovery.
- Resilience of community and individuals will be reduced by people leaving a community following an extreme event.
- Inherent levels of vulnerability and how they may change over time will help prioritise adaptation.
- Community service organisations are important in building resilience and addressing community vulnerability.
- Communities will be more likely to accept adaptation solutions as climatic conditions become more severe.

Community connectedness and local networks are strong contributors to community resilience and recovery. Assistance from friends, neighbours and family during a disaster builds a sense of place, which then supports community resilience. Being connected to neighbours and having friends strongly enhances individuals' resilience, even independently of the length of time of residence in the community (Boon et al. 2012D). Apan et al. (2010) also found that in areas vulnerable to flooding, communities with greater connections displayed more resilience. Furthermore, Boon et al. (2012D) noted that "state government services should not dominate or overshadow local government or volunteer roles, but should support and guide local efforts and initiatives" (p. 264).

Stanley et al. (2013D) identified three ingredients for a community to be successfully adapted: community strength; adequate, secure, ongoing financial support to enable the community to do this work; and a climate change and adaptation governance structure that coordinates, enables, promotes and finances a significant part of the adaptation process. Other identified factors of community resilience include:

- capacity to self-organise
- access to social networks, including family
- collective learning from past experiences
- diversification of markets and employment (Boon et al. 2012D).

Resilience of community and individuals will be reduced by people leaving a community following an extreme event. The departure of individuals may further decrease the resilience of both the community and the individuals leaving as they are likely to be unfamiliar with local conditions and access to support networks in their new location. The desire to leave was predicted following the 2010/11 Queensland floods, which suggests that decisions are influenced by factors relating to reduced adaptability (including ill health, a poor sense of place, low financial capacity) and experience with infrastructure problems. Community members who had received financial support by government or charity groups were also more likely to leave the community, which was consistent with being more financially or emotionally vulnerable, or having sustained extensive damage by the hazard event (Boon et al. 2012D). However, it is also noted that relocation can be considered a form of adaptation, particularly where future climate risks for the location being left are seen as sufficiently high that other adaptive actions may not be perceived as adequate.

Inherent levels of vulnerability and how they may change over time will help prioritise adaptation. Some communities are inherently more vulnerable than others because of their geographical, social, cultural and/or economic situation (Kiem et al. 2010a). Social stratification, particularly wealth inequality, plays a key role in constraining the adaptive capacity of certain communities and individuals, increasing vulnerability (Hanson-Easey et al. 2013D). What has not been well considered in the exploration of adaptation options is how these vulnerabilities may also change over time – particularly with regards to non-climate drivers and factors.

This theory applies to natural systems and human community systems alike. A community that is degraded in habitat and survival options is more inherently vulnerable to changing climatic conditions. For example, adaptation of Australia's natural systems to climate change will be constrained by:

- rates of evolutionary change versus rates of climate change
- reductions of suitable habitat

- limited capacity to migrate due to habitat fragmentation
- extreme events that reduce the capacity of a forest to recover (Boulter 2012).

Community service organisations are important in building resilience and addressing community vulnerability. However, many community service organisations (CSOs) are highly vulnerable to extreme weather events and would face temporary or permanent closure as a result of major damage to physical infrastructure and disruptions to critical services (Mallon et al. 2013D). This closure is likely to occur over periods when there is a critical need for their services to assist clients to respond to and recover from crisis, with many small to medium sized organisations – and in particular those that provide direct services from an office or building – facing the risk of permanent closure. The follow on impacts for those already most vulnerable to climate risks, some of whom rely on CSOs to help overcome everyday adversity, is likely to be severe (Mallon et al. 2013D). Despite these vulnerabilities and the opportunities for CSOs to improve community resilience, they are mostly overlooked in policy and climate adaptation studies.

Communities will be more likely to accept adaptation solutions as climatic conditions become more severe. Hurlimann and Dolnicar (2011) noted that past experience with drought may make people more resilient and less willing to relocate, a response that is discussed further in Section 4.2. Participants stated they would explore many options before choosing to relocate and would delay relocation for multiple reasons, including social, financial and attachments to place. For example, people prefer the solution of introducing recycled or desalinated water to the drinking water supply – a move that has a high level of public resistance – to being forced to move due to a water shortage.

4.1.3 Messaging and communication

Key findings related to messaging and communication in order to increase resilience and adaptive capacity:

- Climate change adaptation terms are often misunderstood or understood differently by different stakeholders.
- Climate change messaging needs to be bespoke to its intended audience and should take care not to induce fear, apathy or scepticism.
- Communication and education about climate change needs to be targeted to vulnerable and hard-to-reach populations (older people, low income groups, people with disabilities, newly-arrived migrants and Indigenous communities).
- Collaboration and effective sharing of information is critical.
- The messenger is just as important as the message.

Climate change adaptation terms are often misunderstood or understood differently by different stakeholders. Concepts such as ‘resilience’ tends to be oversimplified by policy making and planning processes. ‘Resilience’ should not be mistaken for stoicism or ‘bouncing back’ (i.e. returning to a pre-disaster state), as this understanding can actually be a barrier to increasing adaptive capacity by supporting a reluctance to change (Kiem et al. 2010a). Lack of consistent adaptation terminology between organisations will also create issues for cross-jurisdictional communication and cooperation (Hadwen et al. 2011). For example, confusion between ‘mitigation’ and ‘adaptation’ was identified within the private sector (Johnston et al. 2013D). At the same time, Howes et al. (2013D) suggest that use and definition of key terms need to better account for socio-economic diversity and allow for more tailored, context-specific responses. As some organisations and departments utilise terms differently, this suggests that terms need to be clearly defined and discussed at the outset of planning processes to ensure all participants have the same understanding.

Climate change messaging needs to be bespoke to its intended audience and should take care not to induce fear, apathy or scepticism. While much of the research recommended the need for more communication with communities, this is not without risks. Awareness of climate change can result in a sense of helplessness, thereby reducing adaptive capacity.

Climate change knowledge can generate fear and a lack of confidence, as evidenced by residents in Victoria and Queensland concerned about climate change being more inclined to leave a potential climate impacted area. This will have resilience repercussions but can also be seen as individuals managing their own risk. It is important that engagement around disaster preparedness strategies do not focus on climate change messages that may induce further scepticism, apathy or fear; messages regarding climate change need to be constructive and positive, focusing on what can be done and addressing individual interests (Boon et al. 2012D). People can

also be adaptable without believing that climate change is a concern. This was highlighted in the Ingham, Queensland case study where residents who were least concerned about climate change showed a high level of resilience to floods, likely due to their strong sense of place about their community (Boon et al. 2012D).

Promoting the implementation of adaptation strategies may also give a sense of false security. Therefore, communication of adaptation responses needs to be upfront about its objectives and known limitations. This was particularly noted in response to flood control schemes which were felt to encourage development in high risk areas (Wenger et al. 2012D). The community response to the failure of the Wivenhoe Dam to protect downstream communities during the 2010/11 Queensland floods is a recent example of this phenomenon. The role of the dam for opposing purposes (drought and flood protection) was not well understood (Kiem and Austin 2012). Drought and flooding strategies need to coexist and need to be carefully communicated to surrounding communities, particularly as climate change projections predict that droughts and intense short-lived rainfall events are likely to occur with increased frequency in the future (Sherval and Askew 2012).

Climate change messaging is particularly complex because, as Hanson-Easey et al. (2013D) note, perceptions of climate change do not exist in an isolated vacuum; they are linked with political views, media representations, personal values, lifestyle imperatives and other concerns, such as financial or cost of living issues (Hanson-Easey et al. 2013D). Because of this and climate change's inherent nature as a complex topic with some degree of uncertainty, climate change frequently struggles to hold public attention when competing with other everyday challenges. For climate change to be perceived as a risk that demands a response from individuals and the local community, it must be presented as a serious, present danger to an asset valued by and relevant to the community (Hanson-Easey et al. 2013D). This needs to be carefully balanced with the suggestion by Boon et al. (2012D) to avoid generating fear.

Public engagement on climate change, therefore, cannot simply be improved through educating the 'misinformed' with more accurate information (Hanson-Easey et al. 2013D). Instead, the design and implementation of bespoke, tailored climate change communication and visual narratives are needed that align with a community's interests, concerns, and general worldview. This will also help to avoid audience responses being ineffective or eliciting the opposite reaction from those intended (Hine et al. 2013D). "Climate change will always mean different things to different people, and the opportunities this threat engenders for social dialogue on what is valuable, who is most vulnerable, and what type of future we want for future generations, are considerable" (Hanson-Easey et al. 2013D p.53).

Communication and education about climate change needs to be targeted to vulnerable and hard to reach populations (older people, low income groups, people with disabilities, newly-arrived migrants and Indigenous communities). Related to the point above, targeting needs to take into account local and cultural considerations. Research by Reser et al. (2012) shows that people from more closely settled areas with higher levels of education, women and younger generations are more likely to be concerned about climate change, although the gap may be narrowing between rural and urban people (Reser et al. 2012). Boon et al. (2012D) also noted that younger generations are more likely to be concerned about climate change; therefore a focus on disaster education for this age group will help this cohort to adapt to longer-term changes in climate. Older groups, and those less educated have been found to be the least concerned and informed about climate change.

People from culturally and linguistically diverse (CALD) backgrounds can face greater challenges during extreme heatwaves due to socio-economic disadvantage, linguistic barriers, poor housing conditions, and cultural practices (such as heavy clothing or not drinking water). For local and state/territory government, creating refuges (such as community houses), providing sheltered bus stops with drinking water, increasing cultural awareness in health services and other agencies, and building stronger partnerships are additional actions that should also be considered (Hansen et al. 2012D).

Fritze et al. (2009) also note that, regarding climate change, hard-to-reach communities may also include wealthy, high consumption communities, and people who are sceptical about climate change or the proposed actions to address it.

Principles for engaging hard-to-reach communities include devoting time and resources to develop trust, using existing networks and trusted sources of information, and going to places where people feel comfortable.

Carefully designed, well-implemented and effective community engagement strategies are important components of effective and inclusive climate change adaptation measures. Citizen engagement in decisions and actions can have multiple benefits, including but not limited to securing local ownership and support; creating heightened trust, transparency and credibility for decision-making processes; making policies more practical and relevant; and achieving cost savings (Fritze et al. 2009). However, Hansen et al. (2012D) also point out that the identification of vulnerability based on factors that make a group distinct or different to the broader population can be divisive. The response to vulnerability and how it is communicated should be sensitive to this, and ensure that

actions do not reinforce perceptions of difference. Adaptation to climate change should take a 'whole of population' approach while reducing inequalities that increase vulnerability.

Collaboration and effective sharing of information is critical. Information sharing within agencies, between levels of government and with the community was routinely identified in much of the research as critical to collaboration. Information sharing needs to be planned and strategic, particularly for emergency management, which needs to consider operational, tactical and strategic issues.

How to effectively engage stakeholders on adaptation, particularly when change is required, remains a key challenge. The QUT (2010) notes that

"the standard approach of making relatively small adjustments to existing management processes is unlikely to be successful. Fundamental shifts in thinking are needed that explicitly acknowledge the new and uncertain risks a changing climate is likely to bring. Processes for bringing together stakeholders and key decision-makers with the scientific community could help promote new forms of dialogue and consensus-building" (p. 9).

Integrated land management (ILM) is one approach being trialled as a technique for stakeholder engagement to enhance the resilience of socio-ecological systems between stakeholders and across multiple scales through major changes in land use. As a process of greater collaboration, this "involves facilitating interactions, sharing knowledge and joint decision-making between different levels of government and between public and private land managers" (Bennett et al. 2012 p. 5). Bennett et al. (2012) have identified numerous enablers for good collaboration including:

- building on existing formal and informal networks
- creating informal links across governance levels to reduce problems associated with information and imbalances in influence
- using existing policies and strategies as a basis for developing common objectives
- carefully considering the nature of change, particularly climatic change.

Collaborative approaches can increase costs in the short term due to the greater time requirements. Collaboration can also be hindered by unequal power relations, fragmentation, and lack of leadership in interactions and decision-making.

The ACT Government's AP2 recognises the importance of information sharing between state/territory governments and other level of government. At present this includes the NSW and ACT Regional Climate Model Initiatives (NARCliM) to improve the currency and accuracy of climate data available for the ACT. It also recognises the importance of the broader Australian Capital Region (ACR) in adaptation planning (ACT Government 2012a).

The messenger is just as important as the message. The perceived importance of each source of communication was found to vary between and within communities (Boon et al. 2012D). This reinforces the need for communications to occur across multiple modes and by different sources, including emerging social media. Research by Boon et al. at (2012D) at locations in Queensland and Victoria found compelling evidence that the community does not trust the government or media with information about climate change but were more inclined to believe scientists. This result parallels the findings of Reser et al. (2012) on public trust in these sources.

4.1.4 Community expectations for government

Key findings for community expectations for government in relation to efforts to increase resilience and adaptive capacity:

- Community expectations about the role of government for climate change adaptation may not align with government capacity.
- Deliberative processes between government and communities can have a positive effect on perceptions of and engagement with climate change adaptation.

Community expectations about the role of government for climate change adaptation may not align with government responsibilities and capacity. Residents in NSW and Victoria see a significant role for government in adaptation including creating knowledge, sharing information, managing risk to public and private assets, local planning and paying for adaptation action (Barnett and Waters 2013D). Participants distinguished adaptation functions by different levels of government, with state/territory government seen as the best entity to

coordinate local governments and provide funding support. Federal government was seen as needing to focus on providing risk information and bearing adaptation costs. Local government was viewed as more appropriate for managing public assets, regulating decision-making related to private adaptation and coordinating local planning. Community members were not interested in one level of government or sector having sole responsibility for adaptation. This may also apply to other areas of adaptation action.

Deliberative processes between government and communities can have a positive effect on perceptions of and engagement with climate change adaptation. Hobson and Niemeyer (2011) tested the efficacy of employing deliberative processes - that is, creating opportunities for people to share information and examine an issue together to come to some conclusions about it – to foster adaptive capacity for individuals from the ACT region, compared to just providing climate change information. It was found that the discourse increased motivation, fostered a greater desire for action and willingness to act, and reduced scepticism. Being exposed to different opinions and ideas allowed participants to re-evaluate their own positions and form more coherent positions on the climate issues being discussed (Hobson and Niemeyer 2011). The authors noted that this change in attitude does not necessarily translate to adaptive action and suggest that "strong governance signals and leadership are still essential for fostering a positive public response to the challenges of climate change" (Hobson and Niemeyer 2011, p. 957).

Research by McNamara et al. (2011) in two Torres Strait Island communities also indicated that confidence in decision-making or governance processes is critical in the assessment of limits to adaptation. Confidence in the process underpins perceptions of risk, especially as to if, how and when barriers may be addressed, and provides context in which limits to adaptation can be assessed or determined by a community rather than imposed by external circumstances (McNamara et al. 2011).

4.2 Learning from experience

The findings in this section are particularly relevant for emergency management.

"Vows made in storms are forgotten in calm." (Thomas Fuller in Verdon-Kidd et al. 2010)

Natural disasters are generally considered by governments as one-off events, as evidenced in early drought policy (Sherval and Askew 2012). However, the perception of some climate-related events has been shifting over time. For example, drought was viewed until the late-1980s as a climatic abnormality and therefore was treated with disaster relief policies in a similar way to earthquakes or floods (Botterill and Wilhite 2005 in Kiem and Austin 2012). However, today the view of drought as a "*one-off, unpredictable and unmanageable natural disaster*" is questioned in science and policy (Kiem and Austin 2012, p. 5).

Regardless, adaptation planning will be informed by lessons learned from past events. They are a valuable source of information with regard to:

- identification of unknown vulnerabilities or those that have yet to be addressed, including different levels of vulnerability within a single community
- adaptation measures put in place as a result of the knowledge gained from the experience from and immediately after the event
- adaptation measures put in place following subsequent reflection or formal enquiry on ways to better prepare for future events
- understanding community, institutional and governance responses to climate events, and their interactions that may determine the success or failure of climate change adaptation strategies (Kiem et al. 2010a).

Recent events (drought, bushfire, floods and storms) have resulted in various policy responses to disaster risk management across the country that has enabled rapid mobilisation of resources which can assist with adaptation planning (Howes et al. 2013D). The lessons below have been informed by research reviewing these events to help inform adaptation decision-making. Broader emergency management responses have not been considered as part of the methodology of this project.

Learning from experience has tended to focus more on these extreme events rather than more gradual changes. There is a risk that adaptation lessons are skewed by only understanding the impacts and responses to extreme events and opportunities to learn from more gradual changes are missed.

Key findings regarding how past experience with extreme events can inform future adaptation action:

- Prior experience is unpredictable in its influence upon disaster resilience.
- Short-term adaptation responses may create a false sense of security in the longer term.
- Disaster management is a useful starting point to consider renewed institutional arrangements for adaptation.
- Basing decisions on past experiences will become increasingly risky.
- We have already begun adapting; however, climate change creates additional complexity and may not have been the primary driver of change.
- For some disasters, attitudinal barriers can prohibit planning, and public discourse is needed to change views.
- Local policy that is enacted after an extreme event can become a model for new national policy.
- Extreme climatic events can provide impetus for overdue or unpopular adaptation options.

Prior experience is unpredictable in its influence upon disaster resilience (Boon et al. 2012D). Research in Innisfail (post-cyclone) and Ingham (post-flood) found that preparedness was highly predicted by prior disaster experiences, as well as financial capacity and communications. Of note was the finding that homeowners in Innisfail and Ingham did not report having building insurance despite past experience.

Kiem et al. (2010b) noted that lack of system stresses, such as water scarcity, is likely to make communities unprepared for system failures. Communities with a collective memory of a water supply crisis may be capable of responding to water insecurity with adaptive change more easily than those that lack experience.

AECOM (2010) identified that there was a high level of awareness of bushfire in the ACT due to relatively recent and historical bushfire events. This level of awareness can be observed through bushfire preparedness strategies being implemented (including gutter and garden design in some new developments), and is supported and driven by the high quality and highly accessible data on bushfire in the region (AECOM 2010).

However, preparedness for one disaster can make residents and agencies less concerned or prepared for other potential risks. For example, Victoria's drought prior to the 2010/211 floods had caused many residents to become apathetic towards flooding. Residents were more concerned about drought-proofing their homes and some were seeking permits to build on properties covered by flood overlays (Bird et al. 2011). A few residents also thought they were safe because their home was built above 1909 flood levels. Similarly, Victoria's Department of Health had made progress in pre-planning prior to the 2009 heatwave; however, the department was still challenged by service demands and escalating fatalities during the heatwave (QUT 2010). Bushfire risk planning had taken precedence over planning for extreme heat.

On the Gold Coast, significant coastal protection works were carried out and legislation enacted following repeated storm surge events during the 1960s and 1970s. However, an extended period of relative calm (or limited storm surge events) followed, causing lessons to be forgotten and governments to be less proactive. At the same time, significant development has occurred.

While the management and protection responses undertaken have been effective to date, many of its elements have yet to be tested under extreme conditions. Proactive responses are also facing increasing community objections during calm weather (Helman et al. 2010).

Short-term adaptation responses may create a false sense of security in the longer-term. The building of resilience, such as diversifying water supply systems, needs to consider long term viability and sustainability. Current actions may create a false sense of security within individuals and communities and thereby reduce long term resilience (Albrecht et al. 2010). For example, Kalgoorlie, with the provision of the Golden Pipeline to supplement local water supply with that from Perth, have much greater confidence that their water supply will persist into the future due to technology and government support than communities such as Broken Hill (NSW) that have had to endure repeated failure of their water supply. However, Kalgoorlie's water supply is potentially at risk due to climate change and residents may find themselves unprepared for a future of price increases and interruption of supply (Albrecht et al. 2010).

Disaster management is a useful starting point from which to consider renewed institutional arrangements for adaptation. In Australia, risk management arrangements are formed around interagency and

intergovernmental approaches spanning all three levels of government, working together closely with volunteers, NGOs, businesses and the community. Importantly, issues around key definitions have been largely overcome. (Howes et al. 2013D).

Basing decisions on past experiences will become increasingly risky. There is a tendency to stay within known parameters and uncertainties, yet there is a growing need to understand system-wide properties at scales and within timeframes beyond the normal comfort zone of most decision-makers (Albrecht et al. 2010).

Small changes in the sequencing, timing or location of impacts from specific events should be used to hypothesise a number of 'what if' scenarios to consider potentially different or more significant impacts (Verdon-Kidd et al. 2010). Impacts on overall capacity of core services, such as health care and social services, should also be included (e.g. longer-term disasters, multiple disasters across a region or multiple events over short periods of time). The 2009 extreme heatwave and bushfires had major impacts for Victoria's infrastructure, emergency service providers and health care system. The electricity system has been identified as being particularly vulnerable; as it operates with little spare capacity, it lacks resilience to unexpected events such as a heatwave. Scenario testing is recommended to analyse the impact of hotter and more prolonged heatwave events on Victoria's infrastructure (QUT 2010).

We have already begun adapting; however, climate change creates additional complexity and may not have been the primary driver of change. Major events such as cyclones, bushfires and floods, have been a major impetus to undertake adaptation measures (Kiem et al. 2010a). These events have resulted in various changes including:

- introduction of building and infrastructure design standards
- emergency management protocols
- revised coastal policy
- land buy backs and exit grants
- changes in water policy, including the introduction of water trading
- technological and engineering based solutions (such as desalination and flood protection works)
- community awareness programs (including warning systems and pre-event preparation)
- changes to coordination, operations and maintenance of essential infrastructure (e.g. drainage networks and load shedding).

However, measures implemented after these events may not be fit for purpose with continued climate change. For example, flood protection was put in place to address risk in Charleville (Qld) from the Warrego River but failed to take into account flooding from Bradley's Gully; this left the town exposed to flooding as evidenced in 2008 (Kiem et al. 2010a).

In NSW, the residents of Broken Hill have faced numerous water crises and have implemented various engineering strategies to improve the water catchment and supply systems. However, a hotter climate and harsh cost-recovery economic conditions put the security of Broken Hill's future at risk (Albrecht et al. 2010).

For some disasters, attitudinal barriers can prohibit planning and public discourse is needed to change views. During Victoria's 2009 heatwave, there was a general attitude among certain agencies that heatwaves do not require a specific planned response or that a generic disaster response is adequate (QUT 2010). Furthermore, there is a collective attitude among the public that, as Australia is a country where warm temperatures are common, excessive heat is not a threat. Public education campaigns are recommended (QUT 2010). However, the issue of response is compounded by the fact that the heatwaves are not a recognised emergency by the Federal Government; therefore, state/territory governments are unable to claim reimbursement for a percentage of certain response and recovery costs.

Local policy that is enacted after an extreme event can become a model for new national policy. Cyclone Tracy's high intensity and low movement speed caused widespread devastation due to Darwin's inadequate structural engineering design, including the complete destruction of around 60 per cent of housing which led to the evacuation of around 80 per cent of Darwin residents (Mason and Haynes 2010). Following the disaster, design recommendations were produced in response to the failures of building practices by incorporating integrated engineering design into residential buildings (Mason and Haynes 2010). These wind engineering recommendations and design standards have since been refined and incorporated into national building codes for other cyclone-prone areas of Australia. The practice of using structural engineering design in housing is now standard in Australia (Mason and Haynes 2010).

Extreme climatic events can provide impetus for overdue or unpopular adaptation options. Kiem et al. (2010a) note the ability of natural disasters to provide drive for governments, communities and industry to implement adaptation measures that may not be popular or deemed worthwhile during periods of average climate. Engineering-based design requirements for residential buildings in tropical cyclone regions were implemented in response to Cyclone Tracy. Because these changes were mandated, the process of incorporating these requirements became progressively more affordable (Mason and Haynes 2010).

4.3 Costing, financing and funding adaptation

There are considerable challenges associated with costing, financing and funding adaptation actions. Adaptation options entail varying costs, in terms of time and resources involved in their implementation and maintenance, and with respect to the risks involved (Hadwen et al. 2011). Robust costing must take into account a wide range of direct and indirect impacts of both climate change itself and the responses put in place. The effectiveness of some options may decrease as climate change continues or as other factors that modify the impact change. Consideration of who pays for adaptation is also an ongoing issue for many decision-makers.

Key findings regarding how to cost, finance and fund adaptation action:

- There is limited research testing how adaptation costs and benefits might be distributed through the community and over time.
- Disaster relief is not currently an effective tool for financing adaptation.
- Traditional economic approaches and existing policy mechanisms can create barriers to effective adaptation decisions, particularly in the private sector.
- Current insurance products and practices need improvement to be effective adaptation tools in the longer term.

There is limited research testing how adaptation costs and benefits might be distributed through the community and over time. The costs per property of implementing community level adaptation options are likely to be reduced as requirements are introduced and homes are increasingly being built from standardised plans (Mason and Haynes 2010). Some situations will require alternative adaptation options, either at the property level or alternative funding from scales of governance beyond the community; regardless, benefits may not be shared equally across the community (Fletcher et al. 2012D).

Economic tools that estimate costs and benefits throughout the community are useful to inform practical choices about which adaptations, or suite of adaptations, are likely to result in more benefits than they cost to implement (Fletcher et al. 2013D). Such information will be essential to engage communities in adaptation. Community-level coastal adaptation options, such as seawalls, can potentially result in a balanced mix of total benefits and high benefit-to-cost ratios; they also require coordination and funding from the entire community for reasons of both equity and affordability.

Going beyond traditional local and regional scale cost-benefit analyses, to investigate the distributions of costs and benefits within the community, will be vital for ensuring the most efficient adaptation options that are equitable, affordable and economic (Fletcher et al. 2013D).

Draft research by Dobes et al. (2012D) examined the Cairns community's willingness to pay for post cyclone emergency services. This work identified that the community was generally willing to pay for a faster resupply of fresh food and a reconnection of utilities but not for additional services (policing and emergency accommodation for animals). Despite a willingness to pay, faster provision of services may not be feasible due to post-cyclone logistical challenges. The value of these services may need further consideration, especially given that these issues are already being addressed by competition in the private sector. It also would be difficult to restrict faster utility connections only to those willing to pay; all residents in a re-connection area would benefit, incentivising many to free-ride.

Disaster relief is not currently an effective tool for financing adaptation. Combined underinvestment in protection prior to a catastrophic event and taxpayers financing recovery following the event has been critiqued on both efficiency and equity grounds (Crompton et al. 2012D). Disaster relief in response to the 2010/11 flood in Victoria and Queensland was felt by many to be over-generous and untargeted, and under current arrangements would not increase resilience to disaster and adaptation in the longer-term (Wenger et al. 2012D). Regardless, with continued climate change, the long term viability and suitability of existing relief arrangements for natural disasters is questionable. Existing funding mechanisms, such as funding arrangements for Natural Disaster

Recovery Relief Arrangements (NDRRA), provide for the repair of public infrastructure within a short period of time (e.g. 21 days) from the date of declaration of the natural disaster. Councils may not be able to commence emergency works and clean up within this time frame. While extensions have been granted (e.g. Newcastle floods of 2007), this is by exception (Verdon-Kidd et al. 2010).

Reducing reliance on government emergency relief may help defer the costs of subsidies while promoting more strategic adaptive behaviours (Boon et al. 2012D). The Darwin Cyclone Damage Compensation Act was passed in May 1975, which allowed uninsured owners and occupants to claim up to half of the value of their home and contents (capped) from the government. Mason and Haynes (2010) identify that, because the payments were not means tested, this can be seen as having a disincentive for people to cover their own exposure.

Traditional economic approaches and existing policy mechanisms can create barriers to effective adaptation decisions, particularly in the private sector. Communities may not have the capacity to invest in adaptation due to financial constraints or because of lack of consensus (Fletcher et al. 2013D). The level of government and community support will guide adaptation decision-making as much as the cost of the options themselves (King et al. 2012D). The types of adaptation will also be bound by the scale at which adaptation options are governed, which may further constrain funding or financing opportunities (Fletcher et al. 2013D).

Hussey et al. (2013D) note that there are currently no market-based mechanisms to encourage financing adaptation in physical assets and infrastructure. There are also institutional and policy barriers, including a lack of policy incentives to replace or upgrade existing assets to increase climate resilience (Hussey et al. 2013D). For the private sector, Johnston et al. (2013D) identify uncertainty in policy and information, as well as insufficient commercial incentives as a problem for engagement with this sector in general. A combination of information provision, non-coercive adaptation financing policy such as co-financing and market-based mechanisms (tax-credits, grants, tariffs, climate bond. etc.), coercive regulation by requiring adaptation, and the introduction of specific taxations are recommended by Hussey et al. (2013D) to facilitate private sector adaptation action.

The long term protection of physical and financial assets of Australia will require significantly more capital than is available through normal funding options. It is suggested that further adaptation policy and reform include business cases for private investment and financing (Hussey et al. 2013D). Kiem et al. (2010a) note that “power utilities and transport (especially rail) companies find it difficult to invest in adaptation because of regulatory barriers (they are unable to recoup their investments through pricing, for example) – limiting their potential to enhance their adaptive capacity” (p. 34).

Risk information is also needed to trigger private adaptation responses. Johnston et al. (2013D) identify that there is a paradigm in many governments, including those in Australia, that adaptation in the private sector will be predominantly led by market signals; however, it is suggested that without direct policy guiding adaptation, this is a high risk strategy which is untested.

Current insurance products and practices need improvement to be effective adaptation tools in the longer-term. Insurance is generally considered an important tool to help defray the costs of climate change impacts, particularly in the private sector. However, there are limitations associated with insurance arrangements, individual behaviours and government responses to natural disasters. As noted in one report, 26 per cent of all NSW households do not have any form of home and contents insurance (Giles 2007, in Verdon-Kidd et al. 2010, p.44).

Insurance plays a key role in sending price signals that reflect risk and contributes to resilience by supporting recovery from extreme events. While there is growing scientific confidence that many natural hazards will increase in both frequency and intensity, regional and local implications of a warming climate on extreme weather remain uncertain. As a result there is no clear climate change signal in the increasing cost of disasters (Crompton et al. 2012D). The 2013 flooding in Queensland may be the start of such a signal as insurance providers are in the process of withdrawing from high risk areas or significantly increasing premium prices. However, in AECOM’s view, if blanket price increases are implemented irrespective of the risks in a specific location then the signal may lead to perverse outcomes.

Insurance coverage can be linked to prior experience but is more likely associated with financial capacity. The provision of government or charitable assistance has been found to be negatively associated with insurance cover in some flood-and-fire-impacted communities (Boon et al. 2012D). Limited or patchy uptake of insurance by individuals will limit the effectiveness of insurance as an adaptation response. Consumers are reluctant to pay for insurance to cover natural hazards with low probabilities of occurrence, as evidenced through surveys with 2011 Australian flood victims (Crompton et al. 2012D). Furthermore, post-disaster inflation, a surge in demand and shortage of materials and labour can leave fully insured asset owners with significant costs. Many Darwin residents found that after Cyclone Tracy, they were left with significant out-of-pocket expenses for their fully

insured houses due to post-disaster inflation, which was compounded by Darwin's relative isolation (Mason and Haynes 2010).

Limited investment in protection against and preparation for natural disasters combined with government financing of part of the recovery can be critiqued on both efficiency and equity grounds (Crompton et al. 2012D). There are critical issues of equity when examining preparedness for disaster, since people with limited means are likely to be more vulnerable to impacts and hence will be subject to those influences which lead to leaving a community. In addition, they are more likely to be subject to greater psychological distress, and have poor coping and adaptive capacity as a result, bringing an additional burden upon community service organisations, including government agencies (Boon et al. 2012D).

Government has a key role to play in better supporting uptake of insurance by residents and businesses and by seeking to minimise future losses through land use planning and building regulations (Crompton et al. 2012D). Greater consideration by state/territory and federal government to actively support the uptake of insurance, including subsidies for lower socio-economic groups, should also be considered. Government should also consider how to work with industry to promote awareness about standard insurance arrangements regarding coverage. For example, although insurance companies cover the cost of repairs to property damage associated with landslip, they do not generally cover restoration works associated with the landslip itself. Similarly, the cost of removing a fallen tree is also not covered by insurance unless it has fallen on a fence or other insured object (Verdon-Kidd et al. 2010).

4.4 Limits and barriers to adaptation

There are many challenges associated with adaptation. Understanding the limits of and potential barriers to adaptation is important for decision-making for a number of reasons, including:

- determining which responses to climate change are both practicable and legitimate, and the timescales over which adaptation may be needed and considered effective
- engaging with stakeholders to identify issues and values
- prioritising adaptation strategies and refining their objectives (Morrison and Pickering 2011).

Social and economic limits to adaptation are largely subjective. These limits are rarely absolute or insurmountable. Physiological limits of individuals remain largely unknown.

Key findings regarding the limits and barriers to adaptation:

- Lack of community support can be a significant barrier to climate change adaptation.
- Local governments face capacity and resource constraints to effectively support local adaptation.
- Current institutional arrangements can create barriers for effective collaboration.
- Perceptions of adaptation interventions will vary between stakeholders and may be a source of conflict.
- Lack of system understanding remains a key barrier to adaptation.
- Lack of accessibility to the most up-to-date and relevant information can be a limitation for decision makers.
- Key tools to support adaptation are constrained by potential issues of liability.
- Failure to consider the potential consequences of climate change in formal reviews of natural disasters is constraining adaptation learning.

The factors that create limits and barriers are also strongly interrelated and complex – making it difficult to isolate a particular ecological, economic or institutional system as the key factor limiting adaptation (Evans et al. 2011).

Lack of community support can be a significant barrier to climate change adaptation. As evidenced by multiple failed efforts to introduce potable wastewater reuse to supplement failing water supplies, community support for adaptation options is critical (Poloczanska et al. 2012). Similarly, relocation from areas at higher risk from storm surge in Darwin was proposed by the federal government after Cyclone Tracy. This strategy was met with public opposition and eventually abandoned, despite the likely risk of future storm surges (Haynes et al. 2011).

Effective communication has been identified as key to ensuring community engagement for implementing waste and recycled water use for a case study in Queensland. (Freeman, Bates et al. 2008 in Poloczanska et al. 2012). Alternatively, poor communication, combined with top-down management approaches can lead to a disconnect between policy and the communities affected by adaptation strategies.

Local governments face capacity and resource constraints to effectively support local adaptation. Local governments in all states and territories face competing priorities and limited resources when addressing adaptation (Mukheibier et al. 2012). However, long-term, large adaptation projects are likely to be beyond the capabilities of most local governments and need federal funding on a priority basis. The complexity and cross-cutting nature of climate change risks, particularly of coastal areas, requires inter-jurisdictional reform supported by a national coastal policy that clearly articulates roles and responsibilities (Helman et al. 2010).

Current institutional arrangements can create barriers for effective collaboration. Planning, building and insuring are co-dependent elements of the built environment, however there is relatively little transfer of expert personnel between professions. This lack of interaction is compounded by the governance of these issues by the government departments, statutory bodies and boards that have responsibility for current guidelines, codes and legislation (King et al. 2012D).

Perceptions of adaptation interventions will vary between stakeholders and may be a source of conflict. Adaptation interventions will be viewed in different ways by different stakeholders and may affect stakeholders differently. “A benefit to one part of the system (such as maintenance of water level) results in a negative impact to another part of the system, with the emergence of winners and losers being one outcome” (Gross et al. 2011 p. 77). This can divide communities, erode trust, and reduce capacity for stakeholders to work together.

Research by Morrison and Pickering (2011) on limits to adaptation in the Australian Alps worked with tourism operators and conservation managers to identify the value of better consideration of social and governance issues in adaptation planning. This approach identified that conflict may arise between stakeholders as a result of different adaptation actions where objectives are not shared. Perceptions of limits were also identified – for example stakeholders other than tourism operators identified technological and resource limits for ski operators, however, these were not identified by the operators themselves.

Limits for one stakeholder can be viewed as opportunities by a different stakeholder. Evans et al. (2011) sought to identify potential limits to adaptation for the tourism and fisheries sector in the Great Barrier Reef Marine Park Heritage Area.

In the Great Barrier Reef region, there are many examples where addressing limits to adaptation could benefit multiple industries simultaneously, particularly with regard to catchment management and coastal development, although there may be trade-offs for individual land owners (Evans et al. 2011).

Lack of system understanding remains a key barrier to adaptation. Unknown thresholds of ecological resilience and lack of understanding about the interconnectivity within ecosystems limit the identification of effective of adaptation options. Similarly, better understanding of climatic and non-climatic changes over time will influence vulnerability and adaptive capacity (Hadwen et al. 2011). It is recognised that existing pressures on natural environments and ecosystems, including habitat loss/fragmentation and competition with exotic species, have the potential to reduce the capacity of these systems to adapt to climate change (Doerr et al 2011).

Trade-offs between different adaptive management approaches also need to be considered in the short and long-term. For example water managers need to consider a range of short and longer-term solutions, including diversification of supply and storage options, increasing storage capacity and improving water management through changed behaviours. Some of these responses have the potential to push systems to unstable states with limited predictive capacity, meaning that further adaptive responses will be difficult (Albrecht et al. 2010).

As the greatest need for adaptation may not relate to direct impact or a core function, systems level thinking from a local perspective should also be considered. For example, initial operational concerns for ports have been focused on the seaward side of operations (access, mooring, loading and unloading of ships), which are expected to be particularly vulnerable to climate variability; however, disruptions to wider supply chains and supporting infrastructure have experienced the greatest impacts during recent extreme events, suggesting that planning also needs to be look beyond the port (McEvoy and Mullett 2013).

Lack of accessibility to the most up to date and relevant information can be a limitation for decision-makers. The need for increased sharing of information and data is identified as necessary for effective decision-making, including specific and general data relating to climate projections, natural, constructed and social systems, and bio- or geo-physical parameters (Hadwen et al. 2011). There is a distinct lack of coordination of existing databases and data-sharing arrangements between relevant authorities.

Key tools to support adaptation are constrained by potential issues of liability. While the need for information relating to the location of possible risks to support adaptation planning is clear, there is a reluctance to provide this information because of the potential adverse impacts on property values (Wenger et al. 2012D). Furthermore, local and state government planning agencies can be excessively risk averse out of fear of having to compensate people affected by climate hazards (Macintosh et al. 2013D). Formal enquiries following flood events, such as Royal Commissions, are similarly cautious about recommendations for structural measures and were limited to considering options that only protect current development (Wenger et al. 2012D).

Liability shield instruments are one mechanism to reduce this constraint; they provide partial or full exemption from legal liability for action, or lack of action, regarding climate hazards (Macintosh et al. 2013D). Another approach is the use of statutory exemptions, which can provide councils with exemption from liability provided they can demonstrate compliance with applicable codes, guidelines, manuals or demonstrate good faith (Macintosh et al. 2013D).

Failure to consider the potential consequences of climate change in formal reviews of natural disasters is constraining adaptation learning. A review of four recent enquiries on flooding found that they all but ignored the issue of enhanced flooding as a result of climate change and therefore have likely underestimated future risks and adaptation needs. In addition, failure to consider other relevant changes, such as future population pressures and movements, compound this underestimation (Wenger et al. 2012D).

4.5 Maladaptation

Adaptation-related decisions intended to reduce climate change impacts may instead increase vulnerability. This problem of increasing risks as a result of adaptation is often termed 'maladaptation'. Actions that (relative to alternatives) increase greenhouse gas emissions, disproportionately burden the most vulnerable, have high opportunity costs, reduce incentives to adapt, or establish mechanisms that limit the choices available to future generations are maladaptive (Barnett and O'Neill 2010). Adaptation planning decisions should be screened for these possible adverse effects.

Key findings regarding maladaptation:

- The management of evacuation due to extreme weather events can be maladaptive if not handed sensitively, leading to inequities and additional problems after the event.

The management of evacuation due to extreme weather events can be maladaptive if not handed sensitively, leading to inequities and additional problems after the event. The evacuation of Darwin under Cyclone Tracy was enacted under a protocol which prioritised the evacuation of women, children and elderly couples; this split families in some instances, creating disconnected families and communities (Haynes et al. 2011). The negative impacts of the cyclone on mental, physical and social recovery were also observed to be more severe for people who were evacuated (especially non-returned evacuees) than those that stayed. This is explored in Haynes et al. (2011) through the lens of being part of the 'therapeutic community' with those who stayed being able to contribute to the clean-up, rebuilding and reinvigoration efforts. However, it is not known whether evacuees' recovery was hindered by evacuation itself or by the degree of loss experienced by this group; it is also possible that this group may have experienced even greater trauma had they remained in Darwin (Haynes et al. 2011).

4.6 Timing and scale of adaptation

The timing for and scale at which adaptation is best delivered remain two fundamental issues. Adaptation will continue to be a series of reactions to environmental and social changes – some quickly executed in response to emergency, others more autonomously in response to slowly changing social and economic conditions (Gross et al. 2011). Government and communities have tended to favour short-term and responsive approaches, which can make adaptation more difficult to initiate (Stanley et al. 2013D).

Key findings regarding the timing and scale of adaptation:

- Timing of stakeholder engagement needs to be carefully considered.
- Timing and scale of implementation is complex and may not align with financial capacity.
- Adaptation actions need to take a long-term view to be effective.
- Doing nothing may be an appropriate adaptation response.
- Triggers need to be established for extreme events, as do thresholds for when extreme events move from a natural disaster to normal climate.
- Government needs to consider the time and steps it takes to effectively implement adaptation actions.
- Windows of adaptation opportunity following extreme events are short.
- The scale of both the impact and the potential adaptation response need to align.

Timing of stakeholder engagement needs to be carefully considered. Engaging with stakeholders about adaptation to longer-term changes in climate should be considered independently of extreme events when public emotions and political considerations are heightened. Conversely, there is value in capturing learning from extreme events before collective memory fades. Firsthand exposure to climate change-related-risks can create an emotional connection to climate change and make it a more meaningful, pressing issue (Hanson-Easey et al. 2013D). However, previous experience with a climate hazard does not necessarily increase ability to respond or adapt.

Timing and scale of implementation is complex and may not align with financial capacity. Understanding when to respond to adaptation and the scale of this response is a critical and challenging question for policymakers. When the answer of when and how to respond is clear from an economic perspective (based on a cost benefit analysis), the distribution of risk and the distribution of cost may complicate the issue (Fletcher et al. 2013D). Furthermore, communities may not have the financial capacity to fund the recommended adaptation option, such as a seawall, in the short or medium term even if it is economically justifiable and provides broad, equitable benefit to the community. This will put the onus of adaptation in the short term on alternative options, such as individual adaptations funded by the property owner, often at a smaller scale (Fletcher et al. 2013D).

Adaptation actions need to take a long term view to be effective. Although adaptation decisions need to be made now and adaptation measures need to start being implemented, the timeframe that these options need to take into account is long term to ensure they are effective and do not decrease long term adaptive capacity (Hadwen et al. 2011). Having more flexible and dynamic policy and planning that looks beyond political cycles is needed for this forward thinking approach.

Doing nothing may be an appropriate adaptation response. Garnett et al. (2012D) state that a 'do nothing' approach can be considered an appropriate response to climate change risks. However, in order to select this approach, the following are essential:

- full consideration of the potential consequences
- ongoing monitoring of climate change risks
- flexibility to recognise and respond to changed circumstances in a timely manner.

Triggers need to be established for extreme events, as do thresholds for when extreme events move from a natural disaster to normal climate. Governments, hospitals, emergency response organisations and the community were under-prepared for the 2009 heatwave experienced in Victoria (Kiem et al. 2010a, QUT 2010); coping was said to be "the result of reactive competence and capacity rather than proactive planning" (Kiem et al. 2010a p. 33). Part of the reason for this was that, as the event developed over a number of days, there was no clear threshold to trigger the management as a disaster (Kiem et al. 2010a).

The increasing frequency of climate-related events is also changing the perception of what is an extreme and what is 'normal climate' (Kiem et al. 2010a). In light of this, disaster management arrangements may need to be further reviewed. This is typified by changes in drought policy responses in Australia over the past 20 years. The perception of drought has been shifting over time. Drought was viewed until the late-1980s as a climatic abnormality and therefore was treated with disaster relief policies in a similar way to earthquakes or floods (Botterill and Wilhite 2005, in Kiem and Austin 2012). However, today the view of drought as a "one-off,

unpredictable and unmanageable natural disaster" is questioned in science and policy (Kiem and Austin 2012, p. 5). Drought measures are moving from a crisis management approach to risk management.

Government needs to consider the time and steps it takes to effectively implement adaptation actions. A sequence of action necessary to enable adaptation needs to occur. First, there needs to be a focus on governance in order to define roles and responsibilities among levels of government and between sectors. Next, statements of purpose and other institutional preconditions are needed in order for government and sectoral players to take action. Finally, after this statutory support is in place, uncertainty about risks and responses as well as an assessment of resources can be addressed. To support this, government initially needs to play an active role in adaptation rather than leaving action up to individuals and sectors (Barnett and Waters 2013D).

Windows of adaptation opportunity following extreme events are short. Recovery from extreme events and other reactive responses create windows of adaptation opportunities with the goal of reducing the impact. Rapid recovery may hinder adaptation, as new knowledge can take time to incorporate into existing regulations and guidelines (e.g. revised building codes). However, there is a need to act quickly, not just for community recovery, but also while the issue is relevant within the community memory and before complacency sets in, which happens relatively quickly (Helman et al. 2010). Delay of implementation of adaptation strategies, particularly after an extreme event, can be detrimental to success (Kiem et al. 2010a).

Conflict can arise when the timing of adaptation objectives differ between stakeholders. Morrison and Pickering (2011) note that effective long term conservation management goals (usually 10+ years) can often conflict with the short-term decision-making by the tourism industry and political decision-makers (usually less than five years). Rapid recovery responses may over-ride longer-term goals and reduce opportunities for stakeholder engagement.

Other temporal factors will also influence adaptation timing needs. For example environmental goals of adaptation strategies for natural resource management will vary depending on the climate conditions each year (Lukasiewicz et al. 2013D). During dry years, habitat and ecosystem protection will likely be the primary goals, whereas in wet years the focus would be biodiversity enhancement and restoration.

The scale of both the impact and the potential adaptation response need to align. Climate change adaptation actions should be implemented at local or regional scales, as these scales will determine which adaptation approaches are appropriate in order to address adaptation objectives given the physical, ecological, social, economic and cultural features of the area of concern. However, larger scales require consideration since adaptation actions may have consequences for connectivity with ecological and human systems beyond this area (Hadwen et al. 2011).

4.7 Sector-specific findings

A primary purpose of this synthesis was to look across sectors and to integrate and aggregate findings into common threads or themes of learning. This is particularly important in adaptation as responding to climate change largely requires a holistic, systems approach to avoid maladaptation and to manage risks (including non-climatic threats) over the long term. Sector-related messages are relayed, for this reason, throughout this report under broader, interconnected themes. However, as summarised in this section, quite often the research did directly address the adaptation objectives of a specific sector, particularly for natural resource management, primary production and land use planning. It is also important to note that the findings captured below represent the lessons relevant to a sector but in no way did the research reviewed comprehensively cover any individual sector.

4.7.1 Natural environment

Key findings related to adaptation and natural resource management:

- Existing management strategies will lessen the impacts on ecosystems, but the objectives and approaches of conservation and management plans may need to be reconsidered in the context of longer term climate change.
- Adaptation needs to take an ecosystem-based approach where resources are considered and directed towards a suite of actions; however, this approach is constrained by institutional complexity.
- Taking an ecosystem-based approach to adaptation for natural resource management requires adaptive management, meaning actively experimenting with actions and learning from past activities.
- Due to competing demands and pressures on environmental assets, adaptation needs to ensure diverse stakeholder engagement and collaboration to allow value-based decision-making.
- Habitat protection is considered the optimal action for assisting the majority of species adapt to climate change within a limited budget.
- There are conflicting research conclusions regarding whether water pricing is effective in curbing water demand.

Existing management strategies will lessen the impacts on ecosystems, but the objectives and approaches of conservation and management plans may need to be reconsidered in the context of longer term climate change. Many adaptation options already occur in response to stresses other than climate change, including protecting and maintaining habitats, landscape connectivity, species management and population genetics (Lukasiewicz et al. 2013D, Garnett et al. 2012D, Hadwen et al. 2011). These options are also likely to have less potential for maladaptation, offer multiple ecosystem service benefits and have lower risk levels. More interventionist approaches need to be considered for maladaptation potential, ecosystem service benefits and effectiveness (Lukasiewicz et al. 2013D).

A review by Hadwen et al. (2011) of existing management actions in Kakadu National Park found that they were considered to be reasonably robust to threats posed by climate change as a consequence of their focus on sustainability and building resilience to a range of stressors. Many of the identified approaches also need to be considered as complementary strategies where the level of management intensity will have to increase over time (Garnett et al. 2012D).

Policy objectives that seek to restore environments to pre-European states or similar aspirational benchmarks will need to be reconsidered as their value in a changing climate will become increasing obsolete.

Broader spatial and temporal perspectives about conservation benchmarks will need to be employed. To facilitate re-generation, protection of some species at specific locals may have to be abandoned to avoid further exposure and vulnerability in the longer-term or to the system as a whole (Garnett et al. 2012D).

The goal of adaptation also needs to be much more explicit and consider limits posed by climate change. Re-thinking of current objectives for natural resource management may be required as many of those currently set will be both expensive and unsuccessful. Existing goals, targets and thresholds of these management actions need to be reconsidered in order to accommodate climate change threats.

While there is scope for improvement and targeted adaptation actions, a major re-think of legislative objectives is required to ensure that actions are sustainable and not maladaptive in other habitats and/or detrimental to existing economic and social values within a given area (Hadwen et al. 2011).

To provide holistic resilience in natural systems, a change in focus from maintaining all species in their current locations to preserving ecosystem service delivery through a range of diverse and robust ecosystems is suggested (Steffan et al. 2009 in Newton 2009). Garnett et al. (2012D) also support an emphasis on ecosystem processes and function in which individual species are indicators rather than the endpoint of conservation. Maintaining areas that will be crucial for species persistence, such as habitats and refugia, needs to be considered from a variety of approaches – not just climate change. Improving connectivity between these areas may not serve all species (Garnett et al. 2012D).

Frameworks for decision-making in the face of both uncertainty and value-based judgements need to be developed, tested and monitored over time. Currently prioritisation of activities is based more on financial efficiency (Garnett et al. 2012D).

Adaptation needs to take an ecosystem-based approach where resources are considered and directed towards a suite of actions; however, this approach is constrained by institutional complexity. Adaptation pathways for the natural environment identified in Newton (2009) include:

- maintenance of well-functioning ecosystems (terrestrial, aquatic and marine)
- protection of a representative array of ecosystems (underpinned by a National Reserve System)
- removal or minimisation of existing stressors
- building appropriate landscape and seascape connectivity
- identification and protection of refugia
- effective monitoring networks
- flexible policy and management approaches.

This combination of actions will help form the basis of an ecosystem-based approach to adaptation. Many of these actions are currently recognised in the *Draft ACT Nature Conservation Strategy 2012*–22, including enhancing habitat connectivity and ecosystem function, identifying biodiversity refugia, and monitoring the impacts of climate change on native temperate grasslands and grassy box-gum woodlands (ACT Government 2012b). These options have often been implemented in parallel but have yet to be carried out as an integrated climate adaptation package. Institutional complexity (i.e. rules and funding relationships between and within levels of government) can constrain ecosystem approaches. Increasing the scale and speed of measure implementation is needed in addition to an integrated approach (Lukasiewicz et al. 2013D).

Taking an ecosystem-based approach to adaptation for natural resource management requires adaptive management, meaning actively experimenting with actions and learning from past activities. As some experiments may fail, community expectation must allow for learning through implementation, change of practices, and understanding of undesirable results. Ongoing monitoring is also needed to measure the effectiveness of actions (Lukasiewicz et al. 2013D).

Due to competing demands and pressures on environmental assets, adaptation needs to ensure diverse stakeholder engagement and collaboration to allow value-based decision-making. Morrison and Pickering (2011) recommended that government "*formally identify, promote and fund collaborative stakeholder partnerships*" (p. 6). Their study identified conservation managers and the tourism industry as key stakeholders with potential for collaboration but who are likely to have conflicting adaptation agendas and approaches. Identifying opportunities of mutual benefit (for e.g. removal of invasive species) can help build trust and encourage networks for further collaboration.

However, when landowner participation is needed, Lukasiewicz et al. (2013D) also identified numerous constraints that need to be overcome for effective management when undertaking climate change adaptation strategies for catchment management areas. These include:

- physical constraints in the form of both natural and infrastructure features, particularly where dams restrict freshwater habitat connectivity
- financial constraints limiting the ability to establish long term monitoring programs
- social constraints, such as community attitudes towards overbank flows possibly flooding private land
- lack of community concern or aversion to government interventions
- institutional constraints arising from inadequate knowledge of some management options (or lack of adequate funding to acquire expertise.

Habitat protection is considered the optimal action for assisting the majority of species adapt to climate change within a limited budget. Maggini et al. (2013D) explored a process for allocating resources to promote optimal habitat protection and restoration responses to a changing climate. Habitat protection was identified as the optimal action for assisting the majority of species adapt to climate change where a limited budget was available, and was more spatially dominant as the suggested action for 1.8 million km^2 of Australia, as opposed to 3000 km^2 where passive or active restoration was considered necessary.

Maggini et al. (2013D) suggest the optimal focus areas for the allocation of protection and restoration resources (taking into account the cost of implementation, probability of success and benefits across threatened species) are the woodlands and rangelands of eastern Australia, Northern Territory, north-west Western Australia, and southern South Australia and Victoria, with the focus of the restoration efforts in south-eastern Australia. Currently, 54 per cent of the ACT is part of a comprehensive reserve network, protecting areas of high conservation value (ACT Government 2012b).

There are conflicting research conclusions regarding whether water pricing is effective in curbing water demand. Poloczanska et al. (2012) suggest that pricing is commonly considered an effective strategy, though they point out that not all research supports this conclusion. Grafton and Kompas (2007) , in Poloczanska et al. 2012) suggested pricing amongst a range of fundamental changes in water policy to stave off critical water shortages in Sydney; however, a study by Hoffmann et al. 2006 in Poloczanska et al. 2012 on water usage in Brisbane from 1998 to 2003 suggests that water demand is independent of price.

4.7.2 Agriculture, fisheries and forestry

Key findings related to agriculture, fisheries and forestry:

- Agricultural enterprises respond differently to variations in climate; therefore, diversification (meaning cultivating several different crops and livestock) is the most common and effective strategy for mitigating climate-induced variability in net returns from rain-fed agriculture.
- Water trading can be an effective adaptation tool, but not all users will be able to participate and effectively manage associated uncertainty.
- Adaptation in primary production is primarily driven by private sector responses. But Government needs to play a supporting role to ensure the effectiveness of adaptation responses through the provision of information and other resources.
- Clear management goals for adaptation under climate change are needed for forest management.

Agricultural enterprises respond differently to variations in climate; therefore, diversification (meaning cultivating several different crops and livestock) is the most common and effective strategy for mitigating climate-induced variability in net returns from rain-fed agriculture. However, the greatest benefit for this approach is in moderate rainfall areas where trade-offs between the reduced expected net returns and the benefit of reduced variability can be maximised. There is the least benefit in dry regions, as diversification introduces water-intensive and rainfall-sensitive crops (Kandulu et al. 2012).

Water trading can be an effective adaptation tool, but not all users will be able to participate and effectively manage associated uncertainty. Water trading can be complex and fraught with limitations. It appears to succeed in meeting its intent to reallocate water resources to high value users (e.g. mining, manufacturing, electricity production) at the expense of users such as agriculture, the supply of drinking water and the provision of water to protected ecosystems (Kiem and Austin 2012). In particular, Kiem et al. (2010a) report that water trading and allocations have been challenging for farmers in Mildura. The rapidity and volatility of the market have resulted in the loss of considerable amounts of money for some farmers and some have exited farming entirely.

However, water trading also helped other businesses manage the impacts of the most recent drought, faring much better than they would have otherwise (Kiem et al. 2010b). Loch et al. (2012D) also suggest that, on the whole, water markets have been of net benefit for Australian irrigators and will be of increasing importance to adaptation to climate change. Concerns about social implications are discussed by Loch et al. (2012D), and the possibility of transformation change (conversion to dryland farming, relocation, farm exit, etc.) for marginal farms are identified, though it is suggested that there is little evidence of negative social impacts, and that some impacts suggested as relating to water trading are a continuation of ongoing structural change of rural communities that predate water markets.

Key to avoiding or reducing maladaptive water trading and water reform is the need for more complete baseline information on water availability, water quality and current uses (Newton 2009). However, rainfall and stream flow are highly uncertain due to the variability of the climate; this means that defining a sustainable water allocation is extremely difficult (Kiem and Austin 2012). To address this limitation, more research is needed to differentiate which part of the changes in water use (or limitations of water policy) are due to inadequate policy and which parts are due to variable hydroclimatic conditions (Kiem and Verdon-Kidd 2011, Kiem and Austin 2012). Sherval

and Askew (2012) note that stakeholders in their study expressed a need for a stable and secure water allocation and buy-back system that is planned and negotiated with farmers.

Loch et al. (2012D) identified a number of behavioural barriers related to water trading, including unwillingness by some farmers to commit to change given climate uncertainty and variability, the lack of adequate market mechanisms and signals to deal with climate change, economical barriers including debt levels and access to finance disincentives for preparedness including exceptional circumstances support programs and scepticism.

Finally, Loch et al. (2012D) state that water policies should be designed to address both incremental adaptation decisions (a relatively common decision) and transformative decisions (a rarer decision as it results in a major change in location and livelihood identity). Furthermore, it was suggested that water policy:

- be focused on adaptive change for farmers as they adjust to new levels of water scarcity and land management needs. In particular, policy should help educate irrigators on how planning for water shortages can improve farm viability and profitability
- recognise that change is not possible for all farmers; some parts of irrigated districts perhaps should no longer be supported in the future due to soil conditions, costs, environmental conditions or other factors.

Adaptation in primary production is primarily driven by private sector responses. Government needs to play a supporting role to ensure the effectiveness of adaptation responses through the provision of information and other resources. The Victorian Department of Primary Industries has recognised that farmers' adaptation responses can also have flow-on effects and negative consequences. It has developed a Policy Choice Framework (PCF) to examine the nature of the flow-on effects, suggest policy responses to assist (such as education, regulation, research and incentives), and also predict farmers' likely responses to potential policy interventions. The framework can be used to examine when government investment may be required and whether industry needs could be more effectively met by private service providers or by government agencies (Tostovrsnik et al. 2011 p. 7).

The ACT Government's AP2 (2012) recognises that the ACT is heavily reliant on agriculture outside the Territory, and that resilience to climate change impacts could rely on increasing local agricultural production. In 2011 the Minister for Environment and Sustainable Development announced that a scoping study to better understand the potential for increased food production in the ACT.

Clear management goals for adaptation under climate change are needed for forest management. The adaptive capacity of forest management in Australia is supported by several systems, including a well-developed economy; extensive scientific knowledge and technical capabilities, sustainable forest management practices, disaster mitigation strategies and plans, existing policies; and well-developed biosecurity procedures (Boulter 2012). However, previously established principles (such as the principle of setting the composition and biogeography of forests to pre-European settlement conditions as the benchmark) may no longer be appropriate under climate change. Under climate change, it is highly likely that rates of growth and species compositions will change; forests are also likely to shift or change the areas in which they occupy. These impacts will be compounded by other stressors, such as invasive species, disease, habitat fragmentation and economic conditions (Boulter 2012).

Significant financial investment is needed for the adoption of some forest adaptation measures (Boulter 2012). For example, shifting plantation production locations as an adaptation measure for plantations would require significant investment in new infrastructure.

4.7.3 Infrastructure, communities and land use planning

Key findings related to infrastructure, communities and land use planning:

- The role of land use planning in adaptation is extremely important but can be contentious.
- There are issues of continued expansion of populations into at-risk areas.
- Regulatory instruments in land use planning need to have greater flexibility to support adaptation.
- A precautionary approach to land use planning is recommended to address risks.
- Making adaptation-related home and property changes can be hindered by a number of factors post disaster events.
- Climate change adaptation programs targeted to Indigenous communities should focus on empowering communities to identify and implement their own responses.
- Integrating local, Indigenous knowledge with climate change science is critical to adaptation.

The role of land use planning in adaptation is extremely important but can be contentious. Owing to its role in guiding economic, social and environmental activities, spatial planning is viewed by many as an indispensable tool for facilitating efficient and equitable adaptation to climate change. However, the use of land use planning systems to address adaptation issues can be particularly contentious due to uncertainty, the politicisation of the issue of climate change and other factors, raising three particularly prickly issues:

- whether governments should second-guess individual choices and intervene to stop people from putting themselves in harm's way
- the role of government in compensating or assisting individuals who are adversely affected if climate risks materialise (i.e. to share risks and losses)
- to what extent governments should respect the 'property rights' of landholders in designing and implementing land use policies (Macintosh et al. 2013D).

Regardless of these issues, the location and configuration of settlements and infrastructure can influence the vulnerability and resilience of communities to climatic events. By shaping the nature and location of land use and development, spatial adaptation planning can help reduce the adverse impacts of climate change. Urban growth management should consider land for potential abandonment and resettlement as well as plan for more compact communities in areas of reduced risk of inundation, erosion and bushfire (Norman et al. 2012D). Planning processes can also be used as a medium for the dissemination of information about potential climate change impacts, thereby promoting private adaptation initiatives (Macintosh et al. 2013D).

There are issues of continued expansion of populations into at-risk areas. In many coastal and riverine areas, existing development has expanded and populations have increased without taking into consideration climate change impacts.

Planned retreat or relocation is a confronting option to communities, individuals and governments and is only likely to be considered when all other options are exhausted (Hadwen et al. 2011; Hurlimann and Dolnicar 2011).

Over the past two decades, a planning setback policy in Byron Shire has helped serve as a 'managed relocation strategy' in response to historical storm surges. Despite this policy, the ethical, moral, legal, and management issues of relocating beachfront residents have not been addressed. In the absence of more recent extreme storm surges, the policy is also becoming increasingly difficult to maintain as both Council and residents forget the reasons for its genesis (Helman et al. 2010).

In the years since Cyclone Tracy, an increased number of people have moved into the well-characterised storm surge zone of Darwin, and more assets have been constructed in these areas (Haynes et al. 2011).

There has also been high population growth within the Indigenous populations in the northern coastal and floodplain regions of the NT. This has increased the exposure of a group already disproportionally vulnerable to climate risks (due to close connections to the land, lack of elementary infrastructure, lower socio-economic status and existing chronic health problems) (Green 2006). Relocation of the northern suburbs of Darwin out of the storm surge area (towards the southern parts of the city) was proposed during rebuilding efforts after Cyclone

Tracy however, this was met with enough public opposition that the suburbs were rebuilt on the original site, thereby continuing to expose residents to a perceived significant future threat (Haynes et al. 2011).

Regulatory instruments in land use planning need to have greater flexibility to support adaptation. More flexible regulatory instruments at the level of state/territory planning policy and in some local planning schemes need to be considered. Macintosh et al. (2013D) suggest that these instruments should include explicit provision for the use of time-limited and contingent approvals in the context of new development. Norman et al. (2012D) suggest that, at least when assisting communities with adaptation, a risk management approach should be adopted that includes progressive learning from experience in order to ensure strategic and statutory planning controls can adapt to a changing environment.

The ACT Government has committed to publishing a Ministerial Statement which will inform how the built environment and urban open spaces will be developed to respond to climate change. Work is underway to review the Territory Plan development codes and design standards to support this, including exploring changes to development approvals to ensure appropriate assessment of natural hazards linked to climate change is completed (ACT Government 2012a).

A precautionary approach to land use planning is recommended to address risks. The use of highly detailed flood modelling and mapping, consistent application of overlays and controls throughout Victoria, and a more prescriptive response or precautionary approach to planning are all lessons from robust flood regulations recommended to address bushfires. Related to a precautionary planning approach, Buxton et al. (2011) also highlighted the need to look to the decision by the Victorian Civil and Administrative Tribunal's (VCAT) decision regarding Gippsland Coastal Board v South Gippsland Shire Council, which emphasised the "*need to invoke the precautionary principle and introduced the option for responsible authorities to require coastal vulnerability assessments when considering planning applications. The analysis of risk in this judgement applies also to other risks associated with climate change, including from bushfires*" (p. 11). Furthermore, Norman et al. (2012D) support the use of an adaptive decision-making process that incorporates the precautionary principle to ensure the risks of locating future development in the context of climate change is understood.

Making adaptation-related home and property changes can be hindered by a number of factors post-disaster events. After a flood, residents are likely to and do make changes to their home and property, including improving their garden drainage or building a permanent barrier. Land use or development controls, however, can restrict or delay changes. For example, permits are required in some flood area to build a flood levee and restrictions apply. Furthermore, constructing a flood levee is expensive, and perhaps not worth the investment if residents do not think another similar event will occur during their lifetime (Bird et al. 2011). Other residents can be restricted by the structure or material of their homes; brick and slab-on-ground constructions are unable to be modified to reduce future risk. This type of construction should be eliminated if development on floodplains continues (Bird et al. 2011).

Climate change adaptation programs targeted to Indigenous communities should focus on empowering communities to identify and implement their own responses. As only the communities are able to best determine their needs, interests and circumstances, climate change responses need to come from within the community itself; externally imposed or determined solutions are unlikely to be effective or sustainable (Griggs et al. 2013D).

As part of the research by Petheram et al (2013D) in South Goulburn Island, NT, many participants of workshops and interviews expressed a strong interest in being involved in government decision-making around adaptation. They preferred adaptation options that were community-driven and allowed greater self-sufficiency and independence (Petheram et al 2013D). Bird et al (2013D) likewise note that the concerns of the younger Indigenous population regarding migration are more in relation to the level of control they will have over movement rather than movement itself.

The desire for control is also described by Memmot et al (2013D), noting Aboriginal concern for greater collaboration and local control of their living environment regarding housing and infrastructure. Indigenous people in the Upper Georgina River Basin area of Queensland and the Northern Territory have negligible control or representation in either the administration or provision of infrastructure with the exception of Myuma, a civil construction and prevocational training organisation run by and employing Aboriginal people.

Greater participation in decision-making and the supply of infrastructure would improve adaptive capacity. This is particularly important and challenging for housing which must be more climate and culturally responsive (Memmot et al 2013D).

In order to identify adaptation options, communities need support in the form of:

- culturally-relevant climate change information and research, as well as the development of the necessary skills to understand how climate change may affect them and how to determine the most appropriate adaptation options
- meaningful access to regional and national policy and decision-making processes affecting their lands, as well as assistance implementing their selected adaptation options within their community. In particular, governments need to move away from top-down prescriptive approaches to shared decision-making and joint management.
- assistance developing opportunities to share knowledge between Australia's Indigenous communities and First Nation's people in other countries (Griggs et al. 2013D).

Griggs et al. (2013D) also note that academia can support communities with information and research but long term partnerships between communities and academics are needed, which is challenging due to the current institutional structures of research funding. Establishing long term relationships and the building of trust are important parts of Indigenous culture. Face-to-face interactions are particularly important (Griggs et al. 2013D). Currently, distrust and bitterness exists between the many Indigenous communities, government, academia and others due to a long history of disrespect, marginalisation, exclusion and betrayal.

Integrating local, Indigenous knowledge with climate change science is critical to adaptation. This includes the recording of Indigenous knowledge, as well as the education and training of environmental managers who can combine Indigenous knowledge with science and actively engage in environmental management (Memmott et al 2013D). Indigenous knowledge and tools, such as seasonal calendars, can also aid in tracking climate change impacts on the environment beyond records established during European settlement (Choy et al 2013D).

The integration of Indigenous knowledge with science will ensure that adaptation plans are understandable by all readers and users. "Knowledge is not an accepted 'truth' but is in fact constituted differently in different cultural contexts. Western knowledge systems tend to be linear, sequential, and follow scientific principles, whereas Indigenous people's knowledge systems are more circular and different knowledge systems operate concurrently and feedback within a community in various ways (Sillitoe et al. 2002, Croal and Darou 2002 in Nursey-Bray et al. 2013D p. 119).

4.7.4 Health and wellbeing

Key findings related to health and wellbeing:

- There is need for a consistent heatwave policy for the management of aged care facilities.
- State/territory government should ensure adequate health services are available, both during and for the longer-term after disaster events.

There is need for a consistent heatwave policy for the management of aged care facilities. Each state/territory in Australia varies in its creation of heatwave plans. For example, South Australia has a clearly defined heatwave plan administered by SA Health and SAFECOM whereas Queensland has incorporated the state heat wave plan into the State Emergency Plan. Black et al. (2013D) suggest that, where applicable, a consistent heatwave policy for the management of aged care facilities is needed in addition to the broad State-wide Emergency Management Plan. This policy should be created in collaboration with aged care service providers, the Department of Health and Ageing (DoHA) and the Aged Care Association of Australia. Continuous monitoring and response to extreme heat should also be a component of a regular continuous improvement strategy, and disaster/emergency planning (including heatwave response) should be part of Aged Care Facility Accreditation Standards (Black et al. 2013D).

State/territory government should ensure adequate health services are available, both during and for the longer-term after disaster events. Boon et al. (2012D) recommend that state/territory government agencies and NGOs provide counselling and health support services for up to five years after a disaster. As a result of the 2010/11 flood events in Victoria, many residents discussed fears of another flood and being forced to re-live the experience (Bird et al. 2011). Those residents whose wellbeing suffered after the flood felt that they were less able to make changes to reduce their flood risk than others in the community (Bird et al 2011). Ongoing support

to rebuild mental and physical health will increase individual resilience and capacity and contribute to greater community resilience.

[Note: Health and wellbeing is also closely tied to and important for increasing resilience and adaptive capacity. Therefore, there is also multiple health and wellbeing related findings within Section 4.1.]

4.7.5 Business and industry

Key findings related to business and industry:

- Adaptation action within small and medium businesses may be resource constrained.
- Adaptation in some sectors of tourism may require diversification – this may provide additional benefits and/or risk.

Adaptation action within small and medium businesses may be resource constrained. West and Brereton (2013D) have developed a consolidated framework to enable boards and executive managers of the Australian business community to develop an approach to climate change adaptation governance, climate change risk assessment and financial disclosure that leads to increased reporting and disclosure without the need for additional and explicit regulations. However, it is noted that this framework is designed to assist mainly large companies; small and medium businesses do not have the resources to implement this framework. Therefore, more needs to be done to assist this sector undertake climate change adaptation assessment activities.

Adaptation in some sectors of tourism may require diversification – this may provide additional benefits and/or risk. Tourism in the Australian Alps, particularly snow tourism, is expected to be especially impacted by climate change due to loss of snow cover and decreased winter visitors. Adaptation strategies identified by the tourism industry included snow-making, water recycling for snow-making, and the promotion of year-round tourism (Morrison and Pickering 2011). Lack of knowledge of climate change impacts and concerns about decreases in visitor satisfaction was viewed as limits to their climate change adaptation strategies. To correct these limits, the industry identified that accurate research is needed about the social perceptions of climate change and skiing and information about climate change predictions on a relevant time scale. While not identified by the tourism industry itself, other stakeholders interviewed in Morrison and Pickering's study (2011) also reported technological and economic thresholds involved with snow-making and/or manipulation and the social and economic costs of diversifying to year-round tourism as other limits to adaptation for this sector. Pickering and Venn (2013D) identify increased risks to alpine biodiversity through augmented summer tourism, including introduced plants and weeds spreading due to hiking and biking as well as physical damage to flora. While skiing is not available in the ACT, snow-related tourism activities in the territory may need to consider diversification, which may introduce new risks.

4.8 Practical adaptation actions and potential policy options

The following practical adaptation responses have been suggested from the research. Note that this is not an exhaustive list of actions; there are many additional actions that also could be pursued. Many of the actions listed are also either partially or fully underway from the ACT Government.

4.8.1 Natural environment and agriculture, fisheries and forestry

- Develop model flood planning controls for local government (Wenger et al. 2012D). The ACT Government is currently working on requiring new development assess the risks of natural hazards, including floods and bushfires (ACT Government 2012a). The ACT Emergency Services Agency will also continue to play a key role in approval of new developments and development planning, including the development and implementation of mitigation strategies for hazards such as floods.
- Utilise stormwater harvesting to reduce flood risk during extreme events and compliment water supply for open space and street trees while also reducing urban heat island effects (SGS 2010). The ACT Government is currently investigating the long term commercial viability of constructing urban stormwater ponds to supplement urban water supply for irrigation purposes (ACT Government 2012a).
- Reconsider land use to maintain connectivity at landscape, ecological and evolutionary scales to allow species the opportunity for autonomous adaptation (Hadwen et al. 2011)
- Remove trade restrictions to allow for more efficient transfers of water allocations inter-regionally to facilitate more fluid farm adjustment to water scarcity or climate change; better groundwater regulation to avoid over-allocation of the resource; expand water trade products (and cross-sector interaction); improve assessment

and approvals procedures to better provide readily available information on processing, remove assessment factors, address handling process complaints, and other critical requirements to reduce water trade transaction costs; and provide greater transparency where potential conflicts of interest may arise (Loch et al. 2012D). Interstate water trading is not yet available to or from the ACT; interstate trading would be dependent on the agreement between other jurisdictions of the Murray-Darling Basin (ACT Government 2013).

- Develop more robust and detailed market price information signals for water; improve seasonal water allocation announcements through substantial up-front and periodic review to make allocation determinations more transparent; and improve knowledge of potential adaptive responses and their effectiveness across different industries and regions (Loch et al. 2012D).

4.8.2 Infrastructure, communities and land use planning

- Require major infrastructure owners to conduct climate risk assessments (McEvoy and Mullett 2013). A framework was recently developed to provide the ACT government with a diagnostic tool to assist in considering climate change impacts during the planning, development, renewal, maintenance and management of public infrastructure; this climate change assessment framework will be embedded within the ACT Infrastructure Planning Process (AECOM 2012).
- Localise building design requirements beyond current regional zoning in the Building Code of Australia (Hadwen et al. 2011). The ACT Government is currently considering changes to the building code to take into account future climate projections for the ACT (ACT Government 2012a).
- Create building retrofit codes for existing buildings in high risk (flood, bushfire, and cyclone) areas. Continue to evolve the draft Flood Standard in the Building Code of Australia (BCA) into a technical standard for commercial and industrial buildings (currently limited to housing) (Mason et al. 2012D).
- Create clear and nationally consistent guidance on public and private obligations in responding to and preparing for climate change, both in terms of managing changes with existing developments and new developments (Helman et al. 2010). The ACT Government's AP2 notes that work is being undertaken in line with this action (ACT Government 2012a).
- Undertake property buy-backs, compulsory land acquisition and land swapping in high risk areas (Hadwen et al. 2011). However, property buy backs need to be complete and not piecemeal if they are to provide an effective adaptation strategy to hazards such as flooding and bushfire (Helmen et al. 2010).
- Increase flexibility in legislative and planning frameworks to accommodate future change (Hadwen et al. 2011). Adaptation actions taken today may not represent the best solution fifty years from now; therefore flexible responses into the future need to be considered in current decision-making processes and frameworks.
- Tenancy and property management strategies need to consider adaptive responses to climate change, including assigning responsibility for adaptation planning and resourcing (Horne et al. 2013D).
- Future public housing design guidelines should enable and promote adaptive climate practices (Horne et al. 2013D).

4.8.2.1 Emergency Management

- Consider a policy that subsidises insurance purchase for lower socio economic groups as an alternative to charity donations by government (Boon et al. 2012D).

  In AECOM's view, this approach needs further study to understand the potential beneficial and perverse outcomes. This policy could result in a general rise in premiums, negating the benefit to lower socio-economic groups and potentially resulting in insurance becoming less affordable for others, or it could result in increased competition among insurance companies as the pool of buyers grows, decreasing premiums. The impacts would be dependent on the scale of policy implementation (e.g. localised or national) and the level of risk of the area subsidised, among other factors.
- Reconsider conventional and standard levels of risk. Although the 1 per cent annual exceedance probability (AEP) flood extent is almost universal across the world as defining an area that needs some level of planning or building intervention, there is no clear reason why this level of risk has been chosen. In many ways, it is out of line with construction practice for other natural hazards in Australia (e.g. ultimate limit design for wind and earthquake is 0.2 per cent of AEP) (Mason et al. 2012D). The ACT Government is developing a new Territory Wide Risk Assessment, which will include assessment of climate change risks and incorporate responses into broader risk management systems (ACT Government 2012a).

- Establish clear but dynamic thresholds for recognising and responding to a climate event or disaster (Kiem et al. 2010a). The distinction between an event and disaster can be important, as there are often significant changes in strategy and management that follow the declaration of a disaster.
- Embed researchers within emergency management organisations in order to help emergency management staff better understand climate risks and direct research into needed areas (Howes et al. 2013D).

4.8.2.2 Communities

- Include greater local engagement and involvement in planning adaptation at the community level to identify the most effective strategies for building community resilience and adaptive capacity (Petheram et al. 2010).
- Establish collaborative funding mechanisms to manage risks and encourage agencies to form consortiums across all levels of government and the private and community sectors to work together to solve problems, such as finding ways to increase building resilience to a range of natural disasters (such as floods and bushfires) and climate change (Howes et al. 2013D).
- Support local community resilience grants to encourage communities to undertake simple projects to increase resilience (Howes et al. 2013D). The ACT Government currently engages the community on climate change issues through its ACTSmart programs, which includes grants for environmental projects or sustainability initiatives.
- Establish or enhance formal and informal local support networks (Boon et al. 2012D).

4.8.3 Health and wellbeing

- An education resource on maintaining wellness under extreme heat should be developed for aged care staff and service providers (Black et al. 2013D).
- Specific programs for CALD communities to increase awareness about the health risks of heat exposure and of behaviours to reduce the risk that do not rely on home air-conditioning. Provide information and warnings in multiple languages and through multiple, diverse channels, including religious leaders and school children (Hansen et al. 2012D).

4.8.4 Business and industry

- Explore market-based instruments to encourage homeowners to undertake upgrades to their houses, similar to the Florida Comprehensive Hurricane Damage Mitigation Program/My Safe Florida Home program (King et al. 2012D).

4.8.5 General

- Establish adequate monitoring and review of adaptation policy, including assessment and review frameworks (Lukasiewicz et al. 2013D; Aldous et al. 2011; Saintilan et al. 2011; Robson et al. 2013D).
- Develop a shared information system for data on risks, uncertainties and other climate-related information for each jurisdiction (Webb 2011 and Hadwen et al. 2011).
- Develop a standardised approach for evaluating costs and benefits of adaptation investments, particularly for state/territory and local government (Mukheiber et al. 2012).

Tools for decision-making

While there are many uncertainties associated with climate change, decisions must continue to be made which need to be robust across a range of possible futures (Dessai et al. 2009, in Mortazavi et al. 2013D). Many research projects have included the development of tools to assist climate change adaptation decision-making through:

- risk identification, including costing
- communication of hazards
- identification, comparison, optimisation and prioritisation of adaptation options
- stakeholder engagement and collaboration (Bennett et al. 2012).

Limitations or challenges associated with tools are formulating objectives, constraints and decisions. Tools, such as optimisation (i.e. a methodology that identifies optimal and robust planning and operational decisions in the face of uncertain knowledge about future climate change), will not produce a single answer, but may help identify a range of 'good' solutions that can form the basis for adaptation (Mortazavi et al. 2013D).

The interpretation of climate projections and integration into adaptation tools remains problematic. A majority of the research reports included recommendations for improved climate change information particularly for highly localised information average returns periods and event intensities. However, specific needs and issues were largely not identified. Many of the tools discussed in the research are also specific to or have only been tested within the context of a single sector or at discrete locations. It was beyond the scope of this project to further test these tools. However, most of these tools need broader testing and evaluation beyond the initial development phase to better consider broader applicability. Similarly, consideration also needs to be given to promote tools and how to provide adequate support to the range of stakeholders targeted. This is generally beyond the scope of the initial research funding or beyond the skill-set of the researchers in this project.

Look for this icon for tool-related reports. *This icon identifies research reports where a tool or framework is discussed.*

5. POLICY AND RESEARCH ENGAGEMENT

The primary purpose of this synthesis was to identify the common emerging adaptation research lessons that can be used by state and territory decision-makers in their efforts to set policy. Viewing the research through this lens also highlighted a number of lessons regarding how the interactions between policy and research may be improved for researchers to better generate knowledge for adaptation policy and for practitioners to better specify what knowledge is needed for action. This section highlights these findings.

Adaptation policies and strategies need to articulate the adaptation goal in terms of the end point to be attained. Often adaptation policies and strategies do not directly state the goal of adaptation action in terms of the end point to be achieved. Instead, objectives are vaguely stated with a focus on increasing resilience, reducing risk and maximising opportunities (Hadwen et al. 2011). This creates a number of tensions, including the need to have flexibility in order to manage uncertainty. It also leads to a lack of clear measurable objectives to test through research.

Participatory approaches can benefit both researchers and policymakers. A participatory approach to research is important to:

- ensure that existing knowledge and current research is being built upon
- promote access to, and interpretation of data and information necessary for risk assessment and adaptation planning
- allow for iterative feedback to ensure that deliverables are fit for purpose/practical action (McEvoy and Mullett 2013).

A large portion of the research examined for this synthesis studies public engagement and stakeholder collaboration strategies. As supported by the research, engagement with a diverse group of stakeholders is essential and much can be gained through cross-sectoral collaboration. However, the principles and frameworks that emerge from such collaboration can be difficult to incorporate into research reports, as the lessons are best gleaned through the engagement process itself. Furthermore, formal studies evaluating the effectiveness of engagement techniques for climate change initiatives are limited in quality and quantity (Fritze et al. 2009). This is a key barrier to sharing knowledge about successes, failures and possible improvements.

Improvements could be made to increase the value of research for policymakers. Often few distinct lessons emerged from the research that would enable decision-makers to take clear actions. More often, the research identified gaps in knowledge, limitations, barriers and research gaps. While this is an extremely important function for research, it is unlikely to be the type of specific information government decision-makers need so they can develop and implement identified adaptation-related priorities. A few researchers noted this issue in their work. For example, Kiem and Austin (2012) state that a fundamental barrier exists between the information that climate science can provide and the information that is practically useful for end users and decision-makers. The source of this disconnect is unclear; it may be “a communication issue, an education issue, a technological issue, or a fundamental philosophical issue (i.e. that scientists think about things differently than practitioners, decision-makers and/or end-users do)” (Kiem and Austin 2012, p. 22).

Kiem et al. (2010a) also identify a barrier that exists between scientists and researchers providing climate change data and adaptation information, and policymakers, resource managers, emergency response personnel, farmers etc. and others who use the data. This disconnect exist on both sides of the exchange. Information providers do not always understand the needs of end-users or the format that end-users need data and information in for it to be useful. At the same time, end-users can have unrealistic expectations of what science can currently provide or may not understand the limitations and uncertainties of the data outputs provided (Kiem et al. 2010b). Conflicting time constraints can further increase discord between end users and researchers (Hadwen et al. 2011). As a result of this disconnect the priorities of policymakers and other end users do not align with the priorities of climate science researchers, constraining both progression of practical climate knowledge and adaptation action (Kiem et al. 2010a).

An example of a strategy that has worked to bridge this gap in the disconnect between researcher and decision-makers is the strong relationship that exists between the City of Melbourne and the Victorian Climate Change Adaptation Research Facility Institute (Hussey et al. 2013D). This is noted as allowing information providers to gain insights into the decision-making process and what is needed by the organisations, as well as encouraging “a legacy within organisations to identify and assess adaptation options” (p. 68).

This relationship is promoted by Hussey et al. (2013D) as something that should be further explored and encouraged within other organisations (government, NGO and private) and research institutions due to the mutual benefits it provides.

Care needs to be taken in research to avoid stakeholder fatigue and disenfranchisement. Kiem et al. (2010b) report stakeholder fatigue in many rural areas, meaning people are becoming tired and sceptical of climate change research projects because they have been involved in so many but have seen few positive outcomes. "*Further efforts are needed to coordinate 'outcome-based' or applied research activities – a practice that not only provides the benefits of interdisciplinary and interagency knowledge, but also respects those we are working with by not overburdening them with separate and disconnected research interventions*" (Kiem et al. 2010b p. 17).

There is a need for consistent climate change terminology use across research bodies, government departments, relevant industry and organisations to allow greater understanding between research providers and research users. There are current discrepancies in meanings for some words including adaptation, prediction, projection and scenario in documents relating to climate change and adaptation (Hadwen et al. 2011, Verdon-Kidd 2012). Some of this is due to different sectors or organisations adopting different meanings, others due to misuse through lack of knowledge of accepted meanings. It is noted that there are current lists of terminology widely adopted by researchers, predominantly the IPCC definitions; however, there is a need to adopt and educate on standard definitions (Verdon-Kidd 2012). This lack of consistent terminology use also leads to an increase in misunderstanding between the information providers and information users, as identified by Kiem et al. (2010b).

5.1 Strategic cross-sectoral research gaps

A common element of the literature reviewed was identification of research gaps and new questions. Many of these recommendations were focused on areas where further research is required. While it is important that these issues are captured, it is equally important that gaps are identified in relation to application of the research findings themselves for specific end users, in this case state and territory decision-makers.

Understanding of autonomous adaptation. Although autonomous climate adaptation has been observed in some systems, it is not known whether or how long this will be able to match the rate of climate change. Similarly, thresholds of ecological, social and economic resilience are unidentified for many systems and communities. For example, there are significant knowledge gaps regarding which species are capable of shifting their habitat range (including pests). Without this knowledge, the role of protected area conservation as an adaptation option is likely to be limited (Hadwen et al. 2011).

Adaptation effectiveness. Research to assess the efficacy potential and unintended consequences of different potential adaptation actions is limited. This research needs to be done at a regional scale as it is likely that consequences will vary according to local settings and in response to interactions with each other and regional non-climatic stressors (Hadwen et al. 2011). It is acknowledged that the number of on-ground human climate change adaptation practices remains limited (or optimistically, are difficult to identify due to integration). Measuring the success of adaptation actions needs to be undertaken in the short, medium and long term and will need to be informed by careful monitoring.

Understanding of the limits of uncertainty. For effective and robust adaptation-related decisions to be made, realistic and practically useful information on climate change impacts are needed (Verdon-Kidd 2012). For example, a lack of understanding of climate change impacts has been identified as a major barrier to adaptation interventions for freshwater ecosystems (Robson et al. 2013D). However, it appears that this information is not as critical for interventions to improve community resilience. Uncertainty is also unlikely to be reduced for many sectors in the near future (if at all), so effective decisions will need to be made under uncertain conditions (Verdon-Kidd 2012). Understanding for which sectors the uncertainty of climate change impacts limit adaptation action and for which a reduced uncertainty is largely unnecessary would facilitate implementation. It is also important to understand the causes and structure of uncertainty so that decisions can be reviewed and changed as needed over time (Verdon-Kidd 2012).

Non-physical and compounding vulnerability. Research and interest remains focused on adaptation associated with physical vulnerabilities that can be incorporated into policy making. However, non-physical vulnerabilities, such as social and economic vulnerabilities, and how different factors interact and may compound vulnerability remain poorly understood. This information would be useful to inform approaches such as scenario planning.

Examples of where this has been identified in the literature include:

- the interaction between heatwaves, air quality and urban form, establishing a better understanding of sub-groups vulnerable to temperature extremes and characteristics that increase vulnerability (QUT 2010)

- the risks of multi-city extreme events and their effects on emergency services, insurance and disaster relief (QUT 2010)
- mental health and nutrition issues in indigenous communities where climate change impacts affect ceremonial hunting and food gathering practices (Green 2006).

6. CONCLUSIONS

6.1 Fundamental adaptation challenges relevant to state and territory government decision-makers

The complexity of climate change adaptation cannot be underestimated. A wide range of issues play a role, including federal and state/territory policy contexts, local institutional constraints, short and long term climate variability, local community development strategies and local environmental conditions. As pointed out by Gross et al. (2011) "*adaptation to climate change should be considered as one aspect in a complex, ever changing set of environmental, social and economic circumstances*" (p. 77). Through recognition of the emerging fundamental challenges, adaptation approaches can be identified (specific options will be highly contextualised and therefore beyond the scope of this synthesis approach). The breadth of research reviewed both in terms of location and sector, highlight the complexity of these challenge and these common themes, outlined in Table 4. These challenges include potential implications for policy development, programs and management undertaken by state and territory governments.

Table 4: Summary of the fundamental challenges

Fundamental challenge	Issue	Policy implications	Example
Climate change uncertainty	Assessing the impacts of climate change is uncertain due to inherent uncertainty in climate change and numerical modelling but also because impacts will vary over time and space and will be synergistic. Adaptation planning needs to consider the possibility that most uncertainties are unlikely to be resolved by the time decisions need to be made.	Because of uncertainty, it will be difficult to prioritise adaptation planning and when decisions are made, they are likely to be contested. Failure to accept uncertainty is resulting in inertia and stifling the development of flexibility. Issues of uncertainty should be considered a limiting factor to adaptation.	Use of a range of decision support tools such as scenario planning and sensitivity analysis can help identify adaptation options that are robust under a range of conditions or identify trigger points for new adaptation options.
Working with a changing baseline	Climate change represents only one of many drivers of change. Taking into account other drivers is essential to help inform long term adaptation planning.	There is significant economic, institutional, ecological risk in planning adaptation responses without considering all pressures. Adaptation needs and effectiveness will change over time in response to diverse factors. By not considering these shifts, investment may be in ineffective in the longer-term and new risks may arise.	The early introduction of flood barriers has encouraged the concentration of development in high risk floodplains. However, the effectiveness of these barriers has not been reviewed against future increases in rainfall.

Fundamental challenge	Issue	Policy implications	Example
System approaches	Climate change is complex, and vulnerability will be driven by ecological, social and economic responses, interactions between sub-systems and interactions across scales. To maximise adaptation effectiveness, create opportunities for change and avoid maladaptation a holistic approach to adaptation needs to be considered.	Mechanisms for collaboration between and within government need to be facilitated. Collaboration with stakeholders will also be essential. Processes by which to consider trade-offs and the distribution of costs and benefits at local and regional scales will need to inform decision-making.	Water trading/pricing impacts multiple systems and sectors, including natural resource management, agriculture, industry, and infrastructure and community resilience.
Communication and engagement	There is no value in a 'one size fits all' approach to engaging stakeholders on climate change adaptation. Specific, targeted engagement is required.	Greater consideration of the interests, needs and concerns of specific stakeholders is needed to build community support for adaptation.	Information and warnings need to be provided in multiple languages and through multiple, diverse channels.
Articulation of adaptation objectives	Historical policy objectives may no longer be appropriate in the face of climate change and may limit opportunities for transformational change. Failure to explicitly state adaptation objectives may create unrealistic community expectations and fail to trigger autonomous adaptation responses by individuals.	Natural resource management, biodiversity conservation and land use planning objectives will be particularly affected. By working with stakeholders to articulate adaptation objectives, conflict can also be avoided and barriers addressed. This will also help to coordinate the integration of climate adaptation into existing policies, strategies and operational activities at state/territory government departmental and agency portfolio level.	Biodiversity conservation may need to consider adaptation options to maintain ecosystem function rather than the conservation of individual species. The establishment of habitat corridors may need to focus on the needs of a different range of species than what might currently be expected.

Fundamental challenge	Issue	Policy implications	Example
Monitoring and review of both risks and adaptation responses	Monitoring is needed to support flexible decision-making over time. Monitoring can also help define triggers for action, including different or intensified adaptation responses. There is currently little knowledge or experience in evaluating adaptation options.	Consideration of how climate change can be taken into account when reviewing and updating existing policies	Natural resource management requires adaptive management, meaning actively experimenting with actions and learning from past activities. Monitoring is essential to evaluate actions.
Financing adaptation	Issues around who pays for adaptation are largely still unresolved. Linked to this issue is also the concern of government in relation to legal liability.	Private sector investment in adaptation will be guided by government responses and support. Use of traditional tools such as cost-benefit analysis, is emerging but there is limited knowledge on how to best consider distributional issues.	Investment by the government in coastal protection is proving a direct benefit to individual property owners. Post-disaster subsidies, while essential in many instances, could lead to moral hazard and deter households from covering their own known risks.
Learning from recent extreme weather events	Action on the ground to date tends to focus on responses to past severe weather effects. Reviews of these events do not generally consider the implications for the future under a new climate. Substantial long term, continuous changes may require different responses than limited, temporary events such as floods, bushfires and droughts.	While it is important for government to take a continuous improvement approach following extreme events, current recovery support may be compounding risk and reducing the resilience of communities. Opportunities for significant change are lost due to need to support recovery efforts in the short term and as communities discount the impacts of past events.	Consideration of climate change in reviewing extreme events. Exceptional Circumstances payments for farmers can work against communities trying to adapt and transition (Kiem et al. 2010b).

Climate change uncertainty

There are clear challenges associated with the scale of adaptation required, the timing of when to introduce interventions and how interventions are best delivered. Humans tend to be relatively short-term thinkers, and Australia's variable climate and relative short history of European settlement may further discourage consideration of long term changes in climate. In particular, climate change projections for extreme events have significant levels of uncertainty – both in terms of timing and frequency.

The challenge of uncertainty also differs for each sector. For example, knowledge of the broad expected climate change impacts may be enough specificity to implement interventions to improve community resilience.

However, more specificity of the frequency, timing and degree of climate change may be needed for certain natural resource management actions. The reality that improvements in climate change science can only partially

reduce this uncertainty requires that adaptation planning accepts these uncertainties. These uncertainties also highlight the need for flexibility, both as new information emerges and as society evolves. What flexibility actually looks like is only just starting to emerge – particularly in relation to the balance between water management for both floods and drought.

Working with a changing baseline

Climate change uncertainties are not the only constraints, however. Changes within society and the environment – both in response to climate change and other forces and their influence on adaptive capacity and vulnerability – remain one of the greatest limits to effective adaptation. Use of a 'business as usual' baseline to compare impacts and vulnerability over time is overly simplistic at best and misleading at worst. Changes in global and regional economies, demographic shifts, community views, and technological advancements will fundamentally shift underlying vulnerability and adaptive capacity. From these, changes in values and priorities will also emerge. As a result, policy and management objectives, particularly in relation to natural resource management, disaster recovery and land use planning need to be reconsidered at a fundamental level. Objectives must be considered from a non-stationary baseline and in light of longer-term risks, multiple scales and in the context of potentially diverse values.

System approaches

Climate change is complex, and vulnerability will be driven by ecological, social and economic responses, interactions between sub-systems and interactions across scales. The range of areas potentially impacted will require an unprecedented level of collaboration, integration and agreement between government departments, different levels of government and other organisations. This can be a considerable challenge, particularly when responsibilities are not clearly defined or when government resource capacity is constrained.

Communication and engagement

While government engages with community stakeholders on a frequent basis, engagement around climate change can be uniquely challenging. Some members of the community are unwilling to link climate change to observed phenomena. At the opposite end of the spectrum, there are portions of communities overwhelmed by the picture of unstoppable and pervasive climate change. As such, communication regarding disaster preparedness and climate change often need to be separate and offer bespoke, tailored messaging depending on a community's world-view, interests and needs. In fact, significant proportion of the research reviewed for this synthesis recommends the need to better consider messaging and communication on climate change adaptation. It is crucial to engage both stakeholders and the broader community to get behind adaptation actions. Engagement can help increase community preparedness, create ownership of and buy-in for adaptation options, and improve social cohesion. By engaging the community, local and historical knowledge can be also be accessed to help identify risks, opportunities and maladaptive options.

Articulation and implementation of adaptation objectives

Clearly articulating adaptation goals (together with options) is seen as key to engaging the community. Well-defined objectives can also help coordinate the integration of climate adaptation into existing policies, strategies and operational activities. While the articulation of objectives is relatively easy, actually ensuring action is more difficult.

Underlying this challenge, and many of the challenges discussed so far, is political will. Clearly articulated objectives can be watered down due to political sensitivity or can be hard to implement. Uncertainty can be an excuse not to act when an action is challenged or seems unpopular. Other change drivers can take political precedence over climate drivers, crowding out adaptation considerations. Overcoming this barrier with political leadership will be essential for adaptation success.

Monitoring and review of both risks and adaptation responses

Monitoring of both risks and adaptation responses is needed to support flexible decision-making over time. Unfortunately, there is currently little knowledge or experience in evaluating adaptation options; this suggests that there may be an opportunity for researchers to engage with policy-makers to establish effective monitoring systems. Monitoring can also be difficult to implement as it frequently requires a long term commitment of time and resources.

Financing adaptation

Issues around who pays for adaptation are largely still unresolved. This is perhaps the greatest challenge for state and territory government policy-makers, as it can be unclear how much the private sector will engage and take action. Related to the other actions discussed, institutional barriers, political will and uncertainty can reduce

the willingness of government to dedicate limited financial resources to a problem, particularly when responsibility is unclear. Furthermore, financial resources are also frequently dedicated to coping with the impacts of extreme events rather than planning for and addressing longer-term, incremental changes.

Learning from recent extreme weather events

Responses to recent extreme events have been examined to identify potential adaptation lessons, particularly with regards to floods, bushfires and droughts. Unfortunately, the findings for long term adaptation are not as clear. While it is critical that we learn from and address the many issues that arise from these events, we may still be missing key adaptation lessons. Of the formal reviews of these events studied by different pieces of research, the potential influence of further climate change was not considered to gauge or identify where responses beyond 'business as usual' may be necessary or to test recommendations made. Further opportunities are lost by the rush to restore communities and meet shorter-term needs.

Using these experiences as the basis for adaptation planning may also introduce risks and bias. As noted by Kiem et al. (2010b) strategies to deal with extreme events can be irrelevant under climate change as evidenced by 'exceptional circumstances' payments, which were originally enacted as an emergency response, in reality, they worked against rural communities adapting to drought and drier conditions in the long-term.

The question of whether experience with disaster events improves community resilience also remains inconclusive – it appears that the answer depends on a range of factors, unique to each location, each event and each point in time. No research has challenged the validity of the question for policy, which is particularly important when considering the long term nature of climate change.

However, despite the challenges, it is also important to recognise that the experience from extreme events can bring hope. Stories of autonomous self- organisation and neighbourhood support highlight the need to continue efforts that strengthen a sense of community and ultimately improve adaptive capacity. Examples such as the Queensland 'Mud Army' and 'Bake Relief' demonstrate the potential role of social media along with the capacity of the human spirit. Other local or autonomous responses to recent and current climatic stressors have also been identified, including how some farmers have shown innovation and flexibility in adapting livelihood systems to changeable and marginal environments through crop diversity and water management in response to climate variability. Local knowledge provides considerable assets in the form of social capital and natural capital, demonstrating innovation in the face of adversity. Recognition and promotion of these behaviours needs to be considered in community and targeted by support programs.

6.2 Key lessons for state and territory government decision-makers

While a key focus on the research reviewed has been issues associated with research constraints, gaps and limitations, a number of lessons for decision-makers have been identified.

Increase effort in identifying adaptation opportunities and promoting positive change. While there is a need to continue to prioritise adaptation aimed at reducing the risk of harm and in evaluating the limits and barriers of adaptation, there are benefits in seeking to identify potential opportunities, including incentives and regulation. Careful messaging will be required, but this approach may help to positively engage stakeholders, especially those that may feel overwhelmed by climate change. Clear opportunities already exist. For example, on average 35,000 new buildings are built each year in Australia, offering numerous opportunities to improve the climate resilience of Australia's future built environment.

Monitor and evaluate existing adaptation practices for ongoing adaptation. As well as being necessary to monitor the effectiveness of current adaptation options, including those intended to increase adaptive capacity, an evaluation process is critical for continuous improvement, to build trust with stakeholders, and to effectively implement adaptive management.

Ensure structures and institutions are flexible and can react to emerging issues and unforeseen events. From land use planning to natural resource management to primary production, the research reviewed for this synthesis frequently reiterated the need to ensure governance systems are flexible in order to respond to unforeseen events as well as incremental changes. Flexibility will also allow for continuous learning, which is essential for adaptive management.

Clearly define specific adaptation objectives. Understanding what the government's appetite for risk is and what outcomes are expected for an adaptation approach are critical for decision-making, implementation and evaluation. Developing these objectives in consultation with stakeholders will help build support and send appropriate messages to trigger private adaptation. Defining adaptation objectives need to go beyond 'motherhood statements' (e.g. 'a community that is resilient to climate change') and actually articulate what that may look like.

Continue efforts to build community cohesion. Building a sense of community is important to increase adaptive capacity and resilience but will have a range of benefits beyond climate change adaptation. Communities with a strong sense of place and greater social networks tend to have greater adaptive capacity than communities without these characteristics. The topic of climate change does not need to be the focus of community building programs in order to be advantageous for adaptation. This will require continued close engagement with government and community organisations.

Avoid calm weather planning. Taking a risk-based approach which factors in both experience from past extreme events and future potential climate change is a more robust approach for adaptation planning. This approach will also help focus on the co-existence of adaptation needs for diverse events, such as water management planning which considers both floods and droughts.

Create opportunities for greater engagement between researchers and end users. To take advantage of research and to support better adaptation planning and monitoring, government decision-makers need early and frequent engagement with the research community. There also needs to be a greater focus on end-user-focused research that supports policy development and implementation.

Appendix A: FORNSAT Interviews––summary of issues and directions

FORNSAT Interviews

Report compiled 6 August 2012

NCCARF appointed AECOM to prepare a synthesis of adaptation research relevant to each state and territory. The starting research questions for this research are:

- What useful and practical analysis for state and territory policymakers can be provided from the adaptation research now available?
- What are the implications of that analysis for sectors in individual states and territories?

The synthesis reports are to be targeted specifically to the needs of state and territory governments. Therefore, a critical success factor for this project is the extent that the synthesis meets these needs.

To commence this work, AECOM sought input from individual states and territories with regards to:

- the scope and focus of the synthesis
- the inputs into the synthesis
- broader stakeholder engagement
- the outputs of the synthesis.

This input was gathered through interviews with FORNSAT representatives and other invited guests from each state and territory (excluding Tasmania) between 26 and 6 August. Appendix Table 1 provides a full list of interviewees by state or territory.

Appendix Table 1: Interviewees by state/territory

State/territory	Representatives interviewed
New South Wales	Christopher Lee
Victoria	John Houlihan
Western Australia	James Duggie
South Australia	Stephanie Ziersch
Queensland	Lynn Whitfield, John Locke, Nancy Esler, Craig Walton, Kirsten Lovejoy and Daniel Rodriguez
Northern Territory	Bethune Carmichael
Australian Capital Territory	Kathy Tracy and Tim Wong

Summary of findings

Interviewees were asked the same seven interview questions. Feedback received has been qualitatively summarised by question, highlighting key themes, similarities and differences between responses.

1. What do you most want out of this synthesis of adaptation research? What would be of greatest value to the State's adaptation program?

FORNSAT representatives expressed the following needs or interests in this project:

- Identifying and aggregating policy-focused and practically applicable research relevant to each state and territory.
- Providing a clear picture of what research has occurred and where (including types of research). Also, identifying research gaps and research opportunities.
- Supporting the strategic positioning of adaptation efforts and investment by demonstrating the need for adaptation research and benefit of action.

- Drawing out conclusions that can help decision-makers (ensure the synthesis is pragmatic and demonstrates how research can clearly inform actions).
- Identifying transferable lessons from and comparisons with other regions.
- Demonstrating how NCCARF research is complementary to other state/territory-based adaptation research investment.

2. Has your state/territory defined or articulated its priority climate change risks or adaptation priorities?

Few states and territories have formally or publicly defined their priority climate change risks or adaptation priorities. However, where risks have been identified in internal documents, there was a willingness to share this information with AECOM on a confidential basis where feasible.

A regional approach to adaptation planning is being used by a number of states. In these cases, states are working with regions to define their priorities.

Some interviewees suggested specific plans or stated policy objectives that should be used to organise findings. It should be noted that tailoring a state or territory synthesis report to a specific plan's actions is likely to be beyond the scope for this project. AECOM will use existing plans and policy objectives to understand government needs and to guide the creation of the project's synthesis framework. A consistent synthesis framework and approach will be used for all states and territories.

3. Have any literature reviews or broader vulnerability assessments been undertaken that could help inform this project?

Sector-specific and regional vulnerability assessments and climate change impact assessments have been completed or are underway by most states and territories. Many have also internally identified adaptation research needs or have conducted internal literature reviews. AECOM has asked representatives to share this internal information if feasible and relevant.

4. Where you have used research to inform policy and program development, what have been some of the key factors that have ensured the research is useful/applicable?

Many states and territories conduct research for policy and program development in-house or in close partnership with universities. Research undertaken or directly commissioned by individual government agencies is preferred as these agencies are best placed to consider issues pertinent to their sector or department. Similarly, research with active end-user engagement tends to have greater levels of confidence, increased potential for application, and fewer barriers for uptake.

Utilising uncommissioned academic research can be challenging for governments as it tends to be less directly relevant to state or territory needs and/or less practically focused. Some states view this project as an important first pass to identify relevant literature, indicating to states and territories which researchers to engage with further.

The language used in research can also be important for uptake, particularly for less scientific- or academic-focused government staff and policy officers. Language needs to be accessible to a range of users and clearly articulate lessons.

5. What elements of this project would be most useful for you?

FORNSAT representatives had differing views of the utility of project elements, particularly related to the length and detail of the reports.

Appendix Table 2 displays a qualitative assessment of the level of state and territory interest in project outputs.

Appendix Table 2: Project outputs and level of interest

Project element	Level of state/territory interest
A searchable database of NCCARF research	*High*. Considered the most useful project element by one representative. However, representatives frequently requested that the database include more than just NCCARF research.
A scan of adaptation research relevant to your state and territory	*High*. Considered useful by all representatives. Some also expressed the importance of including transferable learnings from other locations within Australia.
A scan of adaptation research relevant to targeted government priorities or critical sectors	*Low*. Considered the most useful project element by two representatives. However, very few states/territories were able to provide clear direction on their key priority sectors.
A stand-alone short report of the synthesis findings (e.g. a document of 6-10 pages for non-technical audiences)	*High*. Considered useful by the majority of representatives; deemed valuable for engaging with ministers and senior management but less valuable for adaptation practitioners. Many representatives stressed the importance of not over-synthesising the research and warned about the potential risks of editorialising. Others stated the need for the synthesis to include analysis and clear direction to end users.
A detailed technical report outlining the project methodology and findings	*Medium*. Considered highly useful for representatives who felt the short synthesis would not provide practitioners with enough technical detail. However, multiple representatives had little interest in this report.

Representatives occasionally suggested additional project elements not listed above. Suggestions included:

- providing useful guidance on how to reach/engage communities (general public) to build resilience
- creating outreach materials to communicate project progress and share the outputs of this project to a broader audience (communities, stakeholder groups, etc.)
- providing guidance on how to use, maintain and adapt the database.

Representatives also provided input on how best to benchmark research within the database. Suggestions included:

- including a variety of categories and key words to search the database, such as type of methodology used, outputs, geography, knowledge transfer mechanisms, completion date
- considering how the database can mesh information between states.

6. Who do you see in state/territory government being the key audience?

Interviewees generally saw two audiences for this work:

- high level decision-makers, where a short, sharp synthesis can help demonstrate the need for adaptation
- policy officers, practitioners, sectoral experts, existing adaptation/climate change working groups, who will want detail that is specifically relevant to them. A searchable database and technical summary is likely to be of greatest interest to this group.

A few states and territories also highlighted the importance of local governments in adaptation planning and emphasised their place as a key audience.

7. How can the value of this project to other end users in your jurisdiction best be communicated?

FORNSAT representatives intend to directly engage with existing interdepartmental working groups throughout this project. Where existing working groups do not exist, representatives intend to utilise existing databases of government stakeholders to distribute information.

Working groups and stakeholders will be asked to provide any relevant adaptation research, review the list of adaptation research to be synthesised, and attend the workshops in November / December to provide feedback on the draft synthesis. In order to ensure end users are responsive and engaged, some representatives emphasised the need for the synthesis to be linked to each government's policy priorities.

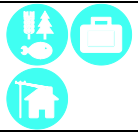
At the end of the project, FORNSAT representatives plan to distribute project end products to a broad audience of government stakeholders using their existing information channels.

Interviewees requested that AECOM provide short, sharp project updates to assist with outreach. It will also be important to consider the timing of communication and outreach (especially in relation to combined run-up to Christmas and potentially bushfire season).

Appendix B: Nationally relevant NCCARF projects

A total of 23 NCCARF research projects included in the synthesis have been determined to be national projects – projects that are not limited to specific locations, have either no geographical case study region or cover common issues for Australia.

Appendix Table 3: Nationally relevant NCCARF research projects

ID	Lead Author	Year	Title	Sectors
SI1004	G. Barnett	2012	Pathways to climate adapted and healthy low income housing	
P1FVA5	S. Boulter	2012	A preliminary assessment of the vulnerability of Australian forests to the impacts of climate change synthesis	
SD1117	R. Crompton	2012	Market-based mechanisms for climate change adaptation: Assessing the potential for and limits to insurance and market-based mechanisms for encouraging climate change adaptation	
FW1109	M. Dunlop	2013	Contributing to a sustainable future for Australia's biodiversity under climate change: conservation goals for dynamic management of ecosystems	
S3BCM1	D. Hine	2013	Enhancing climate change communication: strategies for profiling and targeting Australian interpretive communities	
EM1102	M. Howes	2012	The right tool for the job: achieving climate change adaptation outcomes through improved disaster management policies, planning and risk management strategies	
TB1105	L. Hughes	2013	Determining future invasive plant threats under climate change: an interactive decision tool for managers	
SD1109	K. Hussey	2013	An assessment of Australia's existing statutory frameworks, associated institutions, and policy processes: do they support or impede national adaptation planning and practice?	
S3BCM2	G.S. Johnston	2013	Climate change adaptation in the boardroom	
P2LTA6	A.S. Kiem	2012	Limits and barriers to climate change adaptation for small inland communities affected by drought	

ID	Lead Author	Year	Title	Sectors
EM0901	M.E. Loughnan	2012	A spatial vulnerability analysis of urban populations to extreme heat events in Australian capital cities	
SI11 01	A. Macintosh	2013	Limp, leap or learn?: Developing a legal framework for adaptation planning in Australia	
TB1102	R. Maggini	2013	Optimal habitat protection and restoration for climate adaptation.	
SI1106	K. Mallon	2013	Climate change and the welfare sector – risk and adaptation of Australia's vulnerable and marginalised	
S3BIB1	L. Mason	2012	Leading practice guidelines: planning and preparing for extreme weather events	
S3AFS1	D. Michael	2012	Food security, risk management and climate change	
S3ABA1	P. Mukheibir	2012	Cross-scale barriers to climate change adaptation in local government, Australia	
P2IMLR	E.S. Poloczanska	2012	iClimate Project	
S3AUN2	A. Randall	2012	Understanding end-user decisions and the value of climate information under the risks and uncertainties of future climate	
EM1101	J.P. Reser	2012	Public risk perceptions, understandings, and responses to climate change and natural disasters in Australia, 2010 and 2011	
P1ACP1	T.F. Smith	2010	The nature and utility of adaptive capacity research	
EM1103	S. Trueck	2013	Developing an Excel spread sheet tool for local governments to compare and prioritise investment in climate adaptation	
S3AUN1	D. Verdon-Kidd	2012	Bridging the gap between end-user needs and science capability: dealing with uncertainty in future scenarios	
SI1005	C. Woodroffe	2012	A model framework for assessing risk and adaptation to climate change on Australian coasts	

Appendix C: NCCARF research summaries – ACT

Limits and barriers to climate change adaptation for small inland communities affected by drought	
Authors (Year)	A.S. Kiem, E.K. Austin (2012)
Status	Final report
Summary	This report assessed the implications of using 'market-based' instruments (MBIs) on adaptation. Specifically, it focused on the barriers and limitations to climate change adaptation in small inland communities using water trading. The project found that water trading has potential to deliver beneficial adaptation outcomes, although for some people and industries there may be negative impacts. Water trading will allow those with the financial capacity to purchase water greater flexibility in making decisions about their priorities for water use. However, water trading can also have adverse consequences on local communities (such as smaller agriculture operations and drinking water supply), particularly as residents may sell their water entitlements and exit the community.
Methodology	This study took a case study approach, examining water trading in the Murray-Darling Basin as a MBI for climate change adaptation.
Output	Knowledge, Testing of methodology or approach
States (specific location)	Queensland, New South Wales, Australian Capital Territory, Victoria, South Australia (Murray-Darling Basin)
Sector Relevance	

The role of water markets in climate change adaptation	
Authors (Year)	A. Loch, S. Wheeler, S. Beecham, J. Edwards, H. Bjornlund, H. Shanahan (2012)
Status	Final Draft
Summary	This report investigates the relationship between the southern Murray-Darling Basin water markets and how these may be affected by anticipated future climate change impacts. Specifically, the report investigated how water markets have been implemented in the Murray-Darling Basin, investigated the expected climate change impacts for the southern Murray-Darling Basin and for the agricultural industry. The report then examined the financial, social and ecological impacts of market based water reallocation; and opportunities for future development to encourage positive outcomes in these areas. The report identified predominantly positive financial and ecological outcomes from water markets, and little evidence of negative social impacts as a whole.
Methodology	This study took a literature review approach.
Output	Knowledge
States (specific location)	Queensland, New South Wales, Australian Capital Territory, Victoria, South Australia
Sector Relevance	

Climate change adaptation in the Australian Alps: impacts, strategies, limits and management	
Authors (Year)	C. Morrison, C. M. Pickering (2011)
Status	Final report
Summary	This report assessed potential impacts of climate change on the Australian Alps examining the existing and prospective adaptation strategies, limits to adaptation, and possible partnerships and conflicts between sectors and stakeholder groups. Possible collaborative and conflicting adaptation strategy areas between sectors and stakeholders were identified in the literature, with the focus primarily on the local and regional level. These include accord in endangered species protection strategies between conservation managers and resort operators, and conflict in the strategy of diversification of the tourism season by resort operators, with the possibility of tourists disturbing natural systems at the times that conservation managers may be trying to restore habitats and restrict access. Adaptation limits were identified that include social acceptance, technical restrictions and financial sustainability of artificial snow making (the tourism industry's principal adaptation strategy), and ecological and economic limits for invasive species management when considering changing ecosystems. The research team identify a lack of recognition of the Alps' water resources and knock on importance to the wider Australian economy by the stakeholders interviewed.
Output	Knowledge
Methodology	Literature review was undertaken followed by interviews with stakeholders from conservation managers, the tourism industry, local council, and other researchers.
States (specific location)	New South Wales, Victoria, Australian Capital Territory (Australian Alps)
Sector Relevance	

Determining high-risk vegetation communities and plant species in relation to climate change in the Australian alpine region using functional traits	
Authors (Year)	C.M. Pickering, S.E Venn (2013)
Status	Final report
Summary	This report assessed potential impacts of climate change on the Australian Alps and adaptation strategy priorities. Specifically, the likely biophysical climate change impacts were presented, the functional traits (height, size, shape, reproduction etc.) were collected and analysed to assess species composition change in relation to climate and non-climate impacts; and this was examined in relation to functional diversity. The project found no short term impacts on functional diversity due to climate change, though long term climate change was indicated to lead to distinct differences in flora traits and composition. Adaptation priorities were identified around fire management, invasive flora control, grazing of larger hoofed mammal and summer tourism controls.
Methodology	Literature review, collection of new functional trait data and analysis of existing data was undertaken.
Output	Knowledge
States (specific location)	New South Wales, Victoria, Australian Capital Territory (Australian Alps)
Sector Relevance	

Learning from cross-border regulatory instruments to support and promote climate change adaptation in Australia	
Authors (Year)	W. Steele, L. Eslami-Andargoli, F. Crick, S. Serrao-Neumann, L. Singh-Peterson, P. Dale, D. Low Choy, I. Sporne, S. Shearer, A. Lotti (2013)
Status	Draft report
Summary	This report considered lessons that can be learnt from current cross- border regulatory mechanisms in Australia, to enhance the efficacy of cross-border climate change adaptation practices. Specifically, the study developed a conceptual framework to investigate cross-border arrangements between jurisdictions, using a number of case study regions (which have potential climate change issues that do not adhere to administrative boundaries) and implemented agreements, with a focus on the challenges and opportunities of these arrangements. The project found that there are significant legal, institutional, cultural and historical based challenges hindering cross-border collaboration, particularly at the state level; though local level arrangements often exist, as do an increasing number of National drivers.
Methodology	Desktop review, workshops and semi structured interviews were employed in this study.
Output	Knowledge, Tools or guidelines
States (specific location)	Queensland (Gold Coast), New South Wales (Tweed Heads), Victoria, Australian Capital Territory; (Australian Alps and Murray Darling Basin)
Sector Relevance	

Appendix D: Excluded research (NCCARF)

Appendix Table 4: Reports excluded due to content

Lead author	Title	Reason for exclusion	Geographic Relevance
Barmuta	Joining the dots: integrating climate and hydrological projections with freshwater ecosystem values to develop adaptation options for conserving freshwater biodiversity	The report is focused on Tasmania, which is outside the geographical scope of this synthesis.	Tasmania
Byrne	Climate-resilient vegetation of multi-use landscapes: exploiting genetic variability in widespread species	This research focused on two species of eucalypt in a limited number of regions (two).The application of results to other species or locations was deemed not appropriate, and there is little to no policy relevance.	Western Australia, Victoria
Cockfield	Socio-economic implications of climate change with regard to forests and forest management. Contribution of Work Package 3 to the Forest Vulnerability Assessment	The component reports I to IV was not reviewed for the synthesis, which has been informed by Synthesis and Final Report only.	National
Davis	Building the climate resilience of arid zone freshwater biota: identifying and prioritising processes and scales for management	The focus of this report was on technical findings related to factors influencing connectivity (population genetics, dispersal traits), so there is little policy relevance.	Queensland, South Australia, Northern Territory, Western Australia
Dyer	Predicting water quality and ecological responses to a changing climate: informing adaptation initiatives	The focus of this report was on technical findings, based on Bayesian network models using data from a single location, and so was not considered robust enough for synthesis.	Australian Capital Territory
Guilding	Strata title in a world of climate change: managing greater uncertainty in forecasting and funding common property capital expenditure	The report was deemed not policy-relevant, as its focus is on private investment risk, and it is written more as a technical report for a fund manager audience.	National
Medlyn	Biophysical impacts of climate change on Australia's forests. Contribution of Work Package 2 to the Forest Vulnerability Assessment	The component reports I to IV was not reviewed for the synthesis, which has been informed by Synthesis and Final Report only.	National
Moir	Developing management strategies to mitigate increased co-extinction rates of plant-dwelling insects through global climate change	This project focused on species level assessments and the management of invertebrates under climate change, which does not appear to be a current policy priority for state governments.	Western Australia

Lead author	Title	Reason for exclusion	Geographic Relevance
Padgham	Agent-based simulation framework for improved understanding and enhancement of community and organisational resilience to extreme events	This report was based on the application of agent based modelling (based on the author's main project) at one Victorian location. As there was limited testing, the report was not considered robust enough for synthesis.	Victoria
Padgham	Exploring the adaptive capacity of emergency management using agent-based modelling	This research was deemed more relevant to operational decision-making; although the tool may be useful to assess policies; this has not been part of the research.	Victoria
Reser	Public risk perceptions understandings and responses to climate change and natural disasters in Australia and Great Britain	The follow-on research has been included (EM1101 [Reser]), which has more up-to-date results.	National
Sanò	Adapt between the flags – enhancing the capacity of Surf Life Saving Australia to cope with climate change and to leverage adaptation within coastal communities	The focus of this report is on asset management, lifesaving operations and the role of local clubs in increasing community resilience. There is mention of the role of state funding, and adaptation options have state relevance (such as retreat); however, the discussion (which is in an early stage) does not currently draw enough conclusions relevant to state/territory policy and decision-making.	Queensland, New South Wales, Tasmania
Foster	Analysis of institutional adaptability to redress electricity infrastructure vulnerability due to climate change	Few lessons relevant to state government policy.	National
Thompson	Impacts of elevated temperature and CO_2 on the critical processes underpinning resilience of aquatic ecosystems	The focus of this report is on technical findings related to laboratory testing and modelled future conditions. The report focuses on management options at specific locations rather than on policy.	Victoria
Unsworth	What about me? Factors affecting individual adaptive coping capacity across different population groups	Only 1 of the 4 identified research streams is likely to be relevant to state government adaptation policy (Stream 1 focuses on responses to carbon emissions while Streams 3 and 4 focus on specific population groups defined by employment (resource sector and hospital employees)).	National
Wardell-Johnson	Creating a climate for food security: the businesses, people and landscapes in food production	The report was deemed to lack policy relevance.	Queensland, Western Australia
Willetts	Understanding the Pacific's adaptive capacity to emergencies in the context of climate change	This report covers a topic not relevant to state and territory responsibilities.	National

Lead author	Title	Reason for exclusion	Geographic Relevance
Wilson	Climate change adaptation options, tools and vulnerability. Contribution of Work Package 4 to the Forest Vulnerability Assessment	The component reports I to IV was not reviewed for the synthesis, which has been informed by Synthesis and Final Report only.	National
Wood	Establishing the need and consultation with key stakeholders in forest policy and management under climate change. Contribution of Work Package 1 to the Forest Vulnerability Assessment	The component reports I to IV was not reviewed for the synthesis, which has been informed by Synthesis and Final Report only.	National

Appendix Table 5: Reports excluded due to deadline

NCCARF research reports provided to AECOM after close of business on 14 January 2013 were also unable to be included in the synthesis due to project time constraints. In some cases, the report due date was before 14 January 2013, but the report was delayed.

Lead author	Title	Geographical relevance	Report due date
Abadi	EverFarm® – Design of climate-adapted perennial-based farming systems for dryland agriculture in southern Australia	New South Wales, Victoria, Western Australia	25/01/13
Barrett	Adaptive management of temperate reefs to minimise effects of climate change: developing effective approaches for ecological monitoring and predictive modelling	Tasmania	Draft 1/04/14; Final Report 30/04/14 (March-April)
Bax	Pre-adapting a Tasmanian coastal ecosystem to ongoing climate change through reintroduction of a locally extinct species	Tasmania	Draft 28/02/13; Final report 30/03/13 (March-April)
Beer	Australia's country towns 2050: What will a climate-adapted settlement pattern look like?	National	Draft: 31/12/12
Burton	Urban food security, urban resilience and climate change	National	0/10/12
Caputi	Management implications of climate change effects on fisheries in Western Australia	Western Australia	Draft 30/11/13; Final report 31/12/13 (Nov–Dec)
Correa-Velez	Displaced twice? Investigating the impact of Queensland floods on the wellbeing and settlement of a cohort of men from refugee backgrounds living in Brisbane and Toowoomba	Queensland	Unknown
Crase	Leading gifted horses to water: the economics of climate adaptation in government-sponsored irrigation in Victoria	Victoria	15/01/13 (draft)
Davis	Ensuring that the Australian oyster industry adapts to a changing climate: a natural resource and industry spatial information portal for knowledge action and informed adaptation frameworks	National, New South Wales	Draft 10/12/12; Final report 24/12/12 (Jan–Feb13)
Dear	Changing heat: direct impacts of temperature on health and productivity – current risks and climate change projections	National	Unknown
Dobes	The economics of government as insurer of last resort for climate change adaptation	National	3/03/13 (draft)
Doerr	The architecture of resilient landscapes: scenario modelling to reveal best-practice design principles for climate adaptation	Victoria, Queensland, New South Wales, Australian Capital Territory	3/02/13 (draft)
Frusher	A climate change adaptation blueprint for coastal regional communities	National	Draft: 01/06/13; Final report 30/06/13
Fry	Reforming planning processes trial: Rockhampton 2050	Queensland	28/02/13

Lead author	Title	Geographical relevance	Report due date
Gledhill	Identification of climate-driven species shifts and adaptation options for recreational fishers: learning general lessons from a data-rich case	Tasmania, Victoria, New South Wales, Queensland	(May–June)
Green	Health impacts of climate change on Indigenous Australians: identifying climate thresholds to enable the development of informed adaptation strategies	Western Australia, Northern Territory, Queensland	Unknown
Hanna	Climate change impacts on workplace heat extremes: health risk estimates and adaptive options	National	Unknown
Harley	Dengue transmission under climate change in Northern Australia: linking ecological and population-based models to develop adaptive strategies	Queensland	Unknown
Hertzler	Will primary producers continue to adjust practices and technologies, change production systems or transform their industry – an application of real options	Western Australia, South Australia, New South Wales	31/12/12 draft
Hobday	Growth opportunities and critical elements in the value chain for wild fisheries and aquaculture in a changing climate	National, Western Australia, New South Wales, Victoria, Queensland, Tasmania, South Australia	Draft 30/03/13; Final report 31/05/13 (May–June)
Hobday	Human adaptation options to increase resilience of conservation-dependent seabirds and marine mammals impacted by climate change	National	Draft 30/12/12; Final report 30/01/13 (Jan–Feb 13)
Hugo	Impact of climate change on disadvantaged groups: issues and interventions	South Australia	3/02/13 (draft)
Jerry	Vulnerability of an iconic Australian finfish (Barramundi, *Lates calcarifer*) and related industries to altered climate across tropical Australia	Queensland, Northern Territory	Draft 31/10/13; Final report 31/12/13 (Nov–Dec)
Jones	Valuing adaptation under rapid change: anticipatory adjustments, maladaptation and transformation	National	3/02/13 (draft)
Lockwood	Changing currents in marine biodiversity governance and management responding to climate change	Queensland, New South Wales, Tasmania	Draft: 14/09/13; Final report 27/09/13 (Sept–Oct)
Maani	Overcoming challenges for decision-making about climate change adaptation	National	31/10/12
McMichael	Climate change and rural communities: integrated study of physical and social impacts, health risks and adaptive options	National	Unknown
Parsons	Learning from the past, adapting in the future: identifying pathways to successful adaptation in Indigenous communities	Western Australia	30/04/13
Pecl	Preparing fisheries for climate change: identifying adaptation options for four key fisheries in south-eastern Australia	New South Wales, Victoria, Tasmania, South Australia	Draft 1/09/13; Final report 2/01/14

Lead author	Title	Geographical relevance	Report due date
Pratchett	Effects of climate change on reproduction, larval development and population growth of coral trout	Queensland	Draft 1/03/13; Final report 30/06/13 (Mar–April)
Raybould	Beach and surf tourism and recreation in Australia: vulnerability and adaptation	New South Wales, Queensland	Draft 28/02/13; Final report 30/04/13 (Mar–April)
Saman	A framework for adaptation of Australian households to heat waves	New South Wales, South Australia, Queensland	Draft 11/01/13
Shaw	Climate change adaptation – building community and industry knowledge	Tasmania, Western Australia, Queensland	Draft 1/02/13; Final report 1/04/13
Sheaves	Estuarine and nearshore ecosystems – assessing alternative adaptive management strategies for the management of estuarine and coastal ecosystems	National	Draft 15/12/13; Final report 30/12/13 (Nov–Dec)
Thresher	Adapting to the effects of climate change on Australia's deep marine reserves	Tasmania, Victoria, South Australia, New South Wales	Draft: 1/06/13; Final report 1/12/13
Tong	Projection of the impact of climate change on the transmission of Ross River virus disease	Queensland	Unknown
VanDerWal	Identification and characterisation of freshwater refugia in the face of climate change	National	30/04/13
Webb	Web-based tools for adaptation in Australia – an international and Australian review	National	30/11/12
Weir	Changes to country and culture, changes to climate: strengthening institutions for Indigenous resilience and adaptation	Queensland, Western Australia	Draft 31/12/12
Welch	Management implications of climate change impacts on fisheries resources of tropical Australia	Western Australia, Northern Territory, Queensland	Draft 31/12/13; Final report 14/03/14
West	Climate change adaptation: a framework for best practice in financial risk assessment; governance and disclosure	National	31/12/12 (draft)
Williams	The role of refugia in ecosystem resilience and maintenance of terrestrial biodiversity in the face of global climate change	National	30/04/13

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[2] *In order to incorporate the majority of NCCARF research, draft reports were considered. Many of these reports are still undergoing peer review and are not yet available publically. Draft research incorporated into this synthesis is denoted as such in the reference (for example, Smith, 2013D).*

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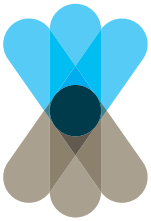

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