DWLBC REPORT

Community perceptions of climate change impacts on natural resource management in the Adelaide and Mount Lofty Ranges

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Government of South Australia
Department of Water, Land and Biodiversity Conservation

Community perceptions of climate change impacts on natural resources management in the Adelaide and Mount Lofty Ranges

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FOREWORD

South Australia's unique and precious natural resources are fundamental to the economic and social wellbeing of the State. It is critical that these resources are managed in a sustainable manner to safeguard them both for current users and for future generations.

The Department of Water, Land and Biodiversity Conservation (DWLBC) strives to ensure that our natural resources are developed and managed in a way that advances economic, social and environmental outcomes.

In order for us to best manage these natural resources it is imperative that we have a sound knowledge of their condition and how they are likely to respond to management changes. DWLBC scientific and technical staff continue to improve this knowledge through undertaking investigations, technical reviews and resource modelling.

Climate change has emerged as one of the most important environmental, social and economic issues we are facing and this has been clearly identified by the Government of South Australia (2003, 2007). The community will play a vital role in addressing climate change through both reducing greenhouse gas emissions and adapting to new climate regimes. This report provides important information on community perspectives of climate change impacts on natural resources management within the Adelaide and Mount Lofty Ranges region. It gauges the natural resources management and wider community's perceptions of the most important aspects of projected climate change, and reviews stakeholders' opinions of where initial effort should be directed to minimise the negative impacts of change and exploit possible benefits. Already, the government has committed to effective water resource planning to manage the expected impact of climate change.

This work was undertaken by the department in partnership with the Adelaide and Mount Lofty Region Natural Resources Management Board and the Australian Greenhouse Office, part of the Commonwealth Government's Department of the Environment and Water Resources.

Rob Freeman
CHIEF EXECUTIVE
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SUMMARY

PURPOSE OF THIS STUDY

Climate change is going to change the way natural resources will be managed in South Australia. The success of adaptation responses will be affected by the timing, form and level of management planning that is put in place and actions that are undertaken. All of these components of a response will be influenced significantly by the perceptions of the people making regional and local decisions regarding natural resources management (NRM).

Research to understand how stakeholders perceive climate risk is important to ensure that methods are employed to best engage the NRM community, to identify requirements for skills and knowledge development, and to help engender community ownership of management responses to change. Climate change projections suggest that there is an immediate need to plan for systems to adapt to change. However, the changes required may not only require better risk management in the short-term but also fundamental transformations of the way that society relates to the natural environment. With a growing community awareness of the need to design and implement directions for NRM in South Australia, it will be less problematic to enact policy and programs to support sustainable adaptation options.

This work examined the perceptions of climate change and associated impacts on NRM[1] amongst key stakeholders in the Adelaide and Mount Lofty Ranges (AMLR) NRM region during 2006. Stakeholder perceptions were collated from responses to a survey questionnaire, as well as through group workshop discussions. The work follows on from an earlier integrated analysis of climate change impacts, which analysed the vulnerability of different regional NRM sectors to projected climate change (see Bardsley 2006), by supporting and strengthening available knowledge of regionally applicable adaptation and mitigation options. The project and associated report aimed to inform stakeholders of the potential implications of projected climate change on the NRM sector, to gauge how people perceive current climate change and to work with NRM stakeholders to examine how projected changes may impact on their particular activities in the future. Respondents were also asked to provide potential adaptation options to respond to projected climate change and support sustainable development of local resources.

The underlying hypothesis employed in engaging with the NRM community was that people readily discount climate change risk because it is largely seen as a long-term problem, so complex as to undermine the legitimacy of any current responses, and lacking in effective response approaches. However, during this work to develop NRM adaptation responses to climate change, the messages emphasised were:

- The impacts of climate change are apparent historically, currently important and will continue to be important in both the short- and long-term.
- The complexity of climate change projections for the Mediterranean climatic system of South Australia can be summarised under major themes associated with:

[1] In this work a broad understanding of the term ‘NRM’ was taken, encompassing environmental, social and economic issues arising from the status and management of natural resources.

- a warming/drying trend
- more variable and extreme weather conditions
- associated secondary environmental change such as reduced average surface runoff and sea level rise
- greater vulnerability of NRM systems.

- In many cases, to respond to the substantial uncertainty, there needs to be an emphasis on the need for new discoveries, ideas and responses. Individuals and groups will need to apply a learning orientation to climate change, rather than to expect knowledge and information to guide specific responses. The learning orientation will involve the trial of adaptation responses, the study of the effectiveness of those responses, and the subsequent adjustment of management and planning to improve outcomes. The framework of the adaptation response can be broken down into:
  - incorporation of climate change into risk management in the short-term
  - the application of adaptive management and planning techniques in the long-term
  - the application of the 'precautionary principle' for the long-term.

OUTCOMES FROM THIS STUDY

The major findings indicate that climate change is now a significant environmental management issue for NRM stakeholders throughout the AMLR, for example:

- On average, respondents rated climate change, drought and bushfire risk as the most important environmental issues likely to be faced in the region by 2030.
- Many respondents provided examples of observed changes in their local landscapes and production systems that could be associated with a changing climate.
- Many respondents already perceive warming of day temperatures, a drying trend in rainfall, and/or increased rainfall variability.
- Where changes in climatic conditions were perceived, as a general rule respondents did not consider that these trends were an indication of 'climate change'.
- Respondents were more likely to attribute warming temperatures to climate change than they were to link perceived changes in rainfall amounts and variability to climate change.
- NRM stakeholders' responses suggest that while people accept the primary impact of climate change will be warming, the broader impacts on climatic patterns are less clear.

The uncertainty of attribution of rainfall variability to climate change is reflected in the scientific projections for climate change at a regional level. While there is significant confidence of a net warming trend for South Australia (see Suppiah et al. 2006), the impacts on future rainfall are uncertain. That said, the Intergovernmental Panel on Climate Change (IPCC) modelling is suggesting that Mediterranean-type climatic systems are seen to be most likely of all climate types to experience a drying trend. Since the 1970s, warming and drying climatic trends have been experienced in Mediterranean climatic regions, including southern Europe, western North America, the South African Cape region and south-west Western Australia (Smith et al. 2000; Cayan et al. 2001; Dünkeloh & Jacobeit 2003; Feidas, Makrogiannis & Bora-senta 2004; Maheras et al. 2004; Piccarreta, Capolongo & Boenzi 2004). Questionnaire responses suggest that a range of possible indicators could be examined for use as indicators of climate trends over time, from tracking the immediate changes to atmospheric conditions through to temporal analyses of broader ecological and social responses to climate.

Climate change will not impact on all areas of NRM evenly and it is perceived by respondents that the key impact areas are likely to be water and biodiversity management, with primary production and coastal issues also ranking highly. These issues were also identified as important vulnerabilities in the integrated assessment undertaken for the region (Bardsley 2006), although it was noted in that earlier review that those systems which are managed more intensively such as water and intensive agriculture are more likely to have substantial adaptive capacities. The relative importance of different climate change impacts on NRM was rated fairly consistently across the sub-regions of the AMLR and sub-regional group responses paralleled responses from the wider NRM community.

Respondents provided a broad range of possible practical examples for effective adaptive responses to climate change at regional, local and sectoral levels. Many of these are detailed in the report, but in one important example respondents placed less emphasis on developing new sources of water, such as via desalination of seawater, and far greater emphasis on managing existing water supplies sustainably through increased stormwater harvesting, improved water-use efficiencies, recycling and reducing consumption.

Even though the work here focused specifically on opportunities to better adapt to future climate change, a large number of suggestions were also provided for greenhouse gas mitigation responses, which respondents saw as part of a broader societal adaptation response. Education, policy, planning and a greater scrutiny of our consumer lifestyles were all suggested as a means to change behaviour and motivate more sustainable practices. In other words, it was rarely perceived by respondents that it would simply be enough to adapt to projected changes at the local or regional NRM level for ongoing sustainable development in the AMLR.

Stakeholder feedback revealed a need among much of the community for more local information relating to both the impacts and timeframes of climate change across all sectors, and realistic options for climate change adaptation and mitigation. While a need for more ‘knowledge’ on climate change issues was identified, and to some extent this can and should be addressed, it is also apparent that the issue of climate change will always involve the management of uncertainty—uncertain levels and rates of climate change and complex, interactive effects on NRM systems. In many cases it is recognised that greater community debate will be required before ‘best practices’ for management can be identified. Even then adaptive management approaches will be required, with outcomes and plans reviewed on a continual basis in light of changing climatic conditions, the shifting status of our natural resources, and updated modelling of future impacts. Given the levels of climate uncertainty, it is highly likely that a greater diversity of management practices will need to be explored and applied to ensure resilience and flexibility in future NRM systems.

Even though the majority of stakeholders suggested that climate change was not underway, the overwhelming majority of respondents indicated a willingness to accept wider policy changes to adapt to climate change, even if it meant that such changes would involve them making personal sacrifices (see Fig. 11).

Results of the survey suggest the NRM community is willing to make significant sacrifices to prepare for climate change: to mitigate greenhouse gas emissions and to increase the resilience of NRM systems in the face of change. Respondents indicated that a full

understanding of the future implications of climate change is not required to begin to implement a significantly increased response to climate change risk.

The fact that people are obviously concerned about the potential intergenerational risks associated with climate change is an important point, with significant implications for policy formulation. In fact, many respondents called for leadership to implement adaptation policy now so that future generations would not need to deal with the projected extremes of climate change if mitigation of greenhouse gas emissions were absent.

RECOMMENDATIONS

As the community becomes increasingly aware of the implications of climate change, there will be great opportunities to generate the will to support specific NRM planning responses. Prescriptive recommendations to respond to climate change do emerge from the report, and provide some important insights into people's thinking on climate change. However, those details are not provided here because the local social and environmental contexts are vital to shape the specific nature of those responses.

At a more general level, important themes emerge to provide guidance on how to move forward, to help put our natural systems, biodiversity, production systems and society on track towards sustainability in an era of rapid climate change. Respondents suggest that we will require a mix of:

- education to raise awareness of the impacts, to better understand options for change and to create the political will for change
- incentives schemes to encourage better management of scarce resources, particularly water
- restrictions on activities that are seen to be highly detrimental to the sustainability of NRM
- research and technological development to better understand the complex impacts on and associated interactions between our natural and production systems, and to create opportunities for management changes
- policy and planning guidelines to incorporate the implications of climate change and support the community to change
- positive, action-based leadership at all levels of NRM and societal governance to bring about the changes required.

One specific suggestion that may be interesting for the NRM sector to respond to is the idea that the sector as a group articulates loudly, clearly and in greater detail the observed and potential risks to their activities, and to the interests of the wider community, from future climate change. A coordinated articulation of the vulnerability of NRM to climate change, framed as a regional sectoral expression of concern, has the potential to stimulate a wide range of changes to practices to build resilience into systems and lead to broader policy responses to support the many transformations that are already underway at a societal level.

1. INTRODUCTION

1.1 THE PURPOSE OF THIS WORK

Climate change is a reality and possibly no other contemporary issue has the potential to so significantly compromise the sustainability of our natural resources base, or indeed our society as a whole. Accordingly, the Government of South Australia (2007) describes climate change as 'the single biggest threat facing our planet'. The causes and potential implications of climate change for South Australia have been outlined in detail elsewhere (see for examples, Suppiah et al. 2006; Bardsley 2006; McInnes et al. 2003; Pittock 2003), and will largely not be repeated in this report.

Mitigation of human-induced climate change via the minimisation of net greenhouse gas outputs will be a priority for action by Australian governments and communities. Importantly however, it is being recognised that societies must develop adaptation responses to climate change processes already underway and prepare for the inevitable future changes. Climate change will challenge many people's ideas and understanding of their world, their place, as well as their climatic and NRM systems. In the face of significant uncertainty regarding future environmental conditions, effective and comprehensive responses by individuals, organisations and governments become vital. The inherent changes and risks associated with climate change need to be factored into NRM, and future regional and urban planning processes.

There is also a clear need to develop methodologies for government and regional bodies to work with local communities and NRM stakeholders to prepare for climate change (Adger, Arnell & Tompkins 2005; Adger, 2003). The participatory research presented in this report aims to assist in South Australia's adaptation to climate change. This work is consistent with the State NRM Plan (DWLBC 2006) which has a long-term goal to deliver 'landscape scale management that maintains healthy natural systems and is adaptive to climate change'.

Research into community perceptions of climate change and risk is a necessary step towards effectively addressing the inherent uncertainties of managing natural resources for a sustainable future. This research is required to learn how to best engage natural resources managers and the community to identify requirements for skills and knowledge development, and to help establish community ownership of management responses to climate change. It is clear that without community belief and ownership of the issues, it will be difficult to implement new policy and programs to support sustainable adaptation options for NRM in South Australia. In fact, social perceptions, along with the underpinning environmental science and economic valuations, will be a large determinant of priorities for investment and action when governments formulate responses to the climate change threat.

The recent report *Tackling Climate Change: South Australia's greenhouse strategy 2007–2020* (Government of South Australia 2007) is a 'call to arms—to government, industry, business and the people of the state—for bold, practical and concerted action'. In tackling climate change three critical goals are addressed:

1. the need to reduce our greenhouse gas emissions
2. the need to adapt to climate change

3. the need to innovate in markets, technologies, institutions and the way we live.

The framework to achieve these three goals is presented as a series of objectives and strategies, broken into six sectors: community; industry; energy; transport and planning; buildings; and natural resources (Government of South Australia 2007). Another recently released report by 2006 Adelaide Thinker in Residence and prominent climate scientist Stephen Schneider (Schneider, 2006), outlines ten recommendations, spanning a range of sectors, for delivering positive sustainability outcomes. The Government of South Australia is making these resources and other information available through a web-based interface, at the website: www.climatechange.sa.gov.au. A further report, *A guide to climate change and adaptation in agriculture in South Australia* (Rebbeck et al. 2007) outlines projected climate trends and broad adaptation strategies relevant to a range of agricultural enterprises.

This Department of Water, Land and Biodiversity Conservation (DWLBC) report aims to complement recent reports released by the Government of South Australia and provide a range of practical, innovative and inspirational ideas, offered by key NRM stakeholders within the AMLR region, to help move towards satisfying the three critical climate change goals described previously. The focus of this report is on adaptation to climate change impacts on NRM (including primary production, biodiversity conservation, natural hazard management, coastal and water issues). However, the wealth of ideas and information generated by the AMLR NRM community also extends into the areas of greenhouse gas mitigation and innovation, and spans sectors beyond natural resources to include community, energy, transport, planning and buildings.

This work concentrates on the AMLR region, and draws and follows on from an initial integrated assessment of projected climate change impacts and adaptation options undertaken for the AMLR region (Bardsley 2006). That original report provides background information on the vulnerability of the region's natural resources management systems, and can be read in conjunction with this community perceptions review.

The remainder of the introduction section summarises work to date within the AMLR NRM region to develop a decision-making framework for adaptation to climate change. A significant outcome of the ongoing community engagement process has been the completion of individual survey questionnaires providing detailed information on various NRM community members' perceptions of climate change risk. The community perceptions of climate change presented in this report have been collated from voluntary responses to a questionnaire presented to NRM workers and other interested community members during 2006. The analysis, outcomes and recommendations arising from these questionnaires form the basis of remaining sections of this report.

1.1.1 THE SUPPORTING SCIENCE

There is considerable evidence that the climate is changing globally and projections suggest that the rates of change will increase into the future. Moreover, projections from the IPCC indicate that Mediterranean-climate types are more likely to experience a future drying trend due to climate change (IPCC 2007a, 2007b; McInnes et al. 2003). Many of the indicators of climate change are suggesting that measurable change is already broadly apparent globally. Suppiah et al. (2006) note that:

> 'Since 1950, South Australia's average maximum temperature has increased by 1.2 °C (0.21 °C per decade), the minimum by 1.01 °C (0.18 °C per decade) and the average

temperature by 1.1 °C (0.20 °C per decade). Thus compared to national trends, South Australian maximum temperature indicates a faster rate of increase, while minimum temperature shows a slower rate.

'Sea surface temperatures in the Spencer Gulf and the (Great Australian) Bight have risen at about half the rate of land-based temperatures (0.05 °C per decade from 1900–2005 and 0.11 °C per decade from 1950–2005).'

'Trends in South Australian annual rainfall since 1900 are generally weaker than other parts of the continent. Much of the northern half of South Australia became wetter while southern coastal regions became drier. These tendencies were strengthened during the last 55 years.'

Although specific implications of climate change are highly uncertain, future projections are not good news for the AMLR region. These include (McInnes et al., 2003):

- a warming/drying trend
- less reliable rainfall
- later breaks in the winter growing season
- more extreme weather events
- hotter, longer hot spells.

The questionnaire used to research community perceptions of climate change provided data on projected future climate change scenarios based on modelling presented in Suppiah et al. (2006), Gillooly and Hutson (2005) and McInnes et al. (2003). It was recognised that, given the available data on experienced and projected change, the work here was necessary to begin to examine how the community would want to see the incorporation of climate change information into future management and planning.

1.2 THE ADELAIDE AND MOUNT LOFTY RANGES REGION

The AMLR NRM region (see Fig. 1) is one of eight South Australian NRM regions defined under the South Australian Natural Resources Management Act 2004. The region is influenced by a Mediterranean climatic regime, and encompasses metropolitan Adelaide and the Mount Lofty Ranges from the Fleurieu Peninsula in the south to the Barossa Valley in the north. The region is of special significance for climate change planning because it is relatively humid in contrast to surrounding areas, and it has profound socio-cultural, economic and environmental values. Uniquely amongst the NRM regions, the AMLR contains a large urban centre. The importance of such an urban and rural context for developing an appropriate regional adaptation response to climate change is discussed in the following sections.

1.3 BUILDING TOWARDS A FRAMEWORK FOR ADAPTATION TO CLIMATE CHANGE

There is a strong call from industry and natural resources managers in the AMLR region, and elsewhere in South Australia, for tools to assist them in their preparedness for climate change. All South Australian regions mention the need for building the capacity to respond to climate change in their NRM investment strategies and/or plans. With the impacts of

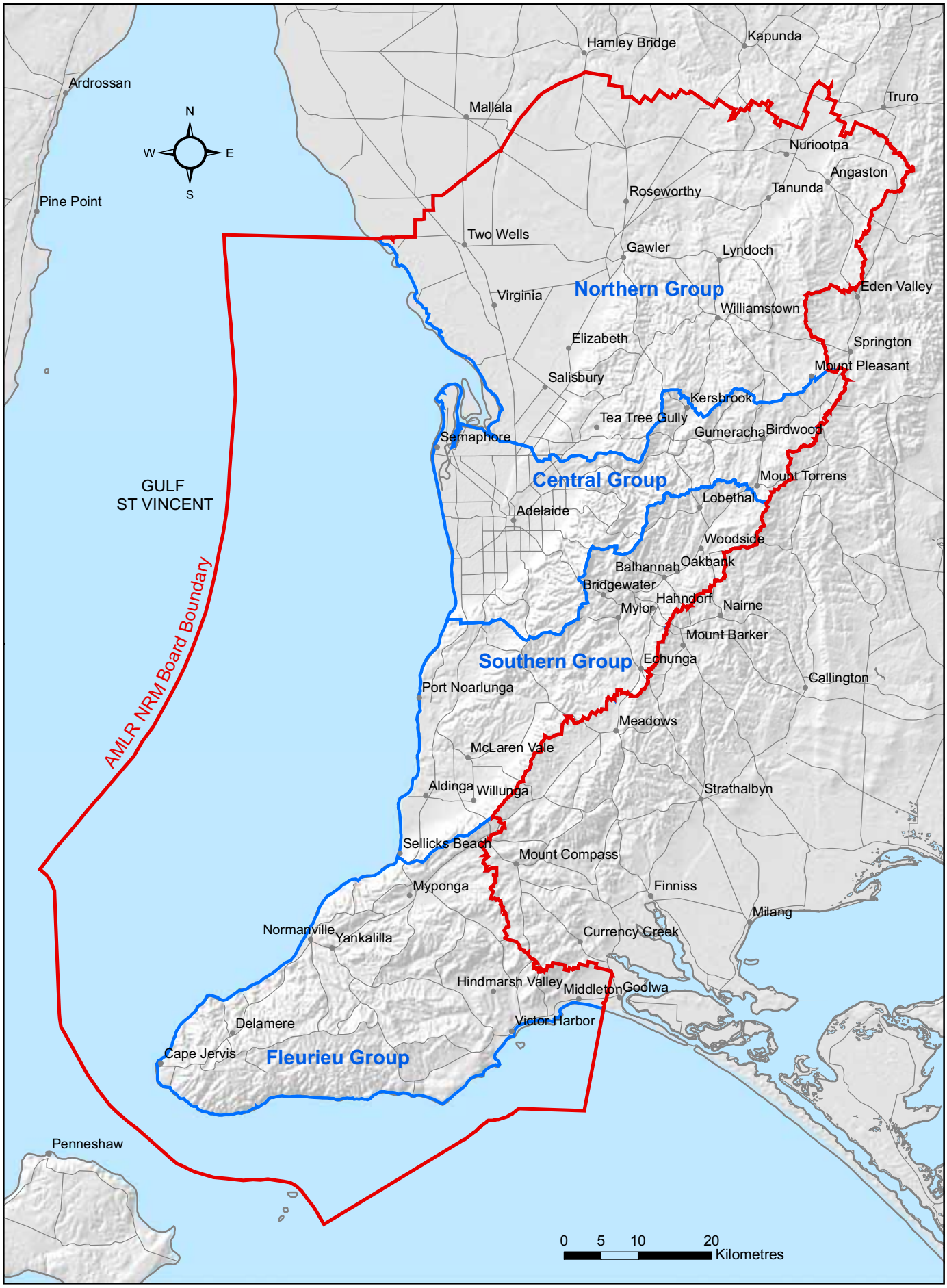


Figure 1. Sub-regional groups within the Adelaide and Mount Lofty Ranges (AMLR) NRM Region.

prolonged drought and perceptions of increasing climate variability evident in recent years, there is increasing concern at the lack of approaches to respond effectively, in both the short-term to climate extremes and in the long-term to climate trends at the regional level. These issues of unpreparedness for climate change impacts at a regional level were raised consistently with DWLBC at recent regional workshops across South Australia associated with this study.

The AMLR NRM Board, in association with the Government of South Australia, has identified the need to understand the implications of climate change in relation to its NRM program. Associated work has begun to develop a framework for strategic and action planning in the face of climate change. The framework aims to explicitly target the concerns of managers, planners, industries and organisations regarding the sustainability of NRM, by working with the latest science and stakeholders themselves to articulate a methodology for adapting to climate change. Previously, an integrated assessment of the vulnerabilities of regional NRM to climate change was generated (Bardsley 2006), to provide a baseline review of information on impacts and ideas for adaptation in a form that could be readily critiqued by regional stakeholders (Granger Morgan & Dowlatabadi 1996; Brooks, Adger & Kelly 2005).

A decision-making framework is emerging that involves steps including:

1. awareness-raising and ownership of change
2. vulnerability analysis
3. development of adaptation responses
4. appropriate integration of adaptation responses into management and planning activities across different timeframes:
    a. incorporation of climate change into risk management approaches in the short-term
    b. the application of adaptive management techniques which can be adjusted over time
    c. the application of the precautionary principle, that is, allowing for increasing long-term risk
5. ongoing revision, reassessment and possible alteration of these approaches.

The background discussion here focuses on the broader context within which decisions will need to be made. In particular, this work was undertaken while exploring and applying emerging techniques of participatory research that simultaneously educate and train the community, while also informing wider management and policy options.

1.3.1 SOCIETAL AND ENVIRONMENTAL CONTEXTS FOR A RESPONSE TO CLIMATE CHANGE

Most environmental issues that societies face require a significant level of wealth before they can be examined in detail and effectively eliminated, mitigated or adapted to (Dunlap & Mertig 1995). While there is considerable evidence to suggest that local or regional poverty or industrial related environmental issues are able to be significantly reduced with increasing wealth, there is a third type of environmental issue related to consumption, which often does not decline simply with increasing economic capacity. These consumption-related environmental issues often require us to make decisions to change societal behaviour. In other words, it is evident that a certain level of societal development is required to be able to

define and then begin to argue for responses both to mitigate and adapt to an enhanced greenhouse effect.

For people to be willing to make sacrifices or direct wealth and effort to respond to climate change will require a considerable recognition of the importance of environmental change management for their own lives, and associated guidance from government. The mechanisms that are employed may involve complex state policy development to lead governance of sustainable development in the form of regulation, incentives, taxes or other policy mechanisms.

The skilful application of technical innovation within NRM, agriculture and associated sectors creates situations of production abundance, releasing societies from the immediacy of ecological concerns and realities of natural resources limits and variabilities (Brown 1995; O'Hear 1997). Such detachment of societal processes, including governance, production and consumption, from the direct concerns of ecological wellbeing has been a major factor enabling the evolution of complex industrial and post-industrial societies. However, by neglecting the immediate ecological constraints pertinent to life on earth, the change from a society reliant on primitive technologies, skills and forms of exchange to one geared to modern production and marketing systems has often come with substantial ecological costs (Tait & Morris 2000).

It is important to step back a moment to examine the broader socio-ecological context within which the AMLR region is now managing its resources. That context is partly defined by a history of progressive expansion of humanity. Up until the beginning of the 21st century there has been room for the further expansion of human societies to fill numerous different spaces and ecological niches (Berry 1996; Gretton & Salma 1996; Altvater 1998). The increased productivity required by growing populations has been met largely by expanding agricultural areas, technological advances and further exploiting natural resources. We are now seeing that human populations have spread around the globe to fill, surround or alter all the spaces and ecosystems able to support life. The dominance of the human species, in other words the social enclosure of the planet, means that regional NRM processes will increasingly need to be made sustainable in the context of global change. That is, NRM in the AMLR will need to be made sustainable within the broader context of the socio-ecological wellbeing of humanity, not just within the limited perspectives of local economic management or resource exploitation. It also follows that adaptation approaches to respond to climate change will need to be undertaken within the constraints of limited opportunities for further exploitation of land and water resources regionally, nationally and globally (Bardsley 2003). The recognition of this fact will need to underpin an effective decision-making framework. Moreover, it could now be argued that climate change provides a further challenge to NRM because the frontiers of viable natural resource exploitation are not only reaching limits of expansion, but some resources, particularly water for dryland and irrigated agriculture, are projected to decline in South Australia (Suppiah et al. 2006).

As people try to develop effective adaptation responses, they are finding that the direct local effects of global climate change are not easily dissociated from climate variability (McInnes et al. 2003; Suppiah et al. 2006). In most cases, the atmospheric science is of such a complex nature that it is not easily explained or understood. It could be argued that until recently, atmospheric scientists have not been able to articulate a strong, clear message to engender a coordinated societal response to what is increasingly perceived as the greatest environmental challenge facing Australian society. For example, modelling results are often presented in a manner that is difficult to decipher, are contradictory or suggest such high

levels of uncertainty that they do not engender faith in their accuracy. Due to the uncertainty of future climate change, science and scientists have been seen to be largely unable to provide sufficiently detailed guidance to enable specific responses. As a result, managers and governors of societal activities to both mitigate emissions and adapt to climate change have been able to discount the importance of the projections. This response, or lack of, has manifest itself at the political level, where cost-benefit analyses have indicated that in the Australian context, major shifts in policy to reduce emissions of greenhouse gases have not been justified (Hamilton & Quiggin 1997).

That said, climate change, in association with the ongoing globalisation and homogenisation of socio-ecological practices, is leading to a new level of awareness of human ecological constraints. The world has woken up to the risk of climate change over the last six months (late 2006 to early 2007)—or at least the perception of many natural resources management stakeholders in the Adelaide–Mount Lofty Ranges region. Therefore, the context of the research and discussions outlined below occurred within a period of rapidly rising community interest in climate change. Apart from actions by the Government of South Australia and others in the community, the 'one in 1000' year drought across much of southern Australia, the film *An Inconvenient Truth*, tours from environmental speakers including Al Gore and David Suzuki and reports on the economic implications of climate change from the Wentworth Group of Concerned Scientists and the UK government (Stern 2006), have all significantly increased awareness of the implications of an enhanced greenhouse effect in South Australia. Indications of the level of interest include statements from self-acknowledged sceptics that climate change is now a serious issue, and it is now broadly discussed at state and federal levels of government. The awareness of the need to develop and implement sustainable responses to climate change must now be utilised by policy makers to develop appropriate responses for adaptation.

Hazards and changing natural resources capacities associated with climate change will be unavoidable by any community, although the impacts are unlikely to strike evenly across natural or social systems (Beck 2000; Gotsch & Rieder 1995). It is imperative that NRM stakeholders analyse where the major vulnerabilities to climate change lie in our society and target appropriate responses to those heightened levels of risk.

Importantly, this study includes a major urban centre as well as important rural production and conservation areas. As urban centres increase their wealth and influence in association with globalisation, the disconnection between the dominant democratic decision-making processes and the need to implement sustainable ecological management practices could increase. It could be argued that an important component of any appropriate response to the increasing ecological risks associated with climate change is the evolution in the perceptions of the community towards society's ecological sustainability.

1.3.2 THE URBAN-RURAL CONTEXT OF THE AMLR

The future for global economic growth is intimately associated with urban development. In a globalising socio-economic environment, urban areas need to strategically position themselves to gain advantage over other like cities. A great advantage that any city offers in relation to providing sustainable outcomes is the economies of scale in relation to human populations and activities, which ensure there can be relatively low per capita, per production or per consumption costs for responding to climate change and reducing impacts on the environment more broadly. The future of Adelaide in a competitive global environment will

likely be the provision of key services and the ongoing retention of some key manufacturing industries, including defence and automobile manufacturing. Other key advantages which could assist Adelaide to position itself as a sustainable futures capital of Australia include its mild climate, high cost-competitiveness in terms of business and affordability of living, strengths in research and development (through both academic institutions and industry), outstanding cultural institutions, relatively few infrastructure constraints (apart from water) and a highly skilled, innovative workforce (DTED 2007).

As a region, the AMLR is characterised by a range of important urban, peri-urban and rural NRM issues. Some key characteristics of the region (Government of South Australia 2003) include:

- covers a land area of ~3880 km^2, and a similar area of marine and estuarine environments
- human population over 1 million
- Adelaide draws 60% of its water from local catchments in most years
- primary industries contribute $1 billion per annum to the state's economy
- contains 50% of the state's native plant species and 75% of native bird species
- 13% of its original terrestrial native vegetation remains.

To achieve the goal of sustainability in an era of climate change will require a substantial commitment to reducing consumption-related environmental impacts within the AMLR. South Australia has made substantial inroads towards reducing industrial and other production-related environmental impacts during the last 50 years. The next important step in the management of the environment is to examine consumption-related impacts, in other words the city's 'ecological footprint'. Issues such as biodiversity degradation, urban expansion, fossil fuel use and greenhouse gas emissions are often not immediately obvious and can be difficult to manage because the benefits of actions are rarely noticeable locally—that is the great social and political challenge of ecological sustainability.

Another component of a sustainable future for Adelaide is to reduce the city's sensitivity to emerging risks. Such risks include the provision of water and energy resources, the unknowns of climate change, and the increasingly competitive global environment for labour, financial resources and markets for goods. The final component is how the state can consequently maximise the socio-economic benefits from the process of change.

It could be argued that no other Australian capital city is as reliant on its immediate hinterland as Adelaide. The history of land-use planning in the region has responded to this importance by making numerous special provisions, including the very effective restrictions on development along the Hills Face Zone of the Mount Lofty Ranges. However, the AMLR region is reaching a fundamental impasse in relation to the management of this space for a number of reasons:

- changing focus on sustainable forestry and agriculture production
- rapidly increasing habitat values
- ongoing expansion of urban space, including commercial and residential buildings, infrastructure for transport and utilities
- limited water resource availability, associated also with climate change
- water pollution associated with agriculture, urban and forestry runoff

- biodiversity loss
- invasive species, particularly the management of olives
- increasing recreation pressures
- perceived risks associated with fire management.

Climate change is likely to exacerbate almost all of these pressures, and any integrated NRM responses to climate change will need to focus on ensuring that climate risk management is built into a sustainable development framework. In particular, water resources could be perceived as the major limiting factor for sustainable development in South Australia. The process of defining environmental limits for sustainable NRM has started in the AMLR by: imposing strict controls on biodiversity clearance; greater prescription of water resources; the retreat of more polluting agricultural activities such as some horticultural and grazing activities; and the expansion of other high-value horticultural and viticultural activities.

Climate change projections suggest that there is likely to be a declining resources base in the AMLR in the future (Suppiah et al. 2006), and so the importance of redefining those limits according to future projections, or at least allowing for the uncertainty of future resources availability, has become paramount. Any effective adaptation response to climate change will need to rely on unique characteristics of the AMLR region itself, and the capacity of the people who manage those resources to implement plans that create sustainable management systems.

1.3.3 AN NRM APPROACH TO RESPOND TO CLIMATE CHANGE IN THE AMLR REGION

It is important to recognise that climate change will be a large global experiment. Early effective responses, which are balanced and reflective of the intensity and scope of change, will help minimise negative impacts and maximise potential benefits. Such responses can no longer be considered as an issue separate to other NRM activities, and we probably have to accept that we will not get everything correct in the first instance. To begin the process of responding to a changing climate will involve the transfer of information to stakeholders, and also an acceptance and ownership of the concept of change itself by managers and planners.

The transfer of environmental information from scientific sources for effective planning applications is challenging all stakeholders: scientists, governments, private extension workers, planners and others. Historically, criticisms of the methods of information transfer have focused on information provision in overly simplistic and regulated forms that do not represent the complexity of experiences that planners must deal with, and which do not represent the need for local interpretations of scientific information. Moreover, planning responses to climate change risks are sensitive issues and present significant governance challenges within intensively settled and managed landscapes. Important issues are raised for effective community education here. It is clear that approaches to raising awareness of emerging climate change risks will need to emphasise the validity of local knowledge to ensure that local managers and planners will both accept information and support adaptation initiatives. To respond to the concern that prescriptive or dictatorial messages are often inapplicable and unwelcome within the local context, a participatory approach has been developed here that combines awareness raising and research goals (Mayo 1999).

The acknowledgement of changing climates may require a paradigm shift for NRM, which has based most of its guidelines on relatively stable, although variable, climate scenarios. An approach to raise awareness of climate change was undertaken within the context of the recently established NRM Boards, which are designed to integrate the previously separate issues of water, land, biodiversity and invasive species management in South Australia. Working in partnership with the AMLR NRM Board to review the vulnerabilities of NRM sectors to projected climate change was seen as a vital first step in developing a regional decision-making framework. A participatory approach to climate change enables the communication of new ideas in a manner that integrates across NRM sectors, to better inform similarly integrative management and planning responses.

The aim of this initial project work was to create an acceptance that, while uncertainty remains about a future under climate change, we need to recognise that change is a reality and so begin to incorporate already available information into NRM decision making and planning, rather than adding it as a quite separate issue to management processes. For that reason and numerous other benefits, strong associations were developed with key NRM contacts and other stakeholder organisations, with the assistance of the AMLR NRM Board and other state agencies. This has been achieved initially by developing a review of climate change impacts and opportunities for adaptation based on current knowledge. An integrated assessment of climate change was undertaken to provide ideas and information on impacts and adaptation options in a form that could be readily critiqued by stakeholders (Bardsley 2006). That work also aimed to increase the preparedness for change by developing a baseline review of potential climate change impacts for a key South Australian NRM region. The vulnerability assessments were developed by applying a methodology outlined by The Allen Consulting Group (2005), and triangulating the available scientific evidence of climate change risks to NRM systems, with projections for change from McInnes et al. (2003) and input from key stakeholders. In particular, input was obtained from a consulting group with members drawn from staff of the AMLR NRM Board, the Bureau of Meteorology, SARDI, CSIRO Land and Water, South Australian Department for Environment and Heritage, and the City of Marion.

As outlined in Table 1, the integrated assessment undertaken indicates that water, land, biodiversity and air resources are particularly vulnerable to projected climate change in the AMLR NRM region.

Vulnerabilities have been assessed previously to be most severe in relation to coastal management issues, biodiversity and bushfires, with water and agriculture management also significant considerations. This does not mean that other NRM issues are not important, rather that the issues mentioned could be considered planning priority areas in the short-term. It could be possible to argue that within the NRM sector, the most vulnerable systems are likely to be those that are not managed intensively by people, such as biodiversity, or those that are managed intensively but have long management response timeframes, such as horticultural production systems. Ideas for adaptation to climate change and important gaps in knowledge were detailed under the different sections within the review document. The temptation to provide prescriptive answers to respond to change was resisted due to the desire to engage each sector in researching particular climate change impacts and developing detailed planning responses.

Table 1. Summary of vulnerability analyses for natural resources management in the Adelaide and Mount Lofty Ranges (Bardsley 2006)

	Exposure	Sensitivity	Potential impact	Adaptive capacity	Vulnerability
Riparian flood management				–	
Surface water				XXX	
Groundwater				XXX	
Coasts: flooding				X	
Coasts: beaches				X	
Biodiversity: terrestrial				X	
Biodiversity: freshwater				–	
Invasive species				X	
Parks & gardens				XXX	
Revegetation				XXX	
Agriculture: annual cropping				XXX	
Agriculture: horticulture				X	
Agriculture: livestock				XXX	
Land management				XXX	
Bushfires				X	
Air quality				XXX	

Colour key for exposure, sensitivity, potential impact and vulnerability (not adaptive capacity):

Low | Low–Medium | Medium | Medium–High | High

Key for adaptive capacity:

Limited	Medium	Significant
–	X	XXX

1.3.4 GENERATING LOCAL INTEREST, INPUT AND OWNERSHIP

The next step following the regional appraisal was to engage with the local NRM communities at a more detailed level. This ongoing process is being undertaken in order to yield valuable local insights, to raise awareness and ownership of the issue, and help inform policy makers of priority responses to the climate change threat. To achieve this goal, activities have included:

- Workshops and presentations to NRM workers and interested members of the wider community (see App. 1).
- Development of the 'The Adaptation Challenge', a workshop tool for integrating climate change impacts into NRM discussions (Bardsley & Bardsley 2007).

- Group analyses of NRM vulnerabilities undertaken during the workshops (see Table 4 and App. 2).
- Individual analyses of NRM vulnerabilities and wider climate change perceptions, via a questionnaire distributed following the workshops. (Results from this questionnaire form the basis of later sections of this report.)
- In-depth interviews of key personnel within a range of NRM organisations to obtain their opinions, both of the vulnerabilities and adaptation options to climate change, and to guide future directions for research and project development.
- Ongoing development of a series of six case studies examining climate change impacts and management responses featuring a range of key NRM vulnerabilities in selected localities.
- Development of an information brochure summarising major issues that will affect the AMLR region (AMLR NRM Board & DWLBC 2007).
- Press coverage within the AMLR of the project work.

A focus group for the study of NRM community perceptions of climate change included the regional NRM groups associated with the four AMLR NRM sub-regions: Northern, Central, Southern and Fleurieu (see Fig. 1). (Numbers of NRM workers from each regional group in the focus group were: Northern – 13, Central – 40, Southern – 25, Fleurieu – 7 [and 2 not recorded].) The four regional groups have been established within the AMLR to advise the regional board on local issues, to raise awareness of NRM and to work with local NRM communities and stakeholders to implement the Regional NRM Plan. Presentations and workshops were undertaken, with the assistance of AMLR Board staff, to raise the project's profile and discuss the framework concept.

The hypothesis employed for these workshops is that people readily discount climate change risk because it is largely seen as a long-term problem, so complex as to undermine the legitimacy of any current responses, and lacking in effective response approaches. Therefore, in talks developing NRM adaptation responses to climate change the messages are emphasised that:

- The impacts of climate change are apparent historically, currently important and will continue to be important in both the short- and long-term.
- The complexity of climate change projections for the Mediterranean climatic system of South Australia can be summarised under major themes associated with:
    - a warming/drying trend
    - more variable and extreme weather conditions
    - associated secondary environmental change such as sea level rise
    - greater vulnerability of NRM systems.
- In many cases, to respond to the substantial uncertainty, there needs to be an emphasis on the need for new discoveries, ideas and responses. Individuals and groups will need to apply a learning orientation to climate change, rather than to expect knowledge and information to guide specific responses. The focus of action can be broken down into:
    - incorporation of climate change into risk management in the short-term
    - the application of adaptive management and planning techniques in the long-term
    - the application of the 'precautionary principle' for the long-term.

The workshops' outcomes have been analysed here to inform the AMLR planning process, to facilitate sectoral responses and to incorporate into the broader project outcome of

developing an NRM framework for decision-making regarding vulnerability analysis, and adaptation planning and management.

Other presentations (see App. 1) have been undertaken throughout the AMLR and other regions to raise awareness of climate change, the major vulnerabilities to climate change, the idea for a response framework and the project itself. These 45 presentations to over 1800 NRM researchers, practitioners, educators and students during the period June to December 2006, have attempted to generate a broad understanding of the vulnerability of NRM to climate change and will provide the foundations for future research that are designed to highlight specific climate change impacts in selected localities. Important feedback was obtained from these presentations and workshops that have already shaped the development of AMLR case study ideas.

2. METHODOLOGY

2.1 BACKGROUND

Individuals' perceptions of climate change were sought from AMLR NRM community stakeholders to help provide information critical for the development and analysis of a regional decision-making framework for adaptation to climate change (as per Section 1.3) (Bruckner et al. 1999; Lempert et al. 2004; Cameron 2005; Lorenzoni, Pidgeon & O'Connor 2005; Hill & Thompson 2006; Zahran et al. 2006). Key components of the decision-making framework assisted by this research include:

- raising awareness and ownership of change
- analysis of NRM vulnerabilities
- development of appropriate adaptation responses.

A questionnaire (see App. 3) was distributed either directly to interested stakeholders or by leaving copies at the back of the room following climate change workshops conducted by DWLBC between July 2006 and December 2006 (see App. 1). The workshops were held throughout the AMLR for the purpose of raising awareness of climate change, stimulating local communities to begin generating adaptation responses to predicted climate change impacts and encouraging them to take ownership of climate change considerations in NRM activities. Workshops presented information on projected changes in climate and avoided the presentation of prescriptive adaptation responses.

The surveys were designed to capture local perspectives on climate change impacts on key local natural resources, both as they were perceived at that time and under projected future changes, as well as collating locally applicable adaptation options derived by the AMLR NRM community themselves. Stakeholders' responses to the questionnaire provide a dataset of perceptions of climate risk and influences on NRM across all sectors. However, no attempt was made to undertake a comprehensive analysis of views on climate change representative of all NRM stakeholders across the AMLR region. Such an attempt was beyond the scope of this project.

While many survey respondents (e.g. members of the NRM community and local government) provided information subsequent to workshops or community meetings in a semi-opportunistic manner, other groups were specifically targeted for their views. The targeted groups included members of four AMLR NRM groups who attended workshops specifically designed to educate on climate change. Environmental management students from Flinders University were also asked to give their opinions on climate change after attending a lecture[2]. Away from the key NRM workers associated with the four AMLR NRM groups and the group of students, the survey process did not aim to comprehensively review

[2] The environmental management students comprised a significant number of the total survey group (see Table 2). This group would be among the most educated in a range of environmental issues and on average was the most moderate in rating the importance of climate change in comparison to other environmental issues (see App. 4).

the perceptions of climate change risk. Rather, by giving NRM stakeholders a chance to voluntarily voice their opinions, the survey process was used to provide people who wished to detail their perceptions of climate risk and ideas for future adaptation, with that option. Therefore, the goal of the survey was to examine concerned NRM stakeholders' perceptions and they were invited to pick up a survey questionnaire on completion of the workshop. Respondents took the questionnaires away with them and completed questionnaires were mailed back to the authors.

There are methodological limitations of the approach taken here. The respondents were provided with, and would have responded to, different information and other stimuli when filling out the questionnaire. In particular, it is highly likely that the information stakeholders were provided with during the workshops and the subsequent discussions would have influenced their responses. There was considerable variation in the workshops and discussions because presentations were framed to meet the needs of the audience. That said, response rates of 80–90% were obtained from the four AMLR groups and the students. In contrast, only a relatively small number of NRM community members who attended workshops chose to complete and send in the questionnaires, so it is highly likely that the sample of NRM community stakeholders analysed is not fully representative of the views of the AMLR NRM community in relation to climate change. No attempt was made to obtain a large response rate from the community as it was not the aim of this project to obtain a representative sample of the community, nor did the authors wish to impose on less than fully interested stakeholders. The repercussions of this sampling method, however, is that it is quite likely that the views represented here are likely to be those of people more concerned about climate change than the average NRM stakeholder. Many people would have chosen to not complete the questionnaire because they did not find the issue particularly important. That said, since the work was undertaken, climate change awareness has grown significantly in Australia. It is probably valid to conclude that the data collected and analysed here for the NRM community are the views of that component of NRM stakeholders more concerned about climate change impacts in the AMLR.

The survey was directed at an interested audience because the workshop/survey process aimed to simultaneously extract climate risk perceptions while also educating, raising awareness and encouraging ownership of the issue amongst the NRM community. Most of the respondents were considered to possess a relatively high level of environmental awareness indicated by their vocations, or their interest in attending community meetings, with many holding positions or volunteering within the NRM workforce. Environmental students, farmers, professionals and business leaders were also among the respondents. In fact, respondents demonstrated an interest in climate change and the environment simply by completing the questionnaire. In doing so, a suggestion of the personal ownership of climate change considerations in future NRM activities is implied. Table 2 provides a breakdown of the socio-demographic characteristics of the survey respondents.

The questionnaire (see App. 3) was designed to help collate detailed information on key stakeholders' perceptions of climate change, with the aim of determining:

- community perceptions of climate change:
    - in relation to other environmental issues
    - whether possible indications of climate change had been observed in local landscapes, productions systems or ecological systems
    - whether climate change was occurring
    - the perceived extent of changes.

Table 2. Socio-demographic characteristics of the survey respondents (N=87)

Characteristic	Number of people in each group	
Sex	Females	34
	Males	52
	(No response)	(1)
Occupation	NRM workers	27
	Students	34
	Business leaders	3
	Farmers	5
	Science-based professionals	7
	Other professionals	5
	Volunteers	2
	Retirees	3
	(No response)	(1)
Location	Northern	13
(AMLR NRM Board sub-region)	Central	40
	Southern	25
	Fleurieu	7
	(No response)	(1)
Highest education level attained	Less than or equal to Year 10	1
	Year 11	5
	Year 12	23
	College or trade certificate	7
	University graduate	26
	Post-graduate degree	24
	(No response)	(1)

- key issues arising from predicted climate change impacts
- potential adaptation responses to deal with the impacts of climate change
- whether or not there are differences in the perceptions or key interests of the AMLR NRM groups, based on their location (or other factors)
- whether the opinions of AMLR NRM Group members were representative of the broader AMLR NRM community.

To support the questionnaire, a series of targeted interviews were also undertaken during the period June 2006–February 2007 to investigate particular emerging issues in greater depth. Selected quotations from these interviews are cited as personal communications in relevant discussions of the questionnaire results below.

The four AMLR NRM Groups are key management bodies for climate change risk for natural resources within the region. Their opinions could be an important guide for AMLR regional planning for climate change. During workshops with the four groups, results were also collated to help inform the planning process. The process and results of this preliminary group activity are described in greater detail in Section 3.1.1 and Appendix 2.

2.2 ANALYSIS

Many survey responses were analysed using the 'Statistix 8.0' statistical software package. The survey yielded nominal (categorical) and ordinal (rank order) level data, therefore nonparametric statistical techniques were used (Table 3).

Table 3. Nonparametric statistics used in the survey analysis

Level of measurement	Purpose of test	Nonparametric statistic
Nominal (i.e. responses in categories, with no implied order)	Test for two independent groups	Chi-square test (for two independent samples)
	Test for differences among several independent groups	Chi-square test (for k independent samples)
Ordinal (i.e. responses were ranked in order)	Test for two independent groups	Wilcoxon Rank Sum Test
	Test for differences among several independent groups	Kruskal-Wallis one way analysis of variance by ranks

Responses from the AMLR NRM Group (a core group of 26 community members who act as key advisors on local issues for the AMLR NRM Board) were contrasted against the wider survey group (N=87) to reveal any similarities and differences. To explore links between the survey responses further, on occasions during the analyses respondents were grouped on the basis of their answers to Questions 2a, 2b, 2d and 2e, as follows:

- **Group I** – respondents who perceived a major change in climate over the last 25 years, and **Group II** – respondents who perceived little to no change in climate or didn't know (Question 2a).
- **Group III** – respondents who perceived less or much less annual rainfall totals in the last 25 years, and **Group IV** – respondents who perceived little change or greater rainfall (Question 2d).
- **Group V** – respondents who perceived warmer or much warmer day temperatures over the last 25 years, and **Group VI** – respondents who perceived little change or cooler conditions (Question 2b).
- **Group VII** – respondents who perceived greater or much greater rainfall variability over the last 25 years, and **Group VIII** – respondents who perceived little change or less variability (Question 2e).

Grouping respondents in this way allows for more in-depth analysis of the major drivers of people's perceptions. This type of approach has been shown previously to assist in the dissection of major issues that might influence NRM stakeholders' views (see for example Bardsley & Edwards-Jones 2006).

3. RESULTS AND DISCUSSION

3.1 HOW IMPORTANT IS CLIMATE CHANGE FOR THE AMLR?

3.1.1 AMLR NRM GROUP PERCEPTIONS OF CLIMATE CHANGE AND NRM VULNERABILITIES

A review of perceptions of climate risk in group discussions at workshops held with each of the four AMLR NRM groups (Northern, Central, Southern and Fleurieu) yielded some initial impressions of vulnerabilities to climate change on a collective basis. During the workshops, the projections for future climate change in South Australia from McInnes et al. (2003) were initially presented to the groups, along with the results of the vulnerability analysis from Bardsley (2006). Groups made statements along the lines of, 'You know you are preaching to the converted here' or 'We are interested in your project, but you know we have been considering climate change for a while now', suggesting that they had already begun to undertake work examining climate change impacts on their respective areas.

Group members were asked to identify how important climate change is for NRM on a scale of 1–10, and most people considered it in the 7–10/10 bracket and almost no-one classified the issue as being less than 5/10. While it can be acknowledged that these groups were largely pre-selected in that they chose to attend workshops and presentations on climate change, they also represent the major NRM stakeholder groups within the region.

The AMLR NRM groups were asked to outline their five major vulnerabilities and discussion led to an examination of regional opportunities for NRM adaptation (App. 2). Once summarised, NRM groups perceptions of vulnerability and adaptation opportunities do not vary considerably, although each groups' focus was influenced by the local conditions (Table 4).

Table 4. Summary of AMLR NRM Groups' perceived vulnerabilities to climate change

Major vulnerability	Fleurieu Group	Southern Group	Central Group	Northern Group
Water	✓	✓	✓[i]	✓
Biodiversity	✓	✓	–	✓
Agriculture	✓	–	✓	✓
Coasts	✓	✓	–	[iii]
Marine	✓	–	–	–
To key hazards (e.g. floods, bushfires)	–	✓	✓[ii]	✓[iii]

i The Central Group had a major focus on water management issues, dividing water management into two major components of increased water demand and reduced water resources.

ii The Central Group divided hazards into two major focus areas of flood and bushfire management.

iii The Northern Group did touch on coastal issues in relation to flood risk, classified under hazards, but did not emphasise the other key hazard (bushfire risk.)

Water management, both in relation to the potential for increasing demand and reductions in ground and surface water reliability, was recognised as a key issue by all groups. The potential implications of changing climate on flood risk were identified as a possible change to an important regional hazard. In contrast, the initial vulnerability analysis undertaken by the project suggests that while the impacts of climate change on water resources are likely to be substantial, there are numerous technical and policy adaptation responses that can be applied to water resources management and planning to greatly improve the sustainability of resources use (see Table 1). In an interview, a DWLBC manager of water prescription in the AMLR supported this view (2006, pers. comm., 12 July):

> 'We know that climate change is going to chip away at the resource and it is something that we'll need to incorporate into our planning. For example, we will need to buy licences to the water back from other users. In terms of keeping Adelaide going, there is significant capacity. But the capacity of horticulture to deal with the changing situation is uncertain. I believe we will have to change the way that water is used for horticulture over time as the resource declines, and so the vulnerability may be significant.'

It may be that stakeholders still consider water resources to be highly vulnerable because they doubt that such adaptation measures will be applied or believe that they will prove ineffective.

The other major vulnerabilities identified here have informed the development of case study themes to further examine critical NRM vulnerabilities in selected localities.

The development of associated case studies is already underway in relation to biodiversity planning, groundwater and soil management, and perceptions of coastal and horticultural production risk. In just one example, the aim is to respond to specific questions that are emerging in relation to biodiversity conservation in South Australia. For example, the AMLR regional manager for biodiversity conservation stated (2006, pers. comm., 15 August):

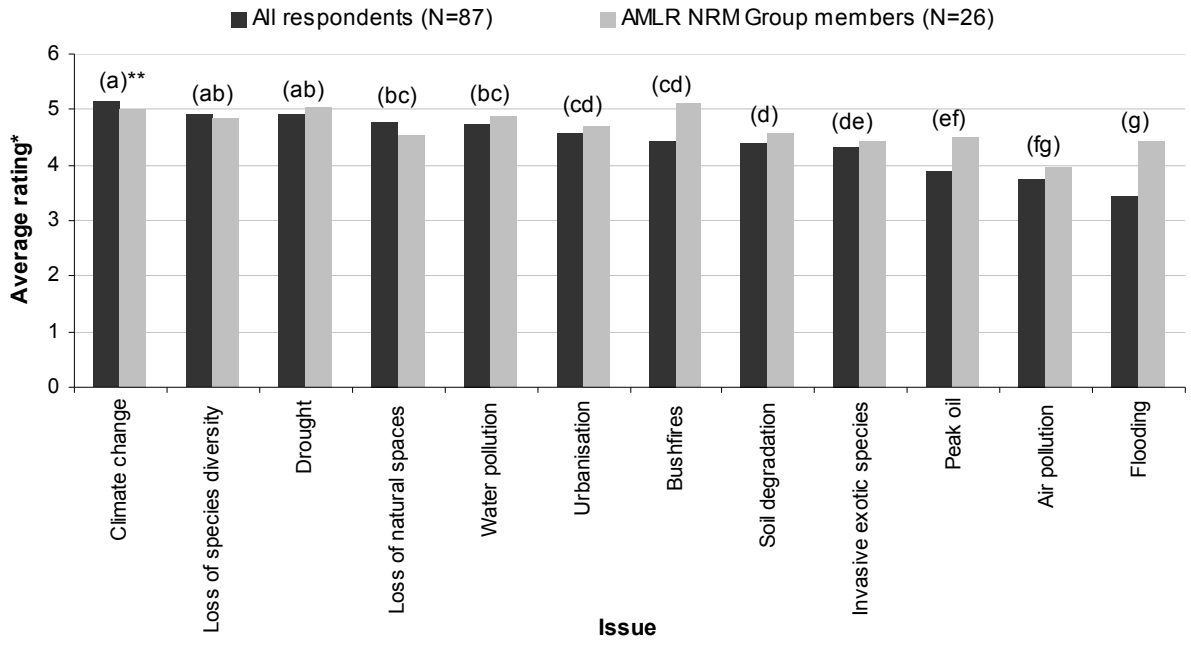
> 'For many people, climate change is only just coming out of whacky-land. But there is a lot of data that would provide important information. A two-pronged approach is required:
> - How do we build climate change into risk assessments? It is time that we became more explicit about climate change to examine some issues like invasive species, threat abatement and regeneration in detail.
> - We need to work to build broader resilience of systems to the negative effects of change into all ecological systems.'

While a range of activities have been undertaken to collect data for this report (e.g. group workshops, interviews with key NRM personnel—as outlined in Section 1.3.4), the remainder of this report will concentrate on the analysis of individual survey questionnaires in which respondents were invited to provide detailed perspectives on climate change risk, NRM vulnerabilities and possible adaptation responses.

The following results sections are based primarily on data obtained from all respondents who completed the questionnaire.

3.1.2 QUESTION 1 – CLIMATE CHANGE AND OTHER ENVIRONMENTAL ISSUES

In the questionnaire, respondents were asked to rate the importance of climate change against 11 other major regional environmental issues. On average, climate change rated as the most important environmental issue for all respondents (Fig. 2). For the AMLR NRM Group members, only drought and bushfires were rated more highly than climate change. However, this result might have been expected given the limitations of the methodology, which positively selected concerned stakeholders (see section 2.1). Furthermore, it is important to note that climate change would have been strongly in the minds of stakeholders because of the associated presentation. Given those limitations, the results nevertheless suggest perceptions by stakeholders, including most AMLR NRM Group members, of a significant emerging climate risk for NRM in the AMLR.



* Rating values: 1= Not relevant, 2= Unimportant, 3= Limited importance, 4= Important, 5= Very important, 6= Extremely important
** Entries with the same letters are not significantly different - considering data from all respondents.

Figure 2. Comparative rating of the importance of current environmental issues

Besides climate change, other important issues for the larger survey group included loss of species diversity, drought, loss of natural spaces/habitat and water pollution. There were no statistically significant differences between the three top rating issues shown in Figure 2 (Kruskal-Wallis, N=87, H=3.02, p>0.05).

Figure 2 also suggests that the opinions of the AMLR NRM Group members provide a good indication of opinions in the larger survey group.

3.1.3 QUESTIONS 2A–E—PERCEPTIONS OF THE EXTENT (IF ANY) OF CLIMATE CHANGE

Figures 3 to 7 display histograms of survey responses to Questions 2a–e. These questions asked respondents whether they had perceived changes in climate over the past 25 years. The majority of respondents perceived that some climate change was already apparent, although responses to Question 2a (Fig. 3) can be grouped into:

- Group I – those who perceived major climate change (N=36).
- Group II – others (N=51).

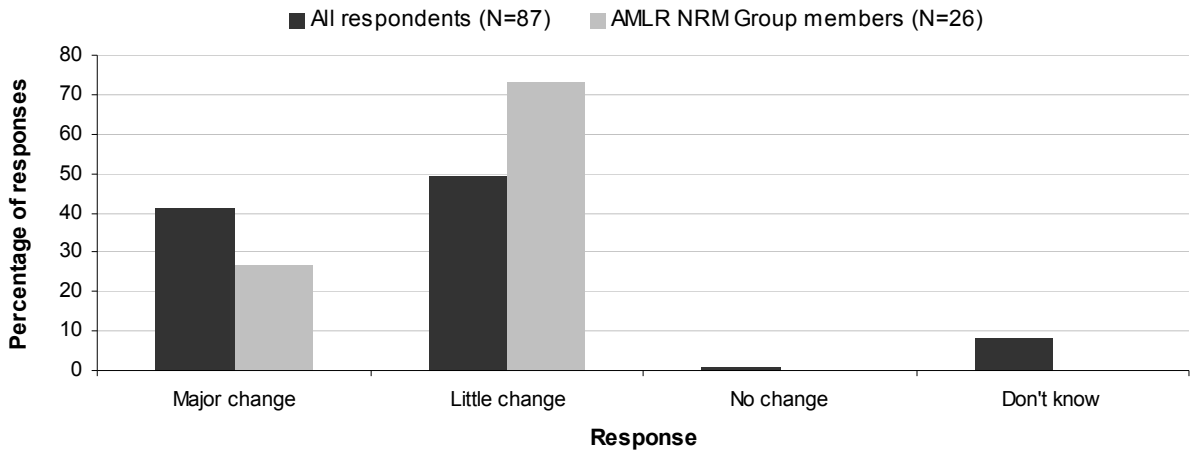


Figure 3. Respondents' perceptions of whether climate has changed within the last 25 years

A substantial percentage of respondents perceived that day temperatures were becoming warmer, such that responses to Question 2b (Fig. 4) can be grouped into:

- Group V – those who perceived a warming in day temperatures (N=59).
- Group VI – others (N=28).

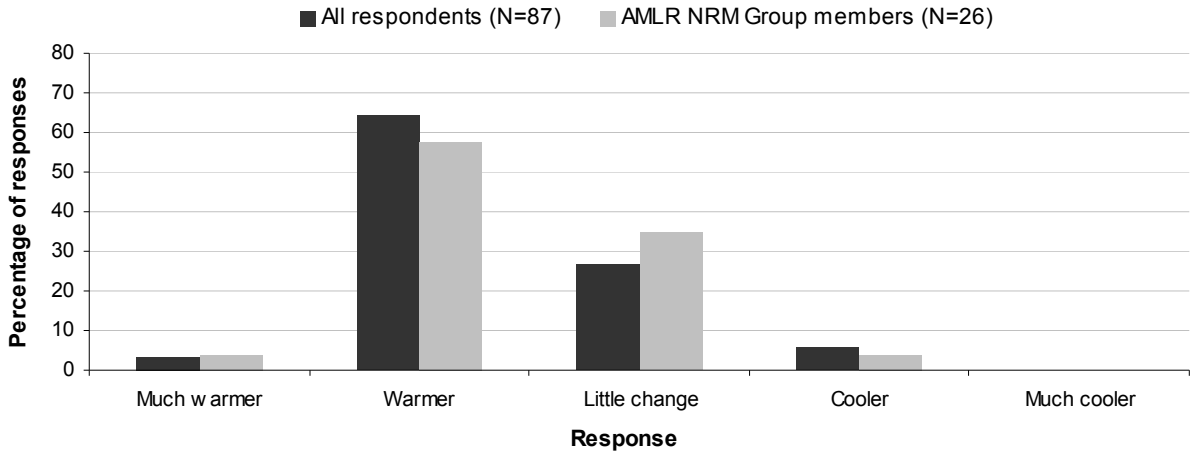


Figure 4. Respondents' perceptions of changes (if any) in day temperatures within the last 25 years

The perception of change in night temperatures was not as clear (Fig. 5), with a relatively even distribution of those who suggest that nights are cooler and those who suggest that they are becoming warmer.

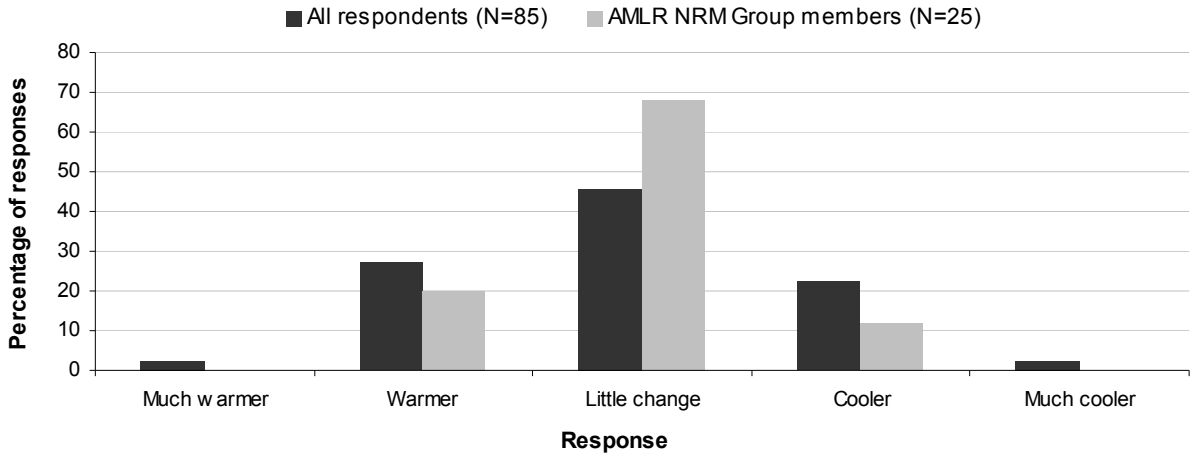


Figure 5. Respondents' perceptions of changes (if any) in night temperatures within the last 25 years

A large majority of stakeholders perceived that annual rainfall totals had declined, such that responses to Question 2d (Fig. 6) can be grouped into:

- Group III – those who perceived a drying trend (N=59).
- Group IV – others (N=28).

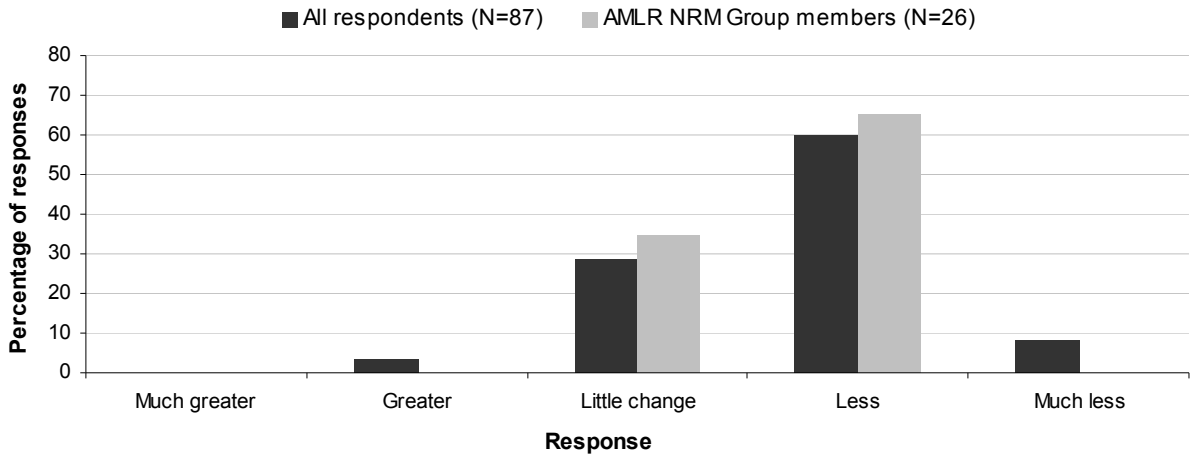


Figure 6. Respondents' perceptions of changes (if any) in annual rainfall totals within the last 25 years

A large percentage of respondents perceived an increase in annual rainfall variability, such that responses to Question 2e (Fig. 7) can be grouped into:

- Group VII – those who perceived greater variability in rainfall (N=71).
- Group VIII – others (N=15).

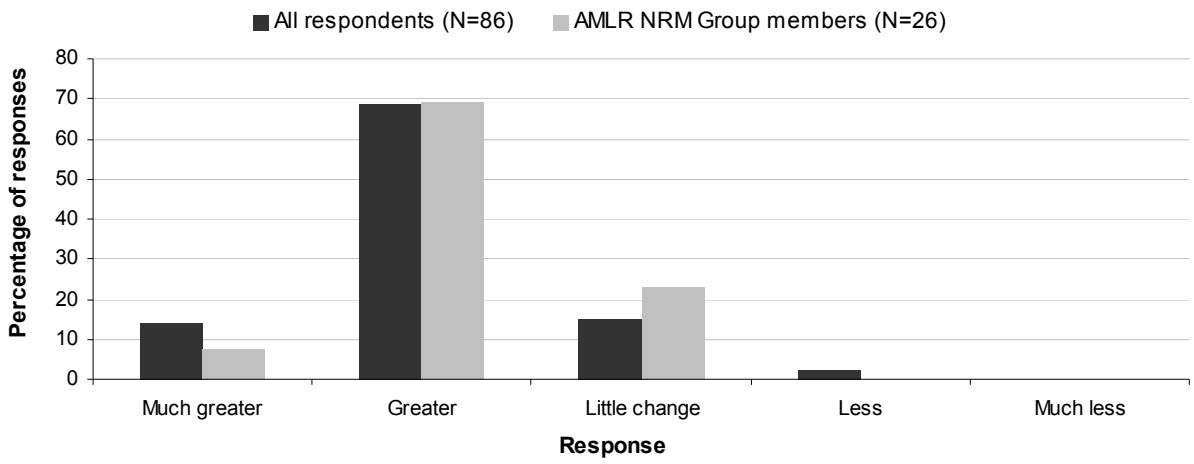


Figure 7. Respondents' perceptions of changes (if any) in annual rainfall variability within the last 25 years

In reality, the AMLR encompasses a variety of biogeographical areas, across which actual, perceived or predicted changes in climate change are not expected to occur uniformly. Perceptions of climate change (described in this section) can be contrasted against spatially interpolated monthly climate records for different areas within the AMLR as shown in Appendix 5.

3.1.4 PERCEPTION OF CURRENT CLIMATE CHANGE AND ITS IMPORTANCE

In Question 1, Group I (those who perceived major climate change) rated the importance of climate change significantly higher than Group II (others) (Wilcoxon Rank Sum Test, $p<0.001$). The mean rating (refer to Fig. 2) for Group I was 5.53 (N=36), while the mean rating for Group II was 4.86 (N=51).

Similarly, Group I rated the importance of drought (which is predicted to increase in frequency and intensity under climate change modelling) significantly higher than Group II (Wilcoxon Rank Sum Test, $p<0.01$). The mean rating for Group I was 5.28 (N=36), while the mean rating for Group II was 4.62 (N=50).

Many respondents perceived drying trends in rainfall, warming of day temperatures and/or increased variability in rainfall over the last 25 years, but may not necessarily have considered that these trends were an indication of a change in climate. An exploration of the relationships between Groups I–VIII (i.e. divisions in stakeholders based on their perceptions of recent climate change) will reveal some of these issues in greater detail.

Perceptions of a drying trend

Around two thirds (59/87) of the respondents perceived a drying trend over the past 25 years (see Table 5). However, there was no significant association with that perception and a belief that climate had changed.

Table 5. Respondents' perceptions of climate change and annual rainfall trends

	Group III (less rain)	Group IV (little change)	Totals
Group I (major climate change)	28	8	36 (31%)
Group II (little or no climate change)	31	20	51 (59%)
Totals	**59 (68%)**	**28 (32%)**	**87 (100%)**

There was no statistically significant relationship between perceptions of climate change (row classifying variable I–II) and perceptions of a drying trend (column classifying variable III–IV) (Chi-square, N=87, H=2.79, p>0.05).

Grouped responses to Question 1 were consistent with this lack of relationship. No statistically significant difference was found between Group III (those who perceived a drying trend) and Group IV (little change in rainfall) in their rating of the importance of climate change (Wilcoxon Rank Sum Test, p>0.05).

Perceptions of a warming trend

In contrast to the perceptions relating to rainfall, while again around two thirds (59/87) of respondents also perceived a warming trend, this was reflected in perceptions of climate change (Table 6).

In this case, there was a significant relationship between perceptions of climate change (row classifying variable I–II) and perceptions of a warming trend (column classifying variable V–VI) (Chi-square, N=87, H=12.49, p<0.001). This is evident by the noticeably high frequency of respondents who perceived both a warming trend and major climate change (N=32).

This relationship is supported by the grouped responses to Question 1. Group V (those who perceived a warming trend) rated the importance of climate change higher than Group VI (no warming trend) (Wilcoxon Rank Sum Test, p<0.05). The mean rating for Group V was 5.27 (N=59), while the mean rating for Group VI was 4.86 (N=28).

Table 6. Respondents' perceptions of climate change and daily temperature trends

	Group V (warming)	Group VI (no warming)	Totals
Group I (major climate change)	32	4	36 (41%)
Group II (little or no climate change)	27	24	51 (59%)
Totals	**59 (68%)**	**28 (32%)**	**87 (100%)**

Perceptions of increased rainfall variability

There was a strong perception among the survey group (N=71) that rainfall variability had increased within the last 25 years (Table 7). However, this was not significantly linked to a perception of climate change.

No statistically significant relationship was found between perceptions of climate change (row classifying variable I–II) and perceptions of rainfall variability (column classifying variable VII–VIII) (Chi-square, N=86, H=3.57, p>0.05).

Table 7. Respondents' perceptions of climate change and rainfall variability

	Group VII (greater variability)	Group VIII (little change)	Totals
Group I (major climate change)	33	3	36 (42%)
Group II (little or no climate change)	38	12	50 (58%)
Totals	**71 (83%)**	**15 (17%)**	**86 (100%)**

This lack of relationship is consistent with grouped responses to Question 1, where no statistically significant difference was found between Group VII (those who perceived greater rainfall variability) and Group VIII (little change) in their rating of the importance of climate change (Wilcoxon Rank Sum Test, $p>0.05$).

Rainfall annual totals and rainfall variability

While the survey group did not link rainfall variability or declining annual rainfall totals with climate change, they did strongly link the two rainfall variables (annual totals and variability) together (Table 8). A highly significant relationship was found between perceptions of declining rainfall (row classifying variable III–IV) and perceptions of increasing rainfall variability (column classifying variable VII–VIII) (Chi-square, N=86, H=18.62, $p<0.0001$).

Table 8. Respondents' perceptions of rainfall annual totals and variability

	Group VII (greater variability)	Group VIII (little change)	Totals
Group III (less rain)	55	3	58 (67%)
Group IV (little change)	16	12	28 (33%)
Totals	**71 (83%)**	**15 (17%)**	**86 (100%)**

3.1.5 WHAT DO THESE RESULTS MEAN?

These results suggest that people are more likely to make links between warming temperatures and climate change, but not attribute perceived changes in rainfall amounts and variability to climate change. Despite the widely perceived importance of water resources and the perceived importance of potential impacts to water resources under climate change modelling predictions (see also the responses to Question 3 and 4), there is a poor perceived connection between the notions of declining rainfall and increasing variability in rainfall—and climate change.

These responses may suggest that while respondents accept that the primary impact of climate change will be warming, the broader impacts on climatic patterns are less clear. This is also reflected in the scientific projections for climate change at a regional level, where there is significant confidence of a net warming trend for South Australia (see Suppiah et al. 2006), but the impacts on future rainfall are less certain. That said, in the short-term the risks of a drying trend are potentially greater than a warming trend due to the likely immediate impacts on water resources for Adelaide, agriculture and sustainable NRM systems.

There is increasing evidence from around the globe that it is regions with Mediterranean climatic systems, such as the AMLR and south-west Western Australia where there is greatest confidence that future drying trends will result from an enhanced greenhouse effect

(Houghton et al. 2001; McInnes et al. 2003; EEA 2006). In fact, since the 1970s warming and drying climatic trends have been experienced in several Mediterranean climatic regions including southern Europe, western North America, the South African Cape region and south-west Western Australia (Smith et al. 2000; Cayan et al. 2001; Dünkeloh & Jacobeit 2003; Feidas, Makrogiannis & Bora-senta 2004; Maheras et al. 2004; Piccarreta, Capolongo & Boenzi 2004).

Interestingly, there have been more significant night frosts or cooler nights than average across large areas of Australia in recent years, often associated with major anticyclones (high pressure weather systems). The same high pressure conditions which limit atmospheric uplift or the movement of moisture laden air onto land, and therefore reduce rainfall activity, may also be leading to clear, cold nights in many areas.

The coincidence of high risk and uncertain science triggers in relation to future rainfall, suggests that there will be an increasing requirement to manage systems that are highly dependent on rainfall amounts and timing with caution. As a technical advisor from the South Australian Wine Industry Association noted (2007, pers. comm., 1 February):

> 'There are major problems with the information. The focus of the information is on possible temperature changes rather than water and rainfall, which could also be limiting. There are overly simplistic, convenient aids to thinking, such as the wines of the Barossa will shift to Loxton, which is not always helpful. Already we are seeing the situation where if people's dams are drying up year after year then we are going to need to adjust.'

The results here could suggest that the broader NRM community may benefit from a raised awareness of climate change issues as they relate to their specific management issues. The focus of the awareness raising would be that climate change is predicted to involve changes in a range of climate and environmental variables, not just temperature increases.

3.2 QUESTIONS 2F–G—INDICATORS OF CLIMATE CHANGE

Respondents were asked if they had noticed changes in climate in their respective regions in the last 25 years, and what indications in the landscape, production systems or ecological systems had lead to their conclusions. These responses are summarised in Table 9. It is recognised that there is a lot of information presented in the table, but some of this detail is very interesting as it suggests some innovative ideas that would be lost in a summary of responses.

A large number of respondents noticed a change in rainfall and seasonal conditions, particularly in the generating mechanism and timing of the onset of winter rains. This suggests the emergence of a less predictable winter growing season. Dry conditions associated with the recent prolonged drought also figure highly in respondents' perceptions and there is concern in the community that the frequency and duration of such events may increase.

It may be possible for the respondents' perceptions of climate change indicators to assist in the guidance of future research and monitoring and evaluation activities, in particular within the AMLR in relation to climate change. While, many of the immediate climatic indicators are

Table 9. Respondents' perceptions of climate change indicators

Indicators	Examples	All respondents (N=87)		AMLR NRM Group members (N=26)	
		No.	*%*	*No.*	*%*
Climatic indicators					
Changed rainfall and seasonal patterns	• Changed rainfall generation and seasonal variability. • Seasons coming later. • Less southern frontal systems. • More tropical thunderstorms. • Less winter rain and more summer rain.	46	53%	13	59%
Drier weather conditions	• More drought. • Less reliable rainfall. • More false breaks.	18	21%	5	23%
Warmer weather patterns	• Warmer summers. • More days over 35 °C. • Increase in frequency and duration of heat waves. • Warmer winter day temperatures.	17	20%	1	5%
Colder weather patterns	• More frosts. • Colder winters.	12	14%	3	14%
Solar radiation	• Greater effects of UV radiation. • More clear skies.	6	7%	1	5%
Increase in humidity		5	6%	3	14%
Unseasonal wind strength and patterns		5	6%	–	–
Landscape/production/ecological indicators					
Drier landscapes	• Reduced, unreliable or highly variable stream flows and dam levels. • Drying and degradation of topsoil. • Increased erosion when rains come (due to less cover on soil)—erosion exacerbated by more intense rainfall events. • Soil fissures and structural damage in urban areas (e.g. bursting water mains, cracking buildings). • Less soaking rains to recharge aquifers.	27	31%	6	27%
Impacts to native flora/fauna/ecosystems	• Increased vegetation stress (canopy thinning, pest and disease). • Unseasonal flowering. • Poor natural regeneration. • Changes in breeding patterns and activity of fauna.	18	21%	5	23%

Indicators	Examples	All respondents (N=87)		AMLR NRM Group members (N=26)	
		No.	*%*	*No.*	*%*
Adverse impacts to primary production	• Reduced earthworm activity. • Local birds being displaced by birds coming from northern (drier) areas. • Reduced health and numbers of kangaroos. • Lower yields. • Unseasonal flowering of fruit trees. • Earlier grape bud burst. • Early harvest/shortening of growing season. • Non-emergence. • Later cropping. • Less feed for stock.	13	15%	5	23%
Weeds	• Changing distribution or activity of opportunistic weed species.	5	6%	4	18%
Bushfires	• More intense and frequent bushfires.	2	2%	1	5%
Tides	• Higher tides at the beach.	2	2%	1	5%
Estuaries/beaches	• Greater build up of sand at local beach due to reduced wave action, from reduced winter frontal systems. • Local river estuary silting up.	2	2%	–	–
Home environment	• Greater use of air conditioner due to warmer weather.	1	1%	–	–

being examined or have been analysed in the past, many of the potential indicators of change within natural and anthropogenic systems could provide useful guides to the rate and extent of change in the future.

3.3 PERCEPTIONS OF FUTURE CLIMATE CHANGE IMPACTS ON NRM

3.3.1 QUESTIONS 3 AND 4—RATING THE IMPACTS OF CLIMATE CHANGE ON NRM

Average ratings of the importance of a range of projected climate change impacts are displayed in Figures 8 and 9. Figure 8 compares perceptions of the AMLR NRM Group members to all respondents, and again shows good consistency between AMLR members and the broader survey group. Figure 9 shows data grouped according to regional locations within the AMLR (refer to regional map, Fig. 1).

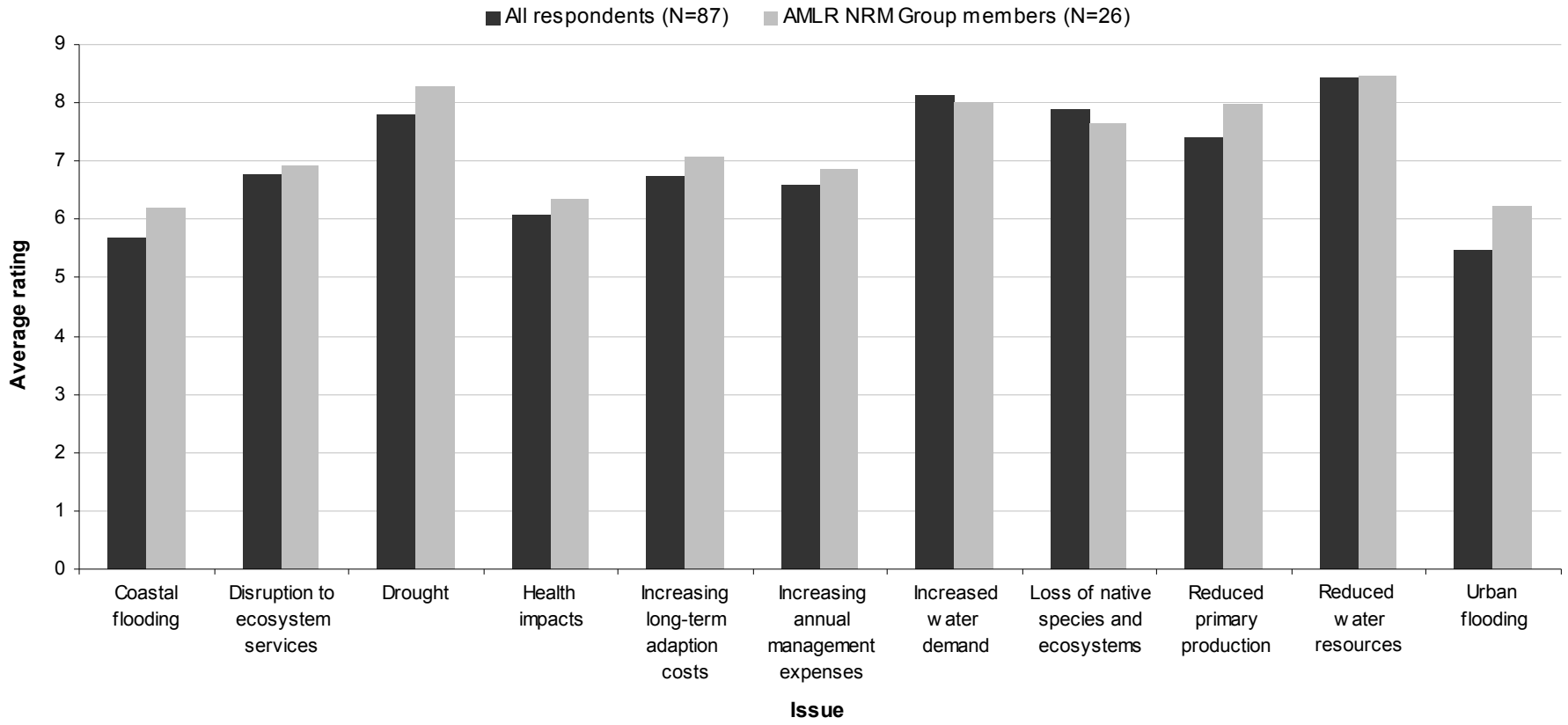


Figure 8. Respondents' comparative rating of the importance of issues arising from projected climate change (rating 1 = no importance, rating 10 = extreme importance)

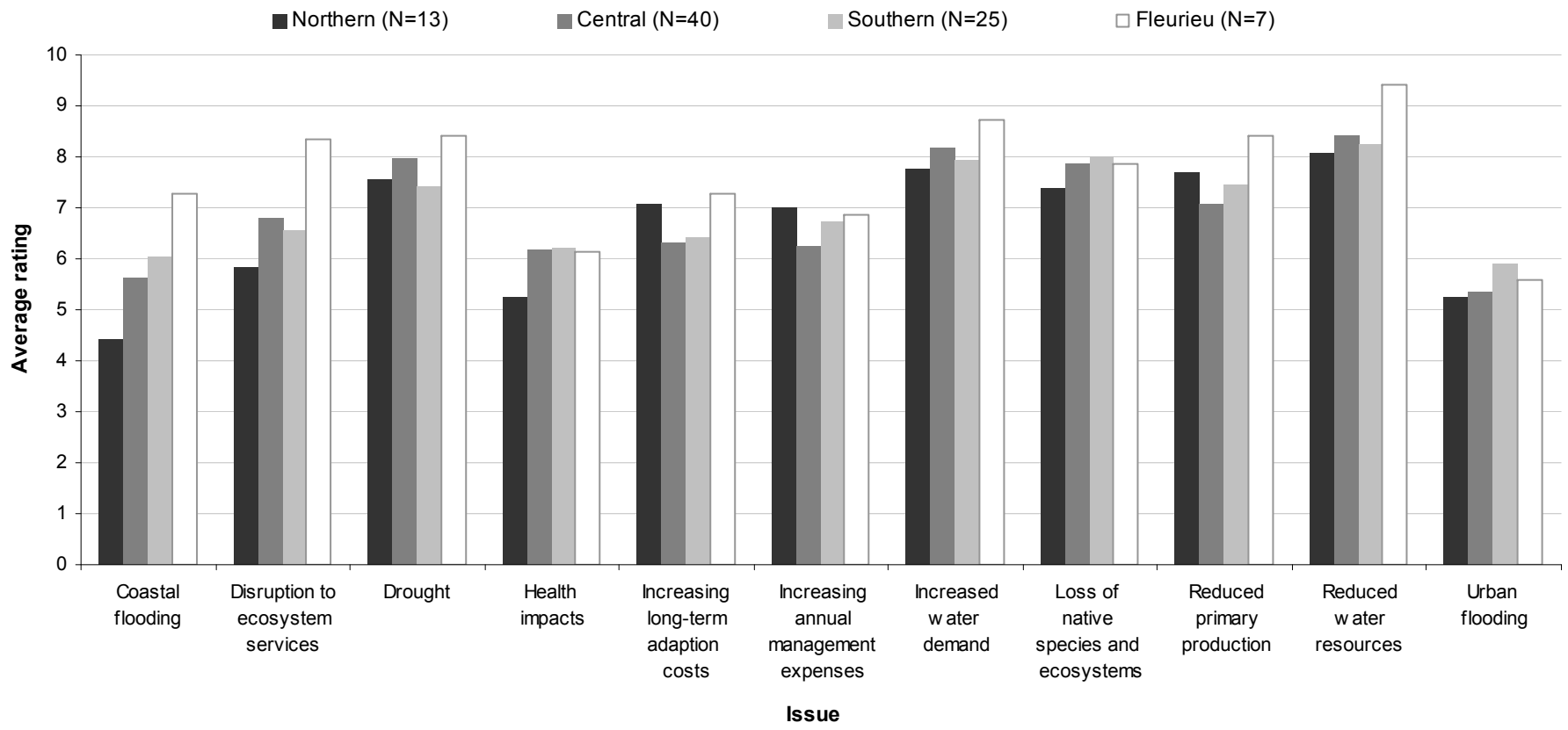


Figure 9. Respondents' comparative rating of the importance of issues arising from projected climate change, grouped by regional location (rating 1 = no importance, rating 10 = extreme importance)

It should be noted that there was some confusion among some respondents regarding the term ‘ecosystem services’ or ‘environmental services’ (which was also used on some surveys). Some respondents understood this to mean services that NRM workers would provide for environmental benefit, whereas it was intended to mean services that are provided by the environment for ecosystem functioning and human benefit (e.g. provision of clean water, pollination of plants, etc.). Once again, the limitations of the methodology (see section 2.1) must be taken into account and the results should be read with the knowledge that stakeholders would have been influenced by the associated presentation.

The respondents noted that drought, reduced water resources and increased water demand would be the most important issues, as well as the sustainable management of primary production and native ecosystems. As represented in Figure 9, the relative importance of different climate change impacts on NRM was rated fairly consistently across the sub-regions, regardless of location within the AMLR. Although there was a smaller subset from the Fleurieu who responded and while there is unlikely to be a statistical significance, this sub-region ranked the importance of climate change higher across most issues, perhaps reflecting the more rural nature of the area.

Question 4 asked respondents to identify their most important NRM issue (or system) at risk from projected climate change impacts and assess the vulnerability of this issue/system. As such, it aimed to provide more detail to the information obtained during Question 3. Question 4 was also designed to stimulate respondents’ thinking about potential impacts, adaptive options, and, where possible, ways to reduce the vulnerability of key NRM issues.

Figure 10 summarises respondents’ most important NRM issues at risk from projected climate change impacts by 2030 (Question 4). Adaptation options to reduce the vulnerability of key NRM issues/systems are summarised in results from Questions 5, 6 and 8 (in the next section).

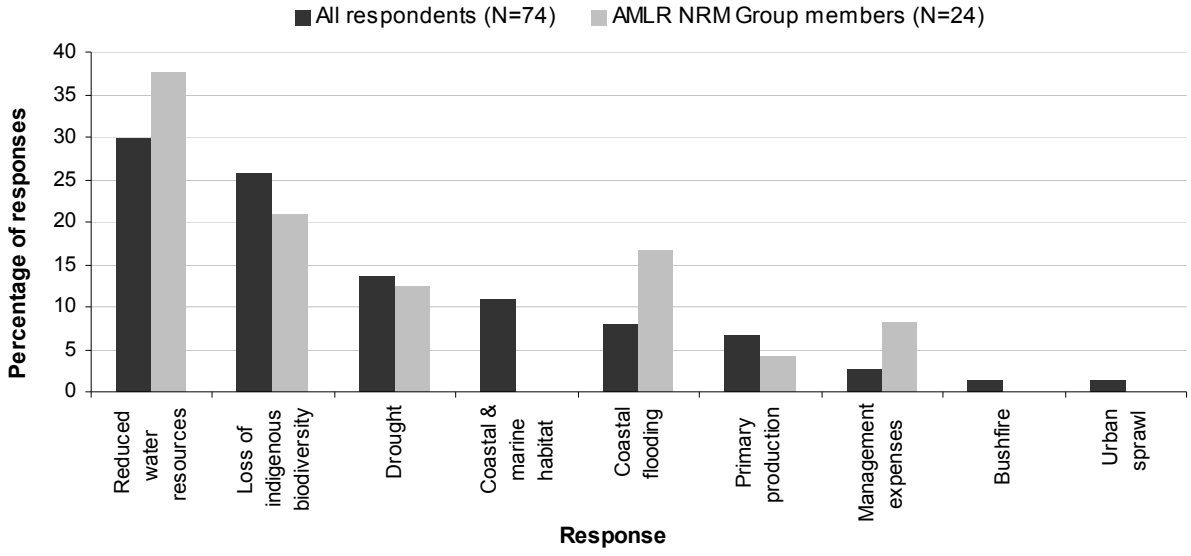


Figure 10. Respondents’ most important NRM issue at risk from projected climate change impacts by 2030

Across all respondents, the key NRM issues at risk from climate change are perceived as (starting from most important):

- reduced water resources
- loss of indigenous biodiversity
- drought
- coastal and marine habitat and coastal flooding
- primary production.

3.3.2 WHAT DO THESE RESULTS MEAN?

Climate change will not impact all sectors of NRM evenly, and it is perceived by respondents that the key sectors that will be impacted are water and biodiversity management, with primary production and coastal issues also ranking highly. These issues were also identified as important vulnerabilities in the integrated assessment undertaken for the region (Bardsley 2006), although it was noted that those systems that are managed more intensively, such as water and agricultural systems, are much more likely to have substantial adaptive capacities within the highly developed NRM sector. It is important to examine this issue further in relation to water resources as the majority of respondents indicated that this would be the key NRM issue in relation to climate change for the AMLR (Figs 8, 10). This was also acknowledged in interviews, for example the DWLBC Program Manager for Surface Water in the AMLR stated (2006, pers. comm., 12 July):

> 'There are key issues for Adelaide's water supply. For example, the central water resource is already fully allocated. There is a risk that climate change will lead to greater variability—more drought and more flood, which will challenge the way we hold and provide water.'

However, it can also be noted that there are significant opportunities for adaptation in the AMLR that will significantly reduce the risk to water resources. A key component of that relationship is how the urban centre of Adelaide relates to the water resources available through the Murray–Darling Basin. South Australian residents saw in 2007 that when water resources became scarce it is the lower value end users, particularly horticulture, which suffered most due to reductions in water availability. In contrast the urban centres are likely to be prioritised by governments. The DWLBC Program Manager for Surface Water in the AMLR went on to say that (2006, pers. comm., 12 July):

> 'We will always be able to buy more water from the Murray and actually, we have someone from SA Water looking at the technical issues associated with that now, such as pumping more and the pipe capacities. We'll deal with the technical issues and let the politicians sort out the politics.
>
> 'Adelaide's water supply systems are flexible and interchangeable, so there is significant adaptive capacity. At any one time there is three months storage sitting in the reservoirs, so we are very secure. That said, there is a base load demand that is driven by population and as the numbers increase and runoff decreases non-linearly in comparison to rainfall, we will come under increasing pressure. In particular, the capacity of pipes to provide water will plateau at some stage and there will need to be significant infrastructure development.'

Of greatest vulnerability here may be the direct water users such as horticulturalists in the Adelaide Hills. Such users may increasingly see significant limitations on their water resource availability, which will mean that they will need to manage their systems so that they are more resilient during drier periods. A key issue raised by numerous stakeholders, including the AMLR NRM Board's Director of Policy and Planning, who stated (2006, pers. comm., 14 August):

> 'There is a specific issue for groundwater management which could be picked up on. If we changed from a method of allocation that was based on a volumetric approach, as we do now, to a share system, which allocates a percentage of the available water resource, the risk could be reduced. In this manner, the NRM Board's risk is transferred to individual users and will act to stimulate improved irrigation efficiencies and flexibilities in the system.'

The South Australian Apple and Pear Growers Association's president noted that (2006, pers. comm., 9 October):

> 'Changing varieties is very difficult, partly because the projections of future change are uncertain—do we go for early or late varieties.'

A horticultural consultant from Rural Solutions SA also noted that (2006, pers. comm., 16 November):

> 'Water is the big one, really horticultural crops equal water. The last five years of work indicate that apple growers don't have enough water now. Already growers are 92–98% efficient, but even then many don't have enough water. Any reduction in the resource will have big impacts on the orchard industry, but if there is significant change the industry may not be there at all.'

The type of management response for intensively managed systems outlined above contrasts strongly with adaptation options available for the second most recognised climate change issue for NRM, which is biodiversity conservation. In ecological systems, human intervention fundamentally alters the systems themselves. The approach will need to examine methods for supporting the natural inherent capacities to adapt to change, such as supporting greater linkages across the landscape. The Department for Enviornment and Heritage (DEH) Manager of Biodiversity Conservation for the AMLR stated that (2006, pers. comm., 15 August):

> 'Priority setting will be a necessary response, and that is where the *NatureLinks* principles are very important. We need to look at building more resilience into the systems, so the general principles of threat abatement and resilience in conservation become more important.
>
> 'Identifying key vulnerabilities is important to set priorities. Water-dependent ecosystems require a sustained period of wetter conditions, otherwise performance will drop off, but most will survive a single dry season. Many species need specific conditions for reproduction, for example. There are no phenological studies explicitly examining the implications of climate change, although these could be done. For example, we have ten years of data on phenology of the Fleurieu Peninsula Swamps which could be examined.'

It is worth examining the example of biodiversity conservation and the *NatureLinks* policy and planning response in some detail (see Section 3.4.4), given the uncertainty of climate

change, appropriate management responses that can build broader resilience into the system should be emphasised.

3.4 PERCEPTIONS OF OPTIONS TO RESPOND TO CLIMATE CHANGE

3.4.1 QUESTIONS 5, 6 AND 8—SUGGESTED RESPONSES TO CLIMATE CHANGE

Respondents provided a broad range of suggestions and practical examples for adaptive responses to climate change. Many of these examples are listed as they are quite instructive on the potential scope for society to respond to climate change and a range of other sustainability issues.

Even though the question related to opportunities to better adapt to climate change, many suggestions were also provided for greenhouse gas mitigation (in contrast to adaptive or adaptation responses). Further comments provided by respondents built towards an overwhelming message that the survey group was looking for greater leadership, education, policy intervention and urgent action on climate change issues. These latter responses are also summarised.

Therefore, respondents' suggestions are grouped in the following manner:

- adaptation responses (Table 10):
  - to reduced water availability (rural and urban)
  - for NRM/revegetation/catchment management
  - for primary production
- mitigation responses (Table 11):
  - energy
  - home and building construction
  - transport
  - waste/resource recovery
- wider societal responses (Table 12):
  - education
  - policy and planning
  - consultation
  - leadership and action.

Once again, there is a considerable amount of information provided in these tables, but some of the unique or unusual suggestions could be of greatest interest to readers as they search for opportunities to respond to climate change. Therefore, we considered the detail in the table to be of significant value to the report.

Table 10. Respondents' suggestions for NRM adaptation responses to climate change

Response type	Examples	All respondents (N=87)	
		No.	*%*
Responses to reduced water availability (urban and rural)			
Increased water harvesting	• More rainwater tanks. • Capture and treat stormwater. • Aquifer storage and recovery. • Engineered structures in urban and rural landscape (swales, holding basins, flood control dams, permeable pavements and grassy infiltration zones). • Slow and catch extreme rainfall events. • Allow greater groundwater recharge, instead of losing stormwater, and causing (fresh) stormwater pollution of the marine coastal environment.	32	37%
Increased efficiency of water use	• Water-wise plants for gardens, including natives. • Less watering of lawns/reduction in lawns. • Improved irrigation technology (drip, computerised). • Mulch, shade plants. • Increase organic content (water holding capacity) of soils. • Reduced flow shower heads and shorter showers. • More efficient appliances. • Waterless car washing. • Fix leaks.	27	31%
Increased water reuse and recycling	• At all scales (reclaim and treat effluent/waste water)—within industry, urban areas, in homes/gardens.	23	26%
Mechanisms to encourage less water use	• Incentives schemes, market instruments, higher pricing/tiered pricing of water/water taxes. • Legislation to regulate/restrict mains water use. • Greater monitoring/regulation of domestic bore water use. • Education. • Better designed systems.	13	15%
Desalination		4	5%
Water allocation planning	• Water allocation plans for surface and groundwater. • Inventory assessment. • Monitor and model of climate and water resource use. • Adaptive management of resources to ensure sustainable use, under changing climatic conditions.	3	3%
Responses for NRM/revegetation/catchment management			
Recreate healthy habitat	• Protect, buffer, restore, re-establish and link habitat. • Recreate diverse, healthy, connected habitats. • Try to restore biodiversity, enabling some species/ecosystems to move as conditions change.	15	17%
Local indigenous species	• Greater focus on local indigenous species in urban and rural landscapes which are more suited to wildlife—in	6	7%

Response type	Examples	All respondents (N=87)	
		No.	*%*
	preference to exotics or non-local natives.		
	• Choose local natives, which are adapted to drier conditions.		
	• Factor in need to water during establishment phase.		
Weeds	• Monitor and manage weeds and other exotic pests.	4	5%
	• Minimise future threats.		
	• Weeds are opportunistic and are likely to benefit from climate change (if not controlled) to the detriment of local species.		
Seed sources for revegetation (*different schools of thought here*)	• Expand areas where seed sources for revegetation are collected (so plantings suited to greater variability or drier conditions).	2	2%
	versus		
	• Greater debate required on widening areas for seed sources—using non-local species, or seed from more arid areas may place additional stress on local ecosystems.		
Funding	• Improved funding for NRM projects.	2	2%
	• Fund for landholder efforts in assisting with ecosystem services (e.g. water quality, habitat).		
NRM legislation	• Enforce NRM legislation, including tougher penalties for breaches.	2	2%
	• Make watercourse protection measures mandatory.		
Erosion	• More measures to reduce erosion from intense rainfall events or summer rains.	1	1%
Marine protected areas	• More marine protected areas.	1	1%
Landholder engagement	• Increased efforts to engage landholders with NRM.	1	1%
Environmental flows	• Improve environmental flows.	1	1%
Catchment management	• Focus on sub-catchment level management, to give people a better understanding of impacts and what improvements can be made.	1	1%
Responses for primary production			
Adopt <u>new enterprises</u> that are more water and energy efficient	• Adopt native, drought-tolerant flora and fauna species in primary production.	20	23%
	• Utilise perennial plant species, including pastures and agroforestry.		
	• Plant crops more suited to drier climates.		
	• Seek alternatives to crops that require flood irrigation (e.g. cotton, rice); industrial hemp instead of cotton (this example reflects issues beyond the scope of the AMLR region—see footnote [1] on next page).		
Improve efficiency of water and energy use in <u>existing enterprises</u>	• Adopt efficient irrigation practices.	10	11%
	• Market initiatives (e.g. on-farm labelling) to promote efficient water and energy use.		
	• Better property planning.		
	• Creating microclimates on the property.		

Response type	Examples	All respondents (N=87)	
		No.	*%*
	• Covers for above-ground water storages.		
Diversify farm enterprises	• Hedge bets, to remain productive under uncertain climate futures.	10	11%
Research and extension	• Research to evaluate new agricultural industries/species/ varieties suited to changed climatic conditions (e.g. perennial species to utilise increased summer rains, different sheep breeds to handle tougher conditions, species adapted to more extreme weather and conditions).	6	7%
	• Extension to raise awareness and adoption of new systems.		
Local food production	• Reduce reliance on fossil fuels for transport and fertilisers/pesticides within food production systems.	4	5%
	• Develop permaculture production systems/organic systems/small intensive farming systems.		
	• Include in urban landscapes.		
Incentives for change	• Incentives to make adaptation changes, e.g. to swap intensive horticulture for less water using crops, to get people off farms in marginal country, to convert to biodiversity conservation.	4	5%
Only grow appropriate crops	• Only grow crops appropriate to Australia (not rice or cotton).	3	3%
	• Import rice from regions with appropriate climates for producing it (not the driest continent).[1]		
Full costs to consumers	• Accurately cost primary production impacts on natural resources and pass this onto consumers.	2	2%
Shift to higher value crops	• Greater economic value for use of water.	1	1%
Contingency planning/ risk mitigation	• Greater storages of supplementary feed.	1	1%
	• Lower stocking rates.		
	• Rest paddocks to ensure ground cover to prevent erosion when rains come.		
Controlled atmosphere systems	• Adopt hydroponic production systems with a controlled atmosphere (sheltered from natural climate).	1	1%
Economic assistance	• Drought assistance to farmers.	1	1%

1. These examples reflect issues beyond the scope of the AMLR region, but impact upon the AMLR via water transfers from the Murray–Darling Basin.

In the following table (Table 11) respondents offer a variety of options for reducing greenhouse gas emissions. Strategies such as these will be crucial in mitigating the full and dramatic potential of unabated climate change. These responses were forwarded by stakeholders as key components of a broader adaptation response by society. In other words, it was rarely perceived by respondents that it would simply be enough to adapt to change at the local or regional NRM level. Numerous respondents infer the need to minimise climate change impacts by reducing greenhouse gases in the atmosphere as a component of a broader societal framework 'adaptation' response.

Table 11. Respondents' suggestions for greenhouse gas mitigation responses to climate change

Response type	Examples	All respondents (N=87)	
		No.	*%*
Energy			
Adopt greener energy options	• Greater adoption/investment in environmentally friendly energy options. • Renewables, e.g. wind power, grid and home solar power, signing up to 'green power', home solar hot water. • Alternatives, e.g. natural gas. • Bring in carbon tax. • More incentives/rebates. • Reduce reliance on fossil fuels.	18	21%
Reduce energy consumption		3	3%
Research nuclear power		1	1%
Home and building construction			
Design new and retrofit old buildings for energy and water conservation	• Design new homes and buildings and retrofit old for energy and water conservation. • Include elements of passive solar design. • Insulation, double glazing, reflective surfaces, natural lighting. • Solar hot water systems, solar photo-voltaic systems, composting toilets. • Use local materials.	22	25%
Incentives	• Offer greater incentives for home builders and businesses to adopt green energy and water conscious building designs and gardens.	1	1%
Urban housing density	• Increase urban housing density by going up and keep significant garden space available for production of food locally.	1	1%
Shared resources	• More communal areas/housing to share costs of heating, cooling and entertainment.	1	1%
Means based approach	• Require asset-rich landholders to have solar photovoltaic systems installed.	1	1%
Transport			
Adopt greener transport options	• Adopt more efficient, environmentally friendly transport options, e.g. use renewable fuels, hybrid cars, biofuels, smaller capacity engines, ride a bike, walk, car pool or take public transport. • Reduced use of fossil fuels. • Increased development/investment in public transport.	20	23%
Transport policy	• Introduce controls on vehicle use. • Introduce policies to promote and/or impose public transport use.	2	2%
Increase transport costs	• Increase costs of car registration and fuel.	1	1%
Waste/resource recovery			
Waste recycling	• Less wastage, better recycling.	3	3%

It is worth noting that some actions will provide both mitigation and adaptation measures. For example, future enterprises needing to adapt to more variable or extreme climatic conditions may aim to adopt more efficient processes which increase profitability while also reducing greenhouse gas emissions. Some examples of such actions would include improved transport management, improved fodder conversion to animal protein, and reduced methane emissions from livestock.

In Table 12, respondents offer some further suggestions for tackling climate change. Key issues raised here are changing behaviour and leadership. Education, policy and planning and a greater scrutiny of our consumer lifestyles were all suggested as a means to motivate more sustainable practices. A significant number of respondents demanded more pro-active leadership to tackle the climate change problem.

Respondents' submissions summarised in this table reflect perceptions of the importance of both individual and collective ownership of the climate change issue, and the high value of addressing climate change in a collaborative manner.

Table 12. Respondents' suggestions for wider societal responses in regards to climate change

Response type	Examples	All respondents (N=87)	
		No.	*%*
Education			
Increased awareness of potential impacts and timeframes	• Greater awareness of potential climate change impacts on all sectors (rural, urban, flora/fauna, primary production). • Greater awareness of time frames for climate change.	13	15%
Mitigation	• Greater awareness of responses to minimise impacts of climate change. • Better education programs for the wider community, e.g. energy efficiency, water efficiency, passive solar design.	8	9%
Adaptation	• Greater awareness of potential adaptation options.	6	7%
Policy and planning			
Incorporate climate change considerations into policy and planning	• Incorporate climate change issues/predictions/mitigation measures into plans, development policy and legislation. • Adjust building designs, development zoning, long-term flood mitigation planning, ecological restoration projects. • Introduce a carbon tax.	16	18%
Community behavioural change	• Behaviour change required to reduce consumption of energy and resources. • Abandon paradigm of exponential growth in consumption, with its obvious links to greater climate/environmental impacts and resource depletion. • Use a combination of options (education, economics/ pricing and legislation) to change behaviours.	7	8%
Relocate affected communities	• Relocate communities impacted or at high risk, e.g. coastal locations or at high risk of bushfires.	2	2%
Joint projects and information sharing	• Share information and resources. • Collaborate, form joint ventures or joint international projects to highlight the global nature of the problem and how we can work together for a positive outcome.	2	2%

Response type	Examples	All respondents (N=87)	
		No.	*%*
Consistent policy for urban and rural areas	• Questions raised over dichotomy of strict water restrictions in urban areas while inefficient irrigation practices can continue in rural areas, particularly interstate.	1	1%
Consultation			
Community consultation	• It is important to keep people onside to implement responses to climate change—adequate community education and consultation provided where tough policy changes are needed.	2	2%
Leadership and action			
Leadership and action	• Government leadership and positive, urgent action on climate change issues is required at local, state, national and global levels.	18	21%
Kyoto Protocol	• Comply with Kyoto Protocol; set deep cuts for carbon emissions; begin carbon trading scheme and carbon taxes.	5	6%

3.4.2 QUESTION 7—WILLINGNESS TO ACCEPT WIDER POLICY CHANGES TO ADAPT TO CLIMATE CHANGE

Figure 11 shows that the overwhelming majority of respondents indicated a willingness to accept wider policy changes to adapt to climate change, even if they would need to make personal sacrifices.

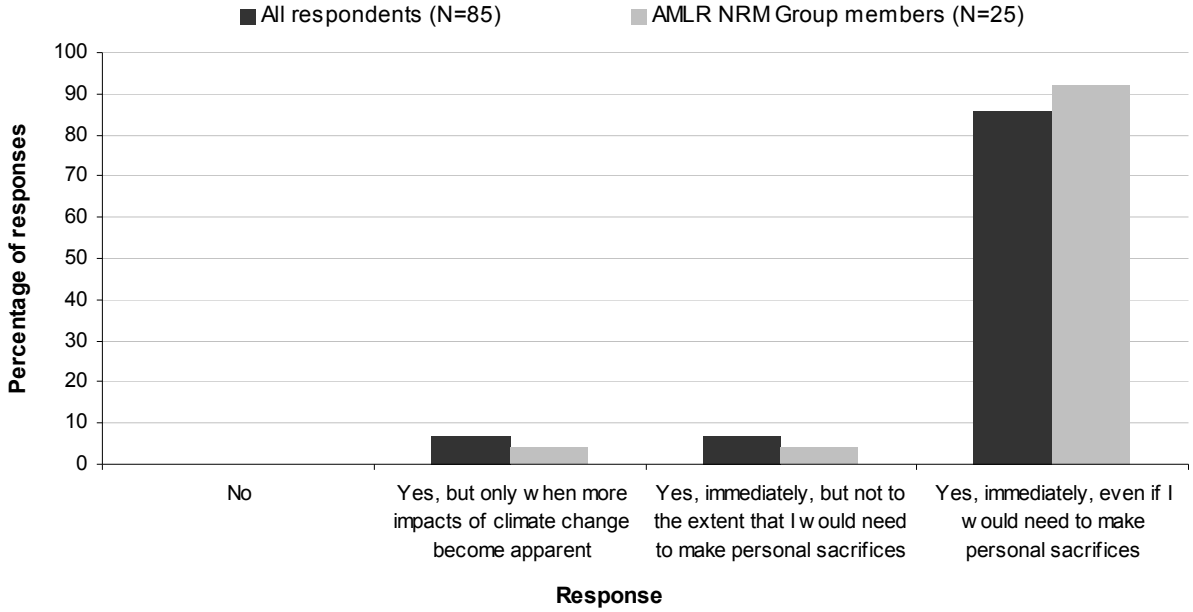


Figure 11. Respondents' willingness to accept wider policy changes to adapt to climate change

3.4.3 WHAT DO THESE RESULTS MEAN?

The results provide some very useful insights into a range of adaptation options available for sustainable NRM both within rural and urban areas, and particularly in response to reduced water availability and risks to primary production. The potential response ideas articulated here may be more or less applicable at local, catchment and regional scales, and therefore, will require detailed review of their applicability to any particular context. Regarding the ever-topical issue of water, respondents placed less emphasis on developing new sources such as desalination, and far greater emphasis on making existing water supplies go further, such as through increased stormwater harvesting, achieving higher water use efficiencies, recycling and reducing consumption.

Given the large number of suggestions provided by respondents to mitigate climate change, it could be argued that the sentiment expressed in Figure 11 would also extend to policy changes related to climate change mitigation. The NRM sector may need to articulate the observed and potential risks to their activities in some greater detail, to stimulate broader policy responses at a societal level.

It is interesting to note that while less than half of the respondents (41%, N=87) perceived that major climate change was occurring, the large majority (86%, N=85) thought that immediate wider policy changes should be implemented to adapt to climate change, even if it required them to make personal sacrifices. This may reflect a perception among the majority of respondents that climate change is a real and serious issue, deserving of an appropriate response, even if respondents had not yet personally seen evidence of climate change. It also suggests that it will not require a full understanding of the specific implications of future climate change to act to increase the resilience or flexibility of systems in the face of change, with implications for policy formulation.

It is worth examining in some detail one example of what policy to build resilience into NRM systems might look like in the South Australian context. One of the best examples is emerging in relation to landscape scale biodiversity conservation in the form of the *NatureLinks* strategy (DEH 2006a).

3.4.4 AN EXAMPLE OF RESILIENCE BUILDING: THE *NATURELINKS* ADAPTATION RESPONSE FOR BIODIVERSITY CONSERVATION

Biodiversity conservation will increasingly need to integrate climate change projections and impacts into planning and management processes. A biodiversity conservation planning response will need to recognise that species and ecosystems require time, space and resilience to adjust effectively to change. While specific studies that detail projected impacts of climate change on the biodiversity in South Australia are limited, we can work to improve the resilience of natural systems now. This is a major focus of the first integrated State NRM Plan, which has as its initial goal, 'landscape scale management that maintains healthy natural systems and is adaptive to climate change' (DWLBC 2006), and significant components of the draft South Australian Nature Conservation Strategy *No Species Loss* (DEH 2006b), and the Commonwealth Government's *National Biodiversity and Climate Change Action Plan* (Commonwealth of Australia 2004).

By emphasising the importance of long-term, landscape-level planning for biodiversity conservation in South Australia, the *NatureLinks* strategy could form a significant component of a comprehensive approach to respond to the types of impacts and uncertain future that are projected for biodiversity in the region (DEH 2006a). In particular, the four elements of the *NatureLinks* biodiversity conservation strategy attempt to outline how this could be achieved at a landscape scale for South Australian conditions (DEH 2006a). Responding directly to a range of emerging concerns, the elements of this strategy are summarised as follows:

1. Connect habitat to overcome fragmentation in the landscape.
2. Maintain ecological integrity to minimise impacts of changing disturbance regimes.
3. Improve linkages between biodiversity conservation and other NRM activities to minimise external pressures on intact ecosystems.
4. Work with the community to ensure ownership of the new levels of environmental risk amongst managers of both natural and anthropogenic landscapes.

Element 1 of *NatureLinks* is to improve the connectedness of ecosystems with the aim for South Australian landscapes of 'connected habitat facilitating ecological flows across the land and sea' (DEH 2006a). It generally holds that the most vulnerable biodiversity will be those species and systems with smaller populations or a smaller adaptive range, and this principle will be reinforced under climate change. The ability of genetic material, native species and ecosystems to remain within bioclimatic envelopes by migrating along climatic and geographical gradients will be a fundamental component of any adaptive response which aims to maintain their ecological integrity and genetic heterogeneity in an era of climate change (McIntyre & Hobbs 1999; Geertsema, Opdam & Kropff 2002). Seventeen percent of survey respondents noted the importance of recreating healthy habitats. A lecturer from the School of Earth and Environmental Sciences at The University of Adelaide noted that (2006, pers. comm., 9 October):

> 'Climate change will be a very big question for habitat restoration. We need to examine the complementarity of habitats because with climate change the guiding principle of local provenance might not hold. There will need to be an adaptive management focus, because we won't know what species will survive.'

The good news is that ecotones, or regions of mixed communities on the boundary of separate ecosystems, have been shown to migrate relatively swiftly across the landscape and, if linkages are maintained between natural systems, species and individuals of both plants and animals can be highly mobile (Allen & Breshears 1998; Harris et al. 2006). Unfortunately, outside of the reserve system, the majority of AMLR's remnant vegetation is present in fragmented areas, often below threshold sizes necessary for many species to sustain populations to ensure survival, and often in degraded states (Hughes 2003; Opdam & Wascher 2003). Many case studies indicate that such 'islands' of biodiversity are highly vulnerable to rapid environmental change (MacArthur & Wilson 2001). A critical part of implementing *NatureLinks* is to build on core areas of native vegetation in good condition by establishing buffers and connecting them across the landscape. Increased connectedness of natural ecosystems will both add to the capacity of species to migrate appropriately and assist managers to monitor any shifts as a result of a changing climate.

Element 2 of *NatureLinks* is to work for no species loss, with 'South Australia's species and ecological communities surviving and continuing to evolve' (DEH 2006a). Some

species/communities/ecosystems will have nowhere to move to, particularly those that have limited ranges or particular requirements that will be impacted by climate change, such as those relying on freshwater wetlands or higher altitude conditions. Actions relating to the most vulnerable systems or species, such as those currently adapted to the cooler, wetter climates of hilltops, gullies, shaded slopes or southern coastal limits, could require particular planning so that they remain as intact as possible (Hulme 2005). There was some disagreement in comments from stakeholders in relation to how such a climatic shift should influence the choice of source material for habitat restoration programs. Many species will still be able to survive and reproduce within their less-than-optimal range, but their competitive ability will be substantially reduced.

Element 3 of *NatureLinks* is to develop and maintain integration and partnerships by working to ensure that NRM across the landscape meets common biodiversity objectives (DEH 2006a). By embedding responses in the community, the efficacy of management can be enhanced, as many individuals and communities with the awareness and capacity to bring about change will respond within their own biophysical and socio-cultural contexts. In this manner, the diversity of management responses across and between regions will be enhanced, as will opportunities for further learning as social and environmental change impacts on southern Australia. For example, as five percent of respondents noted, biosecurity strategies, such as effective invasive species risk management assessments, may need to incorporate climate risk assessments that take into account climate change predictions (Hulme 2005; Bardsley & Edwards-Jones 2007). The availability and use of different potentially invasive species in industries, nurseries and gardens may need to be re-evaluated as climate change may increase the numbers and impacts of potentially invasive species.

Element 4 of *NatureLinks* is to recognise the vital importance of people in nature with the aim of ensuring that 'South Australians share the benefits of ecological sustainability' (DEH 2006b). A key to the success of *NatureLinks* is the ability to develop partnerships. This is going to be critically important as public land is only one component of the landscape and alone will be inadequate to allow for the impact of climate change on species' survival. Private landholders, all levels of government, local and community groups, as well as businesses are crucial to achieving conservation goals to overcome fragmentation and maximise the resilience of native ecosystems and regenerated areas. For example, at the workshop undertaken with the South Australian ecological restoration community on 29 November 2006, representatives, when asked to identify concerns for ecological restoration resulting from climate change, collaboratively outlined some major challenges for all stakeholders (Table 13).

It will be important to strengthen key partnerships with research institutions in order to improve our level of scientific knowledge of adaptation to climate change and to develop methods for building the capacity of the conservation and natural resources management community to implement that knowledge. A base-line target for regional NRM responses to climate change is the ownership of the issue by stakeholders, which leads to an acceptance that actions to adapt and mitigate are both possible and important. Climate change has the potential to reduce the benefits that ecosystems provide to our community in relation to clean water and air, recreation and tourism opportunities, and good land management practices (Pittock 2003). On the other hand, a significant area of opportunity exists if the value of carbon biosequestration within revegetation programs could be fully recognised (Shea 2003; AGO 2005). Ten percent of respondents indicated a greater use of indigenous species in

urban and rural landscapes would be required. An Ecologist from DEH stated (2006, pers. comm., 20 October):

> 'We need a fundamental increase in restoration. Carbon biosequestration could play a role in changing this framework. There are opportunities, but forestry and conservation outcomes are all in competition. We don't have the forward planning to guide the process when new initiatives such as carbon sequestration arrive. It is important that it is not just driven by market forces.'

Due to the recognised risks to biodiversity, it is important that, where possible, such biosequestration plantations lead to simultaneous net biodiversity benefits (Schulze, Valentini & Sanz 2002). If the opportunity to support carbon sequestration outcomes are not guided effectively, however, there is the concerning prospect that the industrial use of scarce land and water resources will fail to provide the broader ecological outcomes that have become vital with the prospect of a warmer, drier future for South Australia.

Table 13. Challenges for ecological restoration as a result of climate change (from meeting of the South Australian ecological restoration community, 29 November 2006)

Challenges/vulnerabilities	Description/examples
1. All species/community survival:	During establishment phase, shifts in species bioclimatic envelopes, seed viability/sourcing, local extinctions, changing ecosystem functioning.
2. Changing disturbance regimes:	Changing species assemblage, e.g. due to fire, weed and pest invasion, sea level and flooding impacts. Definition of 'native' weeds.
3. Uncertainty of correct conservation goals?:	Lack of genetic diversity considerations. Which genetic source is best—local/local provenance/pre-European? Recognition of value of gene flow/source of material/regeneration/changing environmental context. Lack of information/knowledge of natural systems.
4. Inadequate planning response to land use pressures:	Guidance is not sufficiently detailed/ comprehensive/coordinated. Ecological design is under represented while urban and ecological developments are over represented.
5. Inaction, wrong action and degradation of action:	Degradation of ecological restoration/conservation/management with reduced resource base.

4. CONCLUDING COMMENTS

A large range of adaptation options will need to be developed and applied to bring about the transformation of our NRM systems to adapt to climate change. Adaptation responses will need to recognise the important ongoing link between South Australians and their environment. Without a broad understanding and legitimisation of the importance of climate change responses within the NRM community, there could be significant failures in the development or implementation of effective adaptation policies and programs (Leiserowitz 2006). Early effective responses, that are balanced and reflective of the intensity and scope of change, will enable opportunities to minimise negative impacts and maximise opportunities for benefits. To help put our natural systems, biodiversity, production systems and society on track towards sustainability we will require a mix of:

- Education to raise awareness of the impacts, to better understand options for change and to create the political will for change.
- Incentives schemes to encourage better management of scarce resources, particularly water.
- Restrictions on activities that are seen to be highly detrimental to the sustainability of NRM.
- Research and technological development to better understand the impacts on our natural and production systems and create opportunities for changes in management at a local level.
- Policy and planning guidelines to incorporate the implications of climate change and support the community to change.
- Positive, action-based leadership to bring about the changes required.

Education and awareness of climate change and wider sustainability issues are key requirements identified through this work. The state government is working to rectify skills and knowledge shortfalls and build community capacity in these areas (see Government of South Australia 2007; Schneider 2006). However, the survey questionnaire and other community consultation activities associated with this work have revealed a consistent, strong sentiment within the AMLR NRM community that people are concerned about the impacts of climate change and want to implement changes, both for adaptation and mitigation. This is evident through:

- The sentiment expressed in response to Question 7 (Fig. 11) of a large majority willing to accept immediate wider policy changes to adapt to climate change, even if it requires them to make personal sacrifices.
- The large number of suggestions for adaptation responses to climate change (Table 10).
- The large number of suggestions offered to reduce greenhouse gas emissions (Table 11).
- Local perspectives of the negative impacts on natural and production systems from perceived changes in climate to date.
- A focus of concern on reduced water resources, reflecting perhaps both the current concerns regarding water supply in South Australia and climate modelling predictions of a future warming/drying trend for much of the state. Almost certainly, the recent prolonged drought has heightened awareness of the issue and there are concerns that

rainfall will be less predictable and droughts more frequent, with adverse impacts for both irrigated and dryland production systems.

- The many requests for more information on the topic of climate change.

Considering the level of acknowledgement of the importance of climate change for NRM, it might be important to examine further in a future study why there has not there been more action both to lobby for mitigation of emissions and, as is the focus here, to integrate projections into NRM and planning prior to the current time. The issue of leadership was raised by many respondents (as indicated in Table 12), and this perception is reflected more prominently in public and political debates at state and federal levels. While effective leadership was seen as lacking, it was also apparent that many respondents thought that action was required urgently. These sentiments were emphasised by a number of respondents in quotes when provided the opportunity to provide additional information. These quotes included:

- 'Government should lead the way, set examples, have courage to do what is needed, not just what is going to get votes.'
- 'Having dithered and denied for 20 years, an effective response is urgently needed. No more 19th century responses to 21st century problems.'
- 'Encourage diversification of land uses and prioritise retention of natural habitats.'
- 'Change our expectations of the productivity of natural systems based on the "past" to deal with climate change parameters.'
- 'We are all going to have to make personal sacrifices for the sake of generations to come.'
- 'We should look forward to solving and reversing the current problems and trends.'

These perceptions of the role of governance provide significant challenges for all governance levels, including the state government and the AMLR NRM Board. It has become vital that as formalised adaptation responses to climate change are developed and implemented that they become integrated, as much as possible, with other planning and management activities. Without this integration, climate change risk will continue to be discounted. As an Environmental Management Consultant working with the South Australian Apple and Pear Growers Association stated (2006, pers. comm., 26 June):

> 'It is important that we don't take the producers, and particularly those who make a big effort to improve their management activities, for granted. They are very busy people, with a lot of pressures and it will be important to recognise this as any plan for sustainable management in relation to climate change is developed.'

A technical advisor from the South Australian Wine Industry Association also noted (2007, pers. comm., 1 February):

> 'Producers are not aware of the NRM processes or climate change's role in altering the management requirements of natural resources. For example, we are seeing the introduction of prescription of water use in the western Mount Lofty Ranges, but no-one is aware of it. NRM is simply not on people's agenda. At the moment, climate change is coming and people are making decisions in the absence of any information, or good information. At least if we present a process of making decisions, we can improve on that.'

Opinions expressed by the AMLR NRM Group members (26 key technical personnel) were generally typical of the broader NRM community sentiment, as shown by the consistency of many of the histograms comparing the perceptions of these two groupings. As the views of the AMLR NRM Group could be considered representative of the broader concerned NRM community, this should bring confidence to both groups as the holistic NRM governance approach is consolidated within the region.

A key component of the NRM groups' work could be on developing spatial planning outcomes that support sustainable development. In particular, there will probably be a need for spatial planning to become more explicit in relation to climate change to ensure that greater resilience is built into landscape management. These decisions will require considerable community support and vested interests in the landscape will need to be carefully managed.. For example, a strategic planner within the PIRSA Planning Division noted (2006, pers. comm., 18 August):

> 'Where this all becomes both interesting and complex is that in the same area we can expect both population growth and urban development; SA Water and the EPA would argue that there are significant water constraints; there is and we can expect a continuance of the cost/price squeeze for agriculture, for which there are enormous scale issues; and biodiversity planning in the hills will need to be enhanced.'

The stakeholder feedback summarised in this report has revealed a need among much of the community for more information relating to both the impacts and timeframes of climate change across all sectors, and realistic options for climate change adaptation and mitigation. While a need for more 'knowledge' on climate change issues was identified, and to some extent this can and should be addressed, it is apparent that the issue of climate change will always involve the management of a great deal of uncertainty.

In many cases, it is recognised that greater community debate will be required before 'best practices' can be identified for adaptation. Even then adaptive management approaches will be required, with behaviours reviewed on a continual basis in light of changing climatic conditions, the shifting status of our natural resources, updated modelling of future impacts and other impacts on NRM activities. The diversity of both management approaches and natural systems are going to continue to be very important for building and maintaining resilience and flexibility over time (Bardsley & Thomas 2006). To formalise an evolving understanding of adaptation needs, procedures could be put in place to review our current knowledge of climate change and examine key issues of risk at regular intervals. At a less formal level, the discussion of vulnerability will force people to explicitly outline their concerns (Pelling & High 2005). One such example that emerged during interviews was a statement from the Director of Policy and Planning for the AMLR NRM Board, who stated in relation to the Bardsley (2006) report (2006, pers. comm., 14 August):

> 'There are several points that I disagree with in your review. In particular, there is not just a small area of the region at risk of riparian flooding. Actually, previous work has shown that there is quite a large part of the Metropolitan area that would flood from Brown Hill and Gawler Creeks and elsewhere. It may be that a 1:200 year flood becomes 1:100 year flood, in which case it would be a significant area that is severely affected.'

Another respondent, this time from the City of Onkaparinga, similarly stated (2006, pers. comm., 26 September):

> 'I question whether agriculture has a good capacity to adapt to climate change. There is a landscape of crops with quite specific market links. With climate change, they are

> going to have to develop different crops, different markets. For example the wine industry may need to develop different crops and different markets. The industry has taken years to build up the ability to respond to market demand, and they won't be able to change the direction of their marketing pitch very quickly.'

In the face of climate change, the community will play a critical role in shaping a more sustainable society and in this regard, the perceptions and actions of managers of natural resources will be pivotal. This report has collated the perceptions of the NRM community in the AMLR region and suggests significant challenges for future work. The relationships between perceptions of NRM stakeholders and the available science will need to be formally analysed regularly in the future to ensure that management responses occur in a manner that allow for recognition of and learning from failure, and replication of and learning from successes. The many useful suggestions provided by respondents for both adaptation to climate change and mitigation of greenhouse gas emissions could be used to guide responses that may be particularly applicable in the AMLR region. It is believed that this type of learning approach to future environmental management in the AMLR region will form a solid foundation for action to develop community ownership of effective governance responses to climate change.

APPENDICES

1. DETAILS OF PRESENTATIONS AND WORKSHOPS

Notes:

1. These workshops and presentations were undertaken by D Bardsley as part of, or in association with, the DWLBC/AGO/AMLR NRM Board project 'A regional climate change decision framework for natural resources management'.
2. Activities are listed under the month of action in 2006 from June (6/06) through to December (12/06).
3. **Questionnaires** were distributed to the four AMLR NRM groups, Flinders University students and made available to other groups after workshop/presentations (**indicated by ***).
4. Some respondents were targeted (AMLR NRM groups and students) while other respondents (community and local government) responded voluntarily. (Also see Section 2—Methodology.)

6/06

Presented on climate change with SARDI at Lenswood Horticulture Centre to approximately 30 pome fruit growers, including Apple and Pear Growers Association president.

Presented at the Geography Teachers Association of South Australia (GTASA) conference on climate change learning and teaching approximately 200 educators.

Presented on climate change at the *NatureLinks* Cape Borda to Barossa, approximately 40 DEH and NRM staff.

Trialled 'The Adaptation Challenge', Woodcroft College, approximately 65 students, examined planning implications for hypothetical development on coastal dune system.

Presented at *NatureLinks* Corridor Workshop in Brighton, approximately 70people, mostly DEH.

7/06

*Presented to Stirling Rotary Club, approximately 20 people, questionnaires distributed.

*Presented to AMLR NRM Comprehensive Planning team, 8 people, questionnaires distributed.

*Presented to Southern AMLR NRM Group and workers, 12 people, questionnaires distributed.

Presented over two sessions at the 3rd National NRM Facilitator workshop, Canberra to 15 people and 35 people respectively.

8/06

*Presented to Water Allocation Plan Advisory Committee, Norton Summit, 11 people, questionnaires distributed.

Presented to SSABSA Sustainable Futures Board, 15 educators.

Presented at workshop on Eyre Peninsula for Eyre Peninsula NRM Board and using 'The Adaptation Challenge', 40 people.

*Presented at Friends of Patawalonga Creek/St Vincent Gulf 'Curry and Casserole Night', approximately 100 people, questionnaires distributed.

Presented to River Murray (NRM) Executive Director and LM&R Group, 12 people.

Presented at Mypolonga Local Produce Dinner, (Mannum to Wellington LAP group), 140 people.

*Presented to SA Agricultural Weather Committee Meeting, approximately 12 bureau scientists and NRM professionals, questionnaires distributed.

Presented to MurrayCare/MurrayLink Professional Development workshop, approximately 30 primary and secondary teachers.

*Presented to 'Issues in Environmental Management' 2nd/3rd year subject, Flinders University, approximately 80 people, students and academics, distributed questionnaire, completion of which integrated into course assessment.

9/06

Meeting with AMLR CC reference group on case study ideas, approximately 20 people.

*Presented to City of Onkaparinga, approximately 80 people, played 'The Adaptation Challenge', questionnaire distributed.

Presented on climate change and weed management at 15th Australian Weeds Conference, approximately 150 people.

10/06

Presented on climate change and conservation planning, *NatureLinks* workshop, Ceduna, approximately 50 people, EP NRM community.

Presented at SA NRM Council forum, Waite, approximately 100 NRM practitioners.

*Presented to the Central AMLR NRM Group, 10 people, questionnaire distributed.

Presented at two environmental vorums, Berri with Masters student, ran 'The Adaptation Challenge' with 4 irrigators and 5 DEH staff, presented to approximately 30 NRM staff.

*Presented to the City Council Environmental Officers, 25 people, questionnaire distributed.

*Presented to the Fleurieu AMLR NRM Group, 7 people, questionnaire distributed.

*Presented at Blackwood Uniting Church, approximately 100 people, questionnaire distributed.

*Presented to the Friends of Stirling Linear Park, 20 people, questionnaire distributed.

Presented at MurrayCare AGM, on climate change and education, 20 people.

11/06

Presented to the DWLBC Land & Biodiversity Services Seminar Series, 12 people.

*Presented to Northern AMLR NRM Group, 10 people, questionnaire distributed.

*Presented to the Urban Biodiversity Unit, Blackwood, 10 people, questionnaire distributed.

*Presented to the Mount Pleasant Natural Resource Centre, 30 people, played 'The Adaptation Challenge' and questionnaire distributed.

Presented with Flinders University Masters student, to Riverland Wine Industry Development Council, 5th Annual AGM, at Berri Resort Hotel, Berri, 40 people.

*Presented to Fleurieu Olive Growers Association AGM, Willunga, approximately 25 people, questionnaire distributed.

*Presented to Willunga Hillsface Landcare Group AGM and open community forum, Willunga, approximately 60 people, questionnaire distributed.

Presented to Climate Change and Invasive Species Workshop, hosted by the Biological Diversity Advisory Committee (BDAC) and the Department of the Environment and Heritage (DEH), Canberra 20/11/06, approximately 35 people.

*Presented to the South Australia ecological restoration community, 15 people, questionnaire distributed, 29/11/06.

*Presented to Southern AMLR NRM Group, 6 people, questionnaire distributed.

12/06

Presented at DEH *NatureLinks* East Meets West workshop for environmental NGOs, Royal Botanic Gardens, 10 people.

*Presented to Aldgate Valley Landcare group AGM, approximately 25 people, played 'The Adaptation Challenge', questionnaire distributed.

Presented to Goolwa–Wellington Local Action Planning Board, 13 people, played 'The Adaptation Challenge'.

2. AMLR GROUP PERCEPTIONS OF KEY VULNERABILITIES AND ADAPTATION RESPONSES

Group/Organisation:	**Northern Group**, AMLR NRM Board	Date:	8 Nov 2006
Place:	Golden Grove Arts & Recreation Centre	Number of attendees:	10

The area's top 5 NRM vulnerabilities to climate change	Short-term risk management responses	Long-term adaptive management responses	Applications of precautionary principle
1. Loss of native species and ecosystems—terrestrial and freshwater	• Connectivity planning for movement. • Reduce short-term impacts of reduced flows/grazing. • Reduce specific threats to individual species e.g. re-introduce hollows.	• Providence sourcing or wider genetic diversity? • Or precinct approach of dependent ecosystems below association levels • Reintroduction of native species? • Prioritise flows to water-dependent ecosystems.	• Connectivity planning for movement. • Awareness raising and prioritisation of environment? The place of ecosystems in our society.
2. Increased water demand + reduced water resource availability	• Explore energy production that is low on water demand and vice versa e.g. de-salinisation. • Better water pricing will drive better management—more revenue + economic break on overuse. • Reduce peak water/power loads, need to increase costs with demand.	• Better water pricing will drive better management—more revenue + economic break on overuse. • More efficiencies + reallocations.	• Explore energy production that is low on water demand and visa versa. • Development planning should limit high-water use in some areas and direct to other areas e.g. near desalinisation plants or SE of SA.
3. Lack of direct economic signals, NRM links to greenhouse gas emission + costs to management (both short- and long-term) as ecosystem services decline	• Package information to have good uptake.	• Cost signals that respond directly to demand e.g. Make it attractive to reduce water use, recycle or desalinisation or interbasin/state transfers. • Need to build in costs into management systems e.g. hazards and risks may become more costly. • Link consumer choice to good management—convince community of additional costs	• Risk + econometric analyses to assist decision-making for property plans.

The area's top 5 NRM vulnerabilities to climate change	Short-term risk management responses	Long-term adaptive management responses	Applications of precautionary principle
4. Coastal or riparian, flooding and flash floods	• Maintain and extend reserve areas that abut mangrove, samphire plain + examine positioning of levee banks. • Review flood mapping studies in relation to climate change e.g. Gawler river (lower levels) + northern plains.	• Support change to development planning. • Costs associated with infrastructure/removal.	• Policy for development.
5. Droughts—industry costs + reduced production, erosion impacts	• Erosion controls. • New pasture species/mixes that can tolerate variable rainfall. • Education component. • Review systems used for engagement with agriculture. • New landowners – opportunity for changing practice/succession planning.	• Change farming practices, carbon sink ideas including better use of more summer rainfall. • Maintain mosaic + diversity in production systems and landscape. • Adjust incentives to provide correct signals for better management. • Update profitable options with climate change.	• Reduce greenhouse gas emissions. • Develop new varieties.

Group/Organisation:	**Central Group**, AMLR NRM Board	Date:	18 Oct 2006
Place:	205 Greenhill Road, Eastwood	Number of attendees:	8

The area's top 5 NRM vulnerabilities to climate change	Short-term risk management responses	Long-term adaptive management responses	Applications of precautionary principle
1. Bushfire	• Pattern burning. • Permanent location of major airborne water tankers in SA (planes/helicopters)/additional CFS resources. • Managing risk of bushfires according to weather patterns not just based on seasons. • Property maintenance programs. • Public education. • Clear buffer zones.	• Develop good weed strategy. • Increased number/size of public vegetation areas. • Investment in water bombing. • Review full control policies in National Parks. • No urban development in areas of high fire risk. • Permanently resourced fire brigades in high risk areas (i.e. Hills Face Zone). • Legislated requirements for property maintenance in fire prone areas.	• Research into impacts based on climate change. • No urban development in areas of high fire risk. • Greater responsibility on land owners and particular government agencies to manage weeds etc.
2. Flooding (in general)	• Review flood maps to include more intense rainfall predicted. • Publish flood maps of region immediately. • Increase resources for emergency services ($ etc). • Increase permeable surfaces. • Increase capacity of stormwater drainage systems (i.e. replace obviously under sized bridges/culverts). • Mandated policy for water sensitive urban design in new development. • Better planning compliance in developments for stormwater management. • Build levy banks.	• Population movement/control. • Building. • Increased high rise buildings. • Accelerate major proposals for > flood control including flood control dams, etc. • Greater stress on site flood water storage and infill on all new development. • Development of policies (i.e. Port Adelaide Enfield example). • Obtaining adaptation options land (i.e. wetlands). • Amendments/changes to planning to ensure development suitable to flood risk (i.e. Darwin building codes).	• Incorporate population movement into planning. • No further coastal development.

The area's top 5 NRM vulnerabilities to climate change	Short-term risk management responses	Long-term adaptive management responses	Applications of precautionary principle
3. Increased water demand	• Change practices. • Increased priority on prescribing water resources of AMLR region. • Revisit cost of water/tiered water pricing. • Increase groundwater recharge. • Behavioural change programs for industry and community. • Incentive programs for community to reduce water demand. • Water restrictions. • Seek alternative sources of water.	• Choose low-water use industry. • New home design and upgrading directed towards sustainable water use (at least outside). • Investigate different crops that are less water intensive. • Behavioural change in landscape acceptability. • Desalination. • Remove dams in favour of bores. • Shared bore resources for stock and domestic use. • Obtain new sources of water. • Improve consumer use (i.e. education programs).	• Research to reduce use (Adelaide). • Start using other river systems. • Change landscapes to low water use. • Water recycling for all industry uses. • Education of consumers.
4. Reduced water resources	• Use effluent/storm water. • Recycle water. • Prescribed water resources. • Policy to reduce use—further restrictions.	• Reduce/maintain population. • Broaden prescribed water resources? • Investigate desalination/desalinisation plants. • Mandate grey water reuse in new developments. • Decentralised treatment systems to better incorporate recycled/stormwater reuse. • Considerations extended across state boundaries.	• Establish safety net for supplies to urban areas. • Rural trading for best use of resource, having regard to national food requirements. • Limit population growth. • Manage evaporation (i.e. from dams).

The area's top 5 NRM vulnerabilities to climate change	Short-term risk management responses	Long-term adaptive management responses	Applications of precautionary principle
5. Reduced primary production	• Introduce better varieties. • Behavioural changes (i.e. common foods no longer readily available). • Change management techniques. • Greater assistance to industry (i.e. through programs)/planning support. • Different crops/livestock. • Establish comparative advantage production principals.	• Protective covers over horticulture. • Retire marginal properties. • Introduce crops/livestock better equipped for conditions (e.g. kangaroos/bush food). • Rethink business opportunities. • Establish domestic food safety net.	• Low water use plants. • Change types of crops. • Review export objectives and priorities. • Review dairy practices in SA's lower Murray region. • Minimise call on water resources by other users.

Group/Organisation:	**Southern Group**, AMLR NRM Board	Date:	30 Nov 2006
Place:	Flagstaff Hill Golf Club	Number of attendees:	6

The area's top 5 NRM vulnerabilities to climate change	Short-term risk management responses	Long-term adaptive management responses	Applications of precautionary principle
1. Surface and groundwater management: declining resource base + competing, increasing demands e.g. all allocations used in dry years, lack of positive pressures in the groundwater—salinity intrusion	• Water restrictions. • Prescription and changing resource availability. • Give water a true value e.g. why are we buying Australian rice.	• Prescription and changing resource availability. • Greater water re-use rather than relying on natural resource. • Change crops: grapes rather than apples. • EMS and other industry guidelines for better water management by producers. • Give water a true value.	• Greater water re-use rather than relying on natural resource. • Alter reserve boundaries. • New infrastructure? Increased water storage for winter sewerage and stormwater, recycle wine effluent? • Desalinisation? • Lifestyle choices in supporting high water use industries – meat?
2. Biodiversity vulnerable (loss of bioclimatic envelopes)—impacts of disturbance regimes e.g. invasive species, bushfire regimes (currently unrated, interact with CFS, role of remnants and habitat areas). Biodiversity reliance on water regimes, amount of timing of rainfall, groundwater dependence highly vulnerable.	• Better dialogue and communication between different players. • Manage invasive species.	• Identify and management changing invasive species risk. • Better dialogue and communication between different players e.g. planning for bushfire and biodiversity outcomes. • Identify indicator species and monitor—frogs? And respond to changes. • Intensification of reserve management in response to changing disturbance. • Reinterpreting concept and role of exotics.	• Alter reserve boundaries, increase linkages between reserves, purchasing land and reserve management. • Plan for 'lifestyle' land to have biodiversity outcomes, create links to real estate value. • Triage for directing investment.
3. Coastal biodiversity, reefs + sea level rise impacts on natural systems and social development. More and greater summer rainfall impacts on reefs: sediment.	• Seawalls, sand dumping. • Regulations of angling, boating. • Controlling erosion/pollution levels.	• Use of sand – extraction and placement. • Creation of artificial reefs – engineering solutions? • Better re-use of water so it doesn't go into the gulf.	• Plan development for sea level rise e.g. Port Adelaide–Enfield • Planning for the uncertain future—put sensible development in place. • Make sure that nothing is exempt from environmental management e.g. mining.

The area's top 5 NRM vulnerabilities to climate change	Short-term risk management responses	Long-term adaptive management responses	Applications of precautionary principle
4. Emergency impacts of extremes: Emphasise the economic costs of inaction, impacts of floods/fires on social systems.	• Raise awareness. • Better dialogue between groups.	• Plan for floods and fires—they are going to happen, don't overlook the potential for future risk. • Explain the long-term problems that are emerging.	• Broader long-term lifestyle choices, retention of flood channels, calming areas to reduce the potential risks. • Plan for higher risk.
5. Role of Board to reduce emissions: education and demonstration and behavioural change. Economic/energy issues: primary production, changing asset base and costs, loss of amenity value.	• Demonstrate the costs of inaction. • Place cost on economic wellbeing.	• Alternative fuels. • Use levy to support low greenhouse gas emission actions and sustainable management of NRM. • Looking at 'lifestyle' properties as an asset for sustainable outcomes e.g. biodiversity or carbon offsets. • Incentives for renewable energy. • Look at threats and try and turn them around: respond to risk with positive futures.	• No nuclear power station.

Group/Organisation:	**Fleurieu Group**, AMLR NRM Board	Date:	26 Oct 2006
Place:	Willunga Hub	Number of attendees:	7

The area's top 5 NRM vulnerabilities to climate change	Short-term risk management responses	Long-term adaptive management responses	Applications of precautionary principle
1. Coastal impacts: Erosion, sea level/flooding and storm surges	• Purchase seafront land. • Increase value of dune systems. • Implement development controls, which are good ideas anyway. • Alter planning guidelines.	• Purchase seafront land. • Better use of wetlands. • Alter planning guidelines.	• Better knowledge, research and information. • Create a vision of a positive future. • Purchase seafront land. • Alter planning guidelines.
2. Loss of biodiversity and invasive species	• Increase incentives and funding for reserves and heritage vegetation. • Identify intact systems and better manage, link and buffer (especially along north-south and altitudinal transects). • Better weed/pest management.	• Wider recognition of wetland values. • Identify intact systems and better manage, link and buffer (especially along north-south and altitudinal transects). • Monitor pests and broaden the list of declared plants according to cc projections.	• Better knowledge, research and information. • Create a vision of a positive future. • Explore requirements for ex situ conservation. • Identify intact systems and better manage, link and buffer (especially along north-south and altitudinal transects).
3. Agricultural systems	• Broader use of fodder and feed reserves. • Explicit recognition of good NRM within farming systems to provide resources for agricultural producers.	• Increase support for farming communities. • Adaptive management of water resources, that adjust with changing resource. • New crop & pasture varietal development and choice. • Development of marketing methods, including organic and regional marketing.	• Better knowledge, research and information. • Create a vision of a positive future. • Increase support for farming communities. • Increase extension capacity including rural and urban links. • New crop and pasture varietal development and choice.

The area's top 5 NRM vulnerabilities to climate change	Short-term risk management responses	Long-term adaptive management responses	Applications of precautionary principle
4. Water infrastructure and management	• Community education to reduce use. • Increase storage capacity. • Increase use of rainwater tanks. • Improve capacity to re-use and recycle wastewater.	• Community education to reduce use. • Better market recognition of the value of water—potential problem of the urban dominance, therefore city will have capacity to buy water of rural users. • Ensure water management plans adjust with conditions. • Plans to request reduced storage	• Better knowledge, research and information. • Create a vision of a positive future. • Community education to reduce use. • Stormwater infrastructure for recycling, including exploration of aquifer storage.
5. Marine systems	• Reduce impacts of land-based activities on marine systems, especially sedimentation of chemical runoff. • Reduce seawater intrusions into inter-estuarine areas.	• Reduce impacts of land-based activities on marine systems, especially sedimentation of chemical runoff. • Implement and respond to monitoring to manage sustainably over time.	• Better knowledge, research and information. • Create a vision of a positive future. • Reduce impacts of land-based activities on marine systems, especially sedimentation of chemical runoff.

3. REFORMATTED COPY OF THE QUESTIONNAIRE

Impacts of climate change on Natural Resources Management (NRM) in the Adelaide and Mount Lofty Ranges Region

This questionnaire is being conducted as part of an ongoing study by the SA Department of Water, Land and Biodiversity Conservation (DWLBC) and will assist us to examine the effects of climate change on natural resources management in South Australia. Unless directed otherwise, the answers will be treated with absolute confidentiality and the identity of respondents will not be disclosed. The person in charge of this research is Dr Douglas Bardsley, DWLBC, GPO Box 2834, Adelaide SA 5001, Ph: 08 8303 9343, Fax: 08 8303 9320, Email: bardsley.douglas@saugov.sa.gov.au

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Name : _____ Sex: Female ☐ Male ☐

Occupation/Activity : _____Work location: _____

Home Postcode: _____Tel: _____ Email: _____

Highest education level attained: Less than or equal to Year 10 ☐ Year 11 ☐ Year12 ☐

College or Trade Certificate ☐ University graduate ☐ Post-graduate degree ☐

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1. How do you rate the importance of these environmental problems in your region?

(Scale: not relevant – 1, unimportant – 2, limited importance – 3, important 4, very important – 5, extreme importance – 6)

	NOT RELEVANT					EXTREME IMPORTANCE
Air pollution	1	2	3	4	5	6
Bushfires	1	2	3	4	5	6
Climate change	1	2	3	4	5	6
Drought	1	2	3	4	5	6
Flooding	1	2	3	4	5	6
Invasive exotic species	1	2	3	4	5	6
Loss of natural spaces	1	2	3	4	5	6
Loss of species diversity	1	2	3	4	5	6
Peak oil	1	2	3	4	5	6
Soil degradation	1	2	3	4	5	6
Urbanisation	1	2	3	4	5	6
Water pollution	1	2	3	4	5	6
Other _____	1	2	3	4	5	6

2. a) Do you think the **climate** has changed in the last 25 years?

Major change ☐ Little change ☐ No change ☐ Don't know ☐

2. b) In the last 25 years, are **day temperatures**:

Much warmer ☐ Warmer ☐ Little change ☐ Cooler ☐ Much cooler ☐

2. c) In the last 25 years, are **night temperatures**:

Much warmer ☐ Warmer ☐ Little change☐ Cooler ☐ Much cooler ☐

2. d) In the last 25 years, are **rainfall totals** throughout the year:

Much greater ☐ Greater ☐ Little change ☐ Less ☐ Much less ☐

2. e) In the last 25 years, is **rainfall variability**:

Much greater ☐ Greater ☐ Little change ☐ Less ☐ Much less☐

2. f) Are there any other changes in climate that you have noticed in your region in the last 25 years?

_____

_____

2. g) Are there any indications you have seen in the landscape, your production system or ecological systems that have lead you to these conclusions?

_____

_____

3. CSIRO projections for future climate change suggest that there will be significant impacts on the Adelaide–Mount Lofty Ranges.

Projected Climate Changes in the Adelaide & Mount Lofty Ranges

	2030				
	Annual	Summer	Autumn	Winter	Spring
Ave. range of warming (^{o}C)	0.3–1.2	0.4–1.3	0.4–1.2	0.4–1.1	0.4–1.2
Ave. range (%) of rainfall change	-10 – -1	-11 – +6	-7 – +2	-11 – -1	-20 – -2
Ave. range (%) of pot. evaporation change	2–5	1–4	1–5	2–7	2–7
Ave. range of change of moisture deficit[2] (mm)	35–105	12–40	7–23	5–16	9–29
CO_2 concentration current = ~380ppm	420–480ppm				
Annual days above 35^{o}C (Adelaide): now=14	15–20				
Ave. range (%) decrease in frost days	20–80				
High estimate (%) of ave. runoff reduction	24				
Ave. range (%) increase in rainfall intensity	0–10				
Ave. range (cm) sea level rise	3–17cm				

(Data used from models using SRES emission scenarios: Suppiah et al. 2006; Gillooly & Hutson 2005; McInnes et al. 2003)

3. a) What do you think could be the most important impacts of climate change in your region by 2030? Please summarise the impacts and scale the importance of the particular impact of climate variability from 1 to 10, where 1 = no importance and 10 = extreme importance.

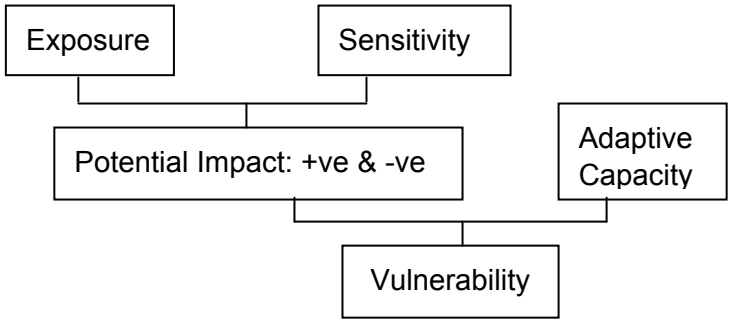
Impacts of climate change	***Importance (1–10)***	***Details of impact***
Coastal flooding		
Disruption to ecosystem services		
Drought		
Health impacts		
Increasing long-term adaptation costs		
Increasing annual management expenses		
Increased water demand		
Loss of native species & ecosystems		
Reduced primary production		
Reduced water resources		
Urban flooding		
Other:		
Other:		

4. How vulnerable is your most important NRM issue to projected climate change by 2030? (please find example overleaf)

Vulnerability of (NRM issue of interest) _____ to climate change

	Potential Impact	Adaptive capacity	Vulnerability
ASSESS-MENT (please underline 1 or 2 terms per column)	Low Medium High	Limited Medium Significant	Low Medium High
Issues relevant to assessment			

Vulnerability analyses procedure (adapted from The Allen Consulting Group report 2005)



Exposure: *relates to the important climate trends, weather patterns and events that affect the system.*

Sensitivity: *reflects the responsiveness of the system to climate and the degree to which climate change might affect it in its current form.*

Adaptation*: reflects the ability of a system to change in a way that makes it better equipped to deal with external influences via either autonomous or planned adaptation.*

An example of a climate change vulnerability analysis for A&MLR flood management

Impact	**Adaptive capacity**	**Vulnerability**
Low Medium High	Limited Medium Significant	Low Medium High
• Flood impact directly related to climatic conditions • More extreme events increasing likelihood of flood thresholds being reached more often • Although only a relatively small area is at risk of flooding, the impact is significant on human welfare, infrastructure & economic activity • Any increase in frequency in flooding will be a significant economic issue.	• Increase infiltration, reduce runoff, maintain calming areas • Increase drainage and runoff storage capacities • Limited as area is highly developed and space is required for adaptation options • Significant investment required into infrastructure to bring about change	

5. Are you making any adjustments to your systems to adapt to climate change? Yes No
If so, what are some examples where you assess climate risks or incorporate adaptation ideas to increase resilience in your management systems?

_____
_____
_____
_____
_____
_____

6. What are some examples of important adaptation changes that could be implemented in the future in natural resources management at the property, landscape or regional scales?

_____
_____
_____
_____
_____
_____

7. Do you believe that wider policy changes should be implemented to adapt to climate change?

☐ No

☐ Yes, but only when more impacts of climate change become apparent

☐ Yes, immediately, but not to the extent that I would need to make personal sacrifices

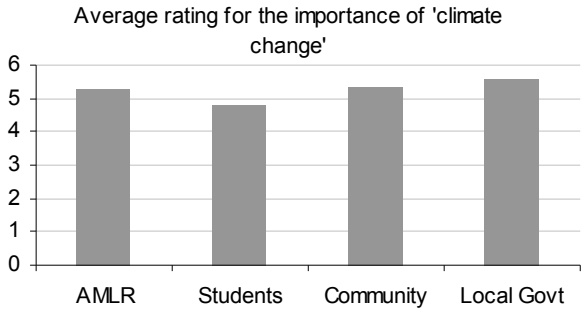
☐ Yes, immediately, even if I would need to make personal sacrifices

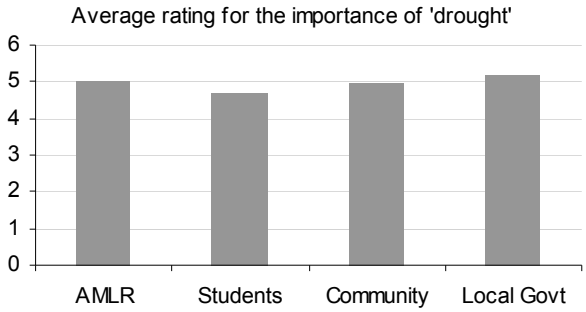
8. Is there anything else you would like to add regarding adaptation to climate change?

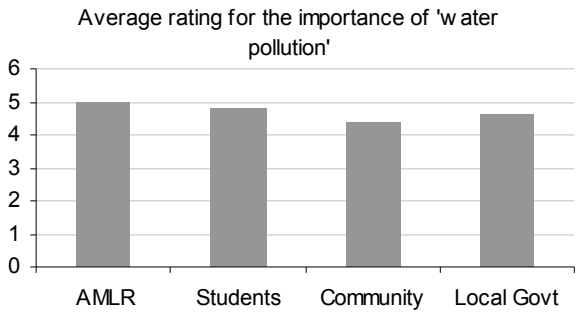
_____
_____
_____
_____
_____

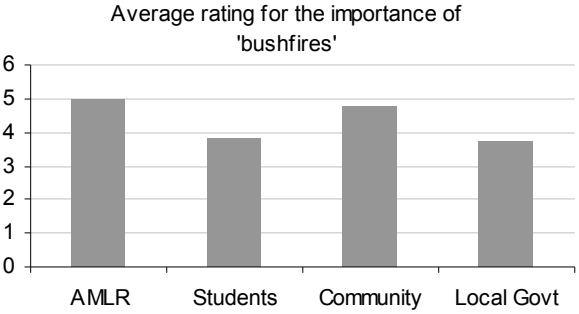
4. STUDENTS PERCEPTIONS OF CLIMATE CHANGE – COMPARED TO OTHER RESPONDENTS

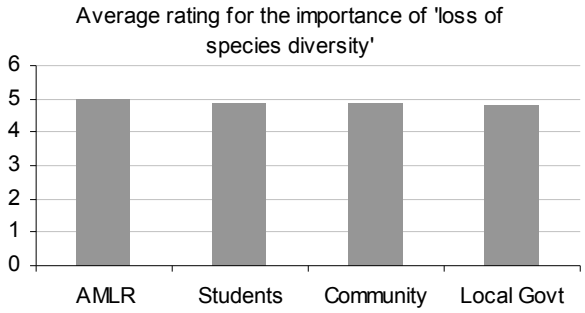
In answering ***'Question 1 – How do you rate the importance of these environmental problems in your region?'*** students had similar perceptions to other groups. Interestingly their views on the importance of climate change were on average the most moderate (see also Fig. 2).

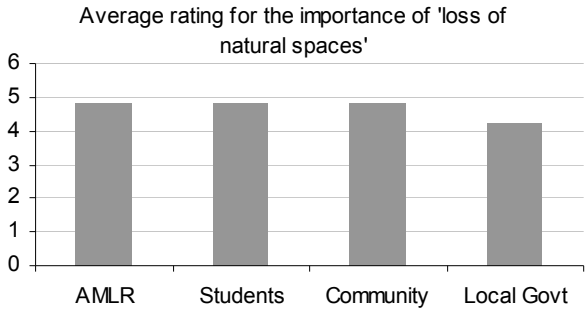


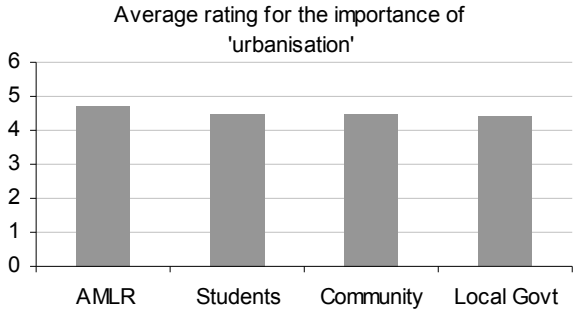




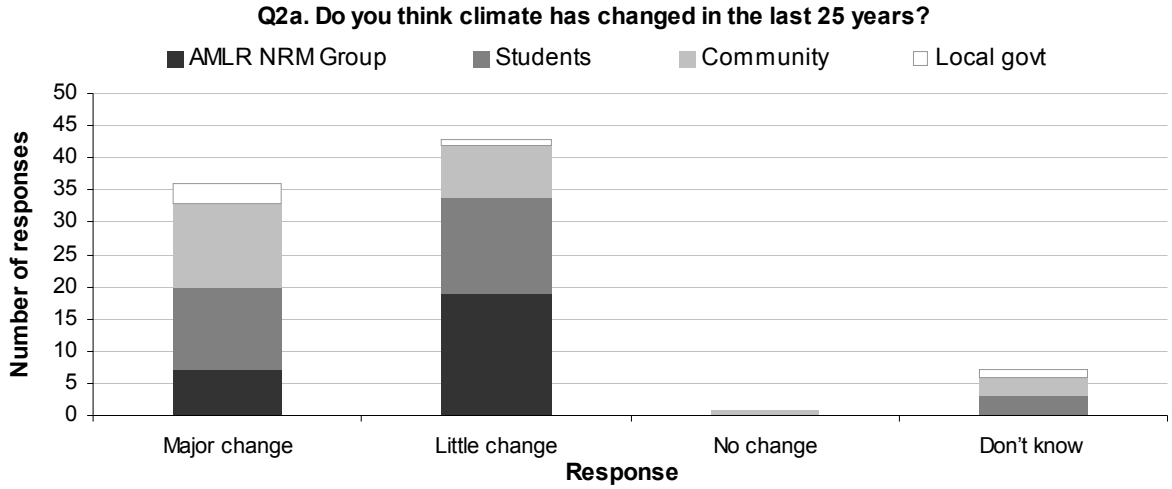








In answering ***'Question 2a – Do you think the climate has changed in the last 25 years?'*** students were more moderate in their responses (as a %) than members of the community or local government (see also Figure 3).



Percentage of category giving particular responses:

Response	AMLR	Students	Community	Local Govt
Major change	26.9%	41.9%	52%	60%
Little change	73.1%	48.4%	32%	20%
No change	0%	0%	4%	0%
Don't know	0%	9.7%	12%	20%

Actual number of responses in each category:

Response	AMLR	Students	Community	Local Govt
Major change	7	13	13	3
Little change	19	15	8	1
No change	0	0	1	0
Don't know	0	3	3	1

5. CLIMATE RECORDS FOR SELECTED LOCATIONS

The AMLR encompasses a variety of biogeographical areas, across which predicted changes in climate are not expected to occur uniformly. Similarly, actual change and perceptions of change in climate will vary across the AMLR.

Suppiah et al. (2006) provides an indication of broad rainfall trends across South Australia (Fig. A5.1), however this offers little detail at local levels, for example within the AMLR.

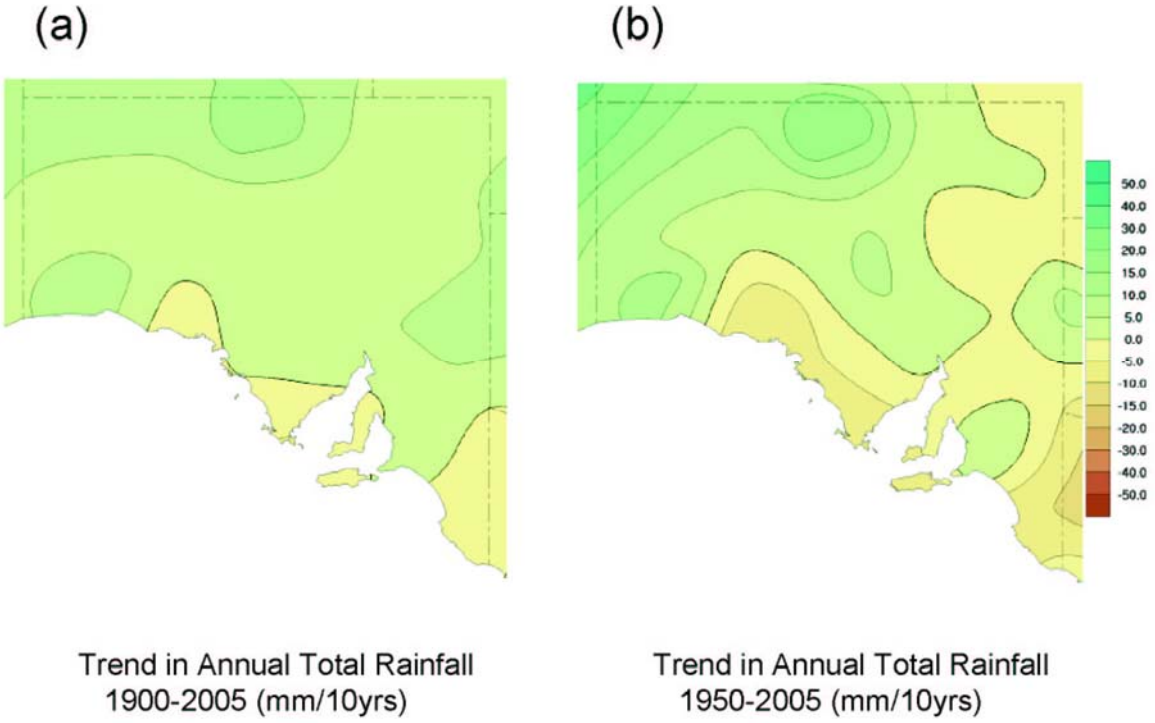


Figure A5.1. Rainfall trends in South Australia for (a) 1900 to 2005 and (b) 1950 to 2005. Trends are shown as mm change per ten years. Source: Australian Bureau of Meteorology (as shown in Suppiah et al. 2006)

There is a clear lack of detailed information on the climate of the AMLR which might be used to gain some insight into climate variation across the region. Here we have used a simple method to gauge whether there have been any obvious climate trends across the region to date, in order to provide a context for perceptions of climate change provided by respondents to the questionnaire. It should be noted that this data is based on spatially interpolated monthly climate data and should not be taken as highly accurate.

Monthly climate (temperature and rainfall) data were extracted for selected locations (see Figure A5.2) from the Queensland Department of Natural Resources and Water 'SILO Data Drill' meteorological database (Qld NRW, 2007). Data periods reflect the length of climate records available from nearby Bureau of Meteorology stations.

These records confirm that climate variables (and past and future trends in these variables) will vary across the AMLR.

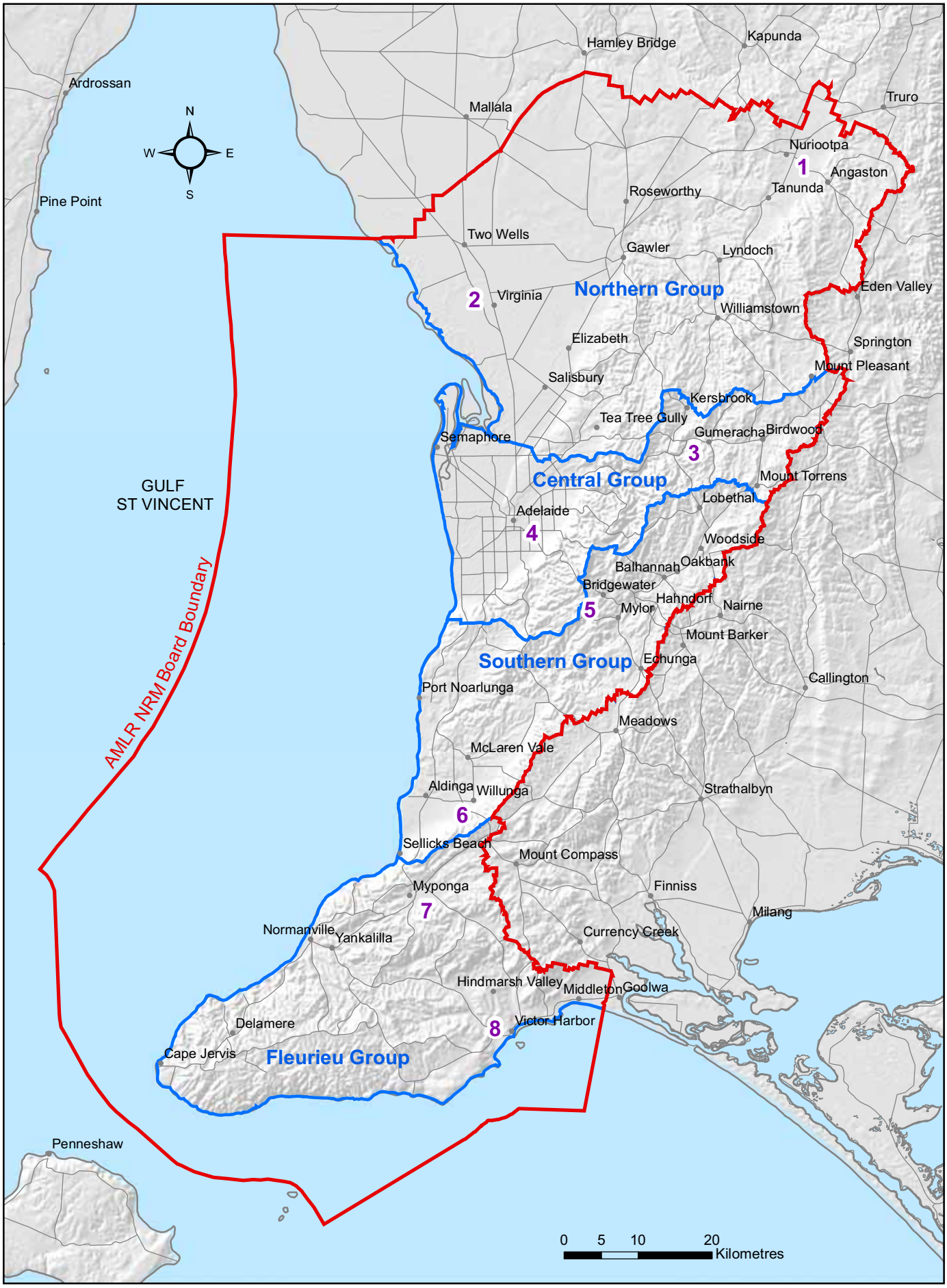
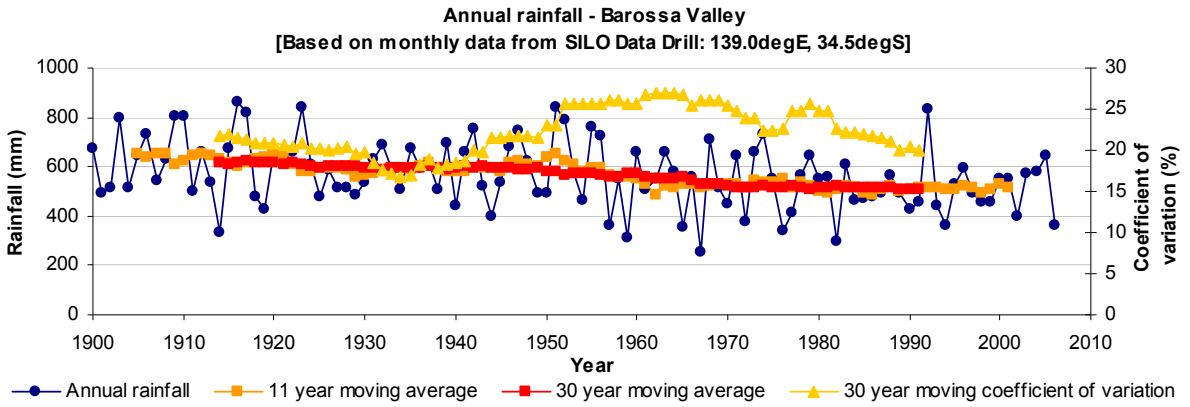
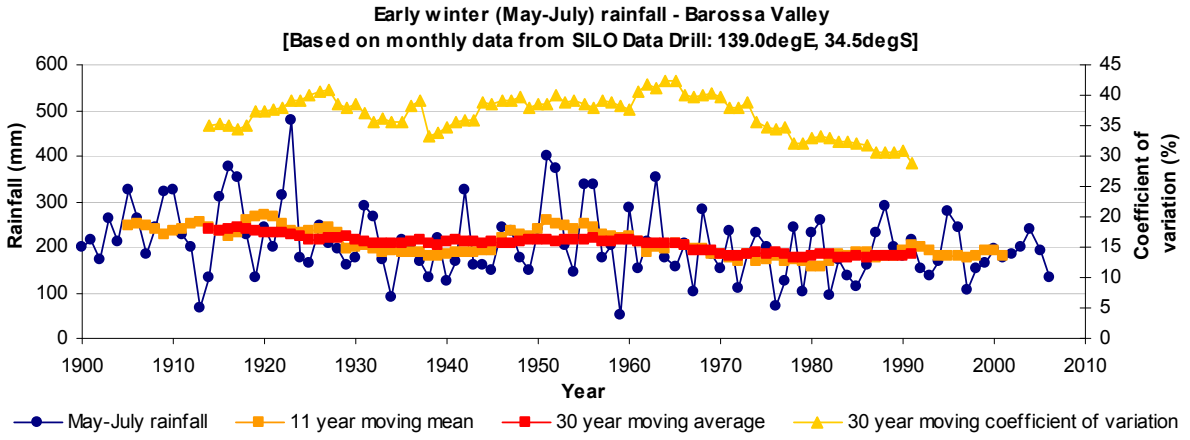
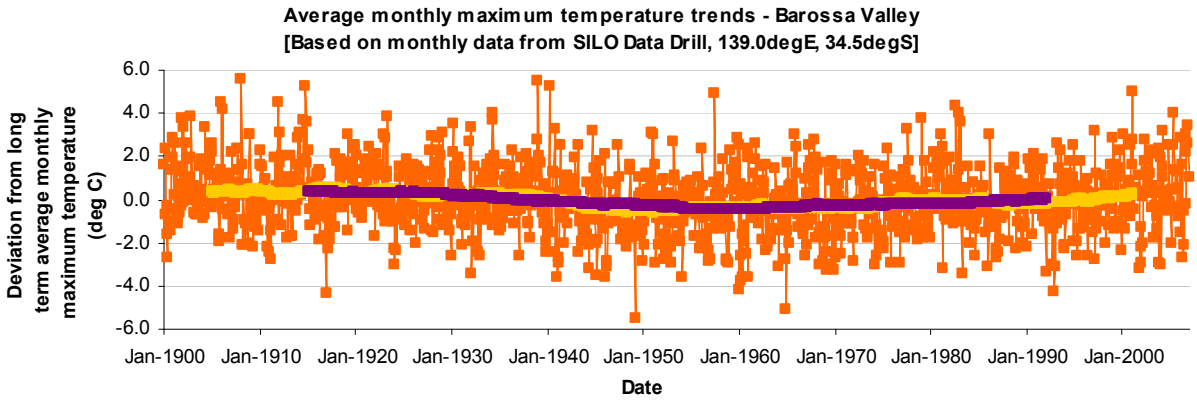


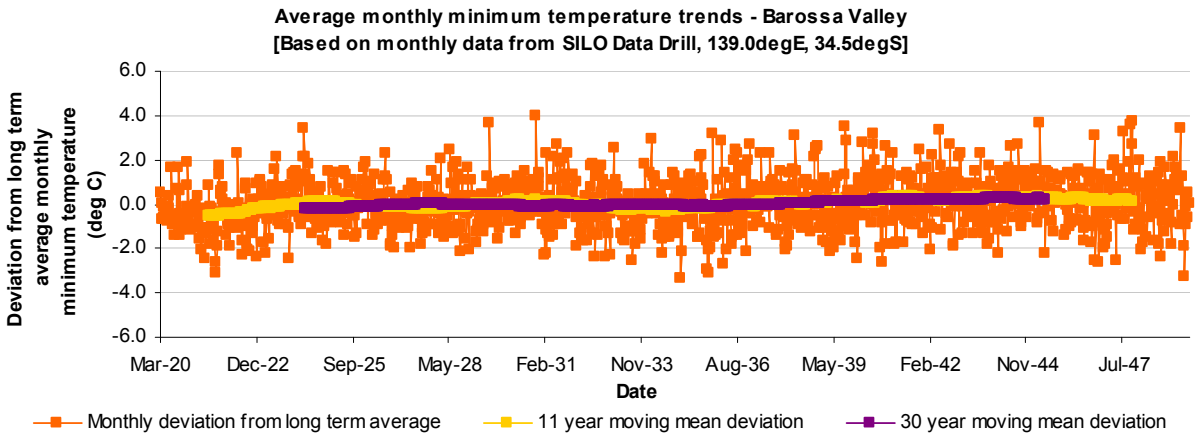
Figure A5.2. Location of selected sites with monthly climate records.

1. Barossa Valley [139.00°E, 34.50°S]

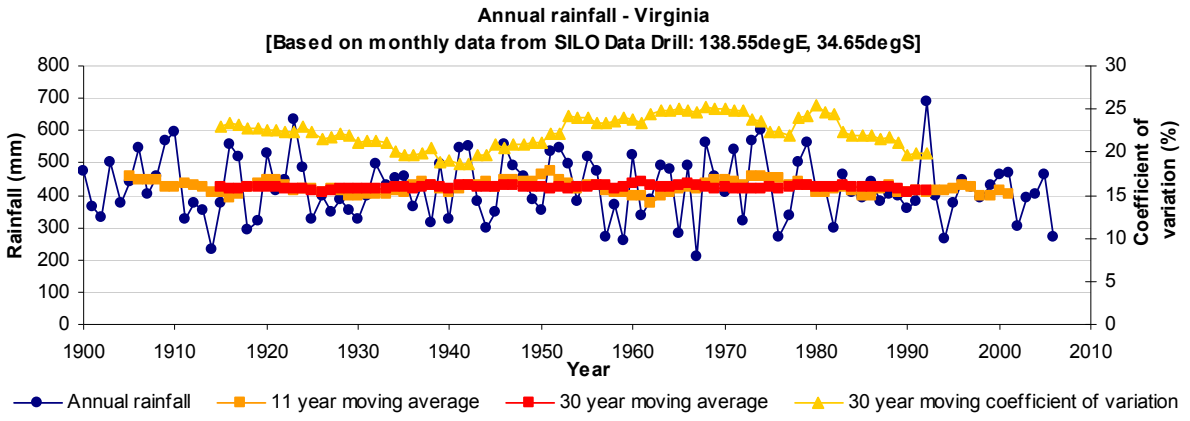


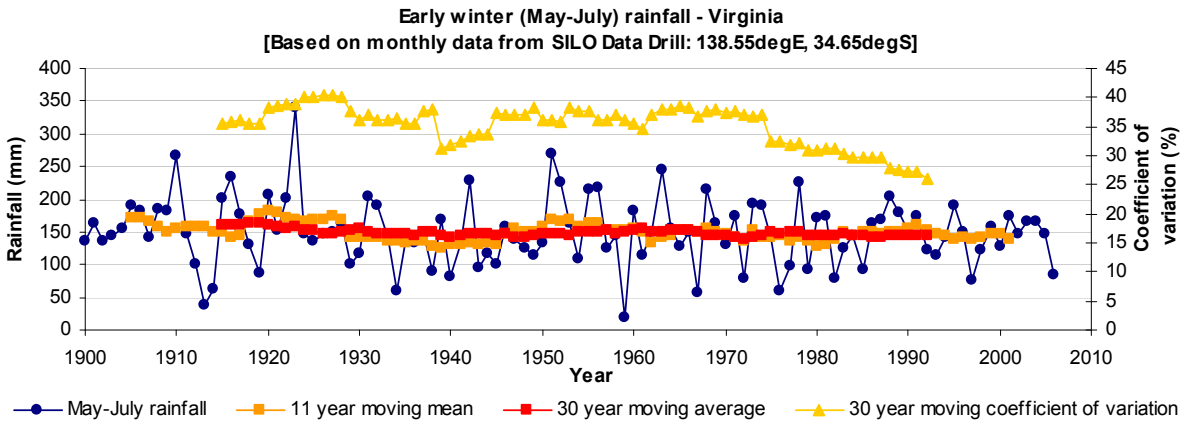


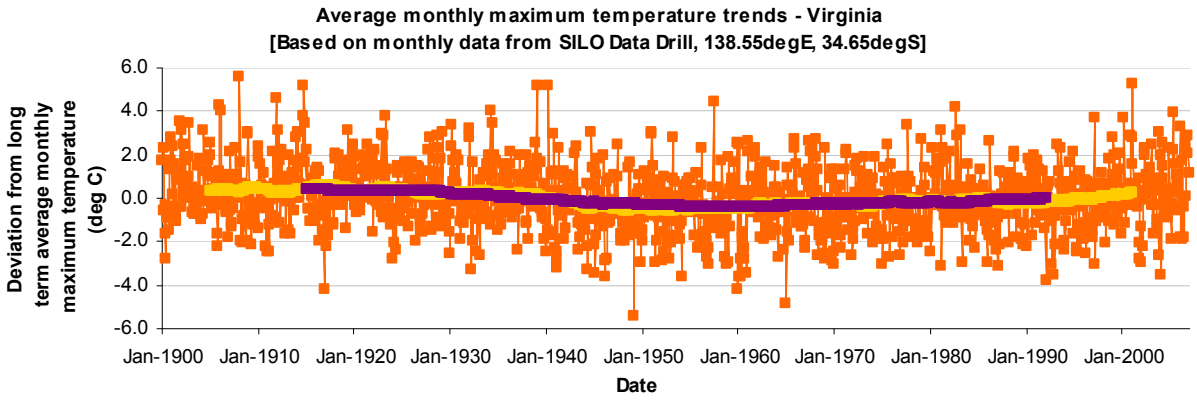


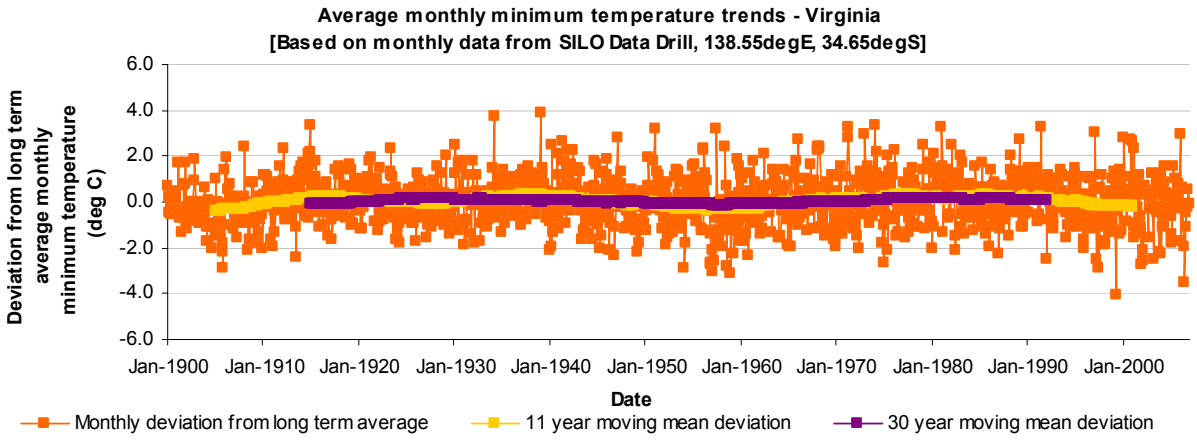


2. Virginia [138.55°E, 34.65°S]

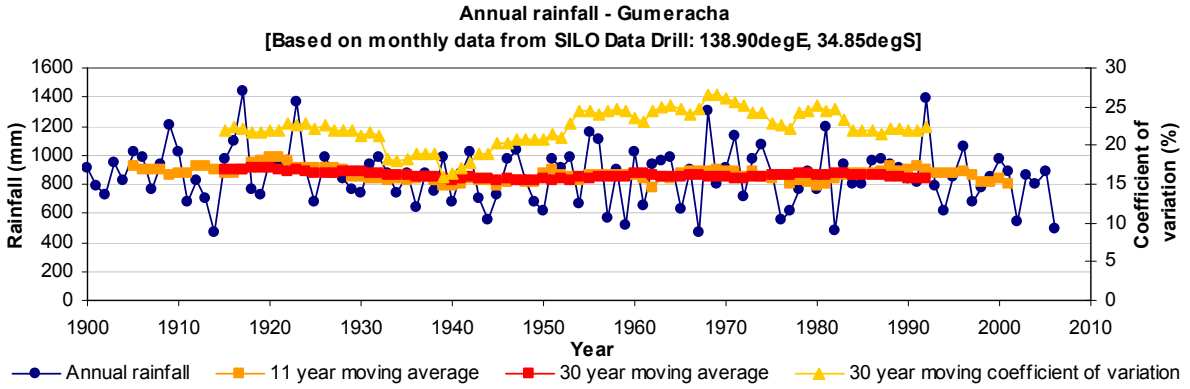


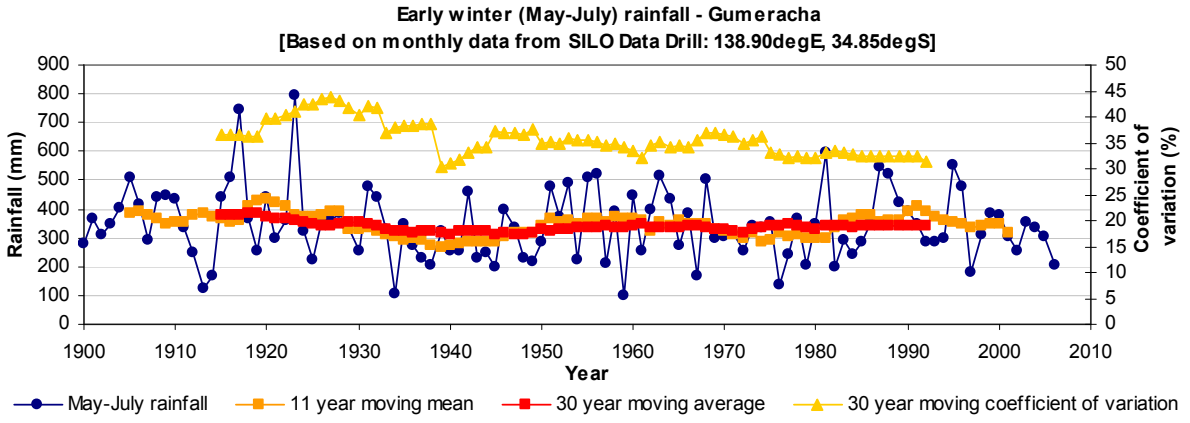


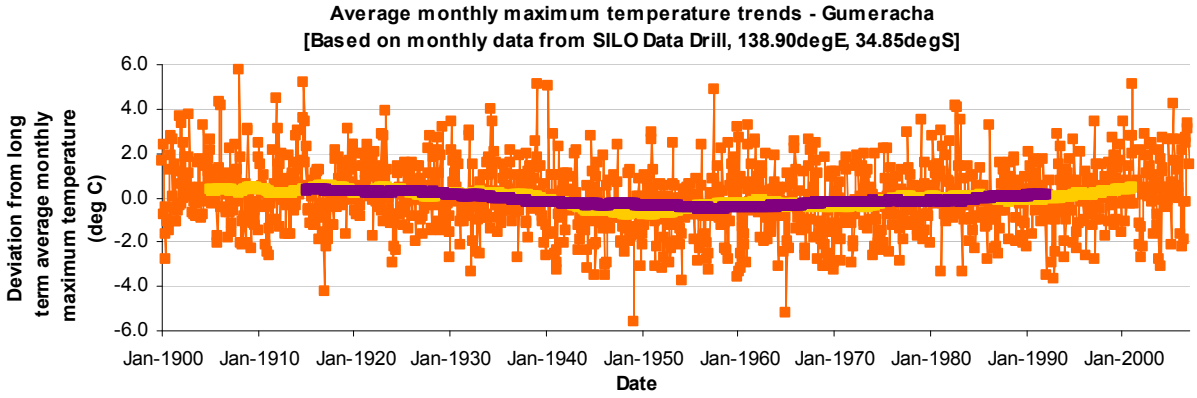


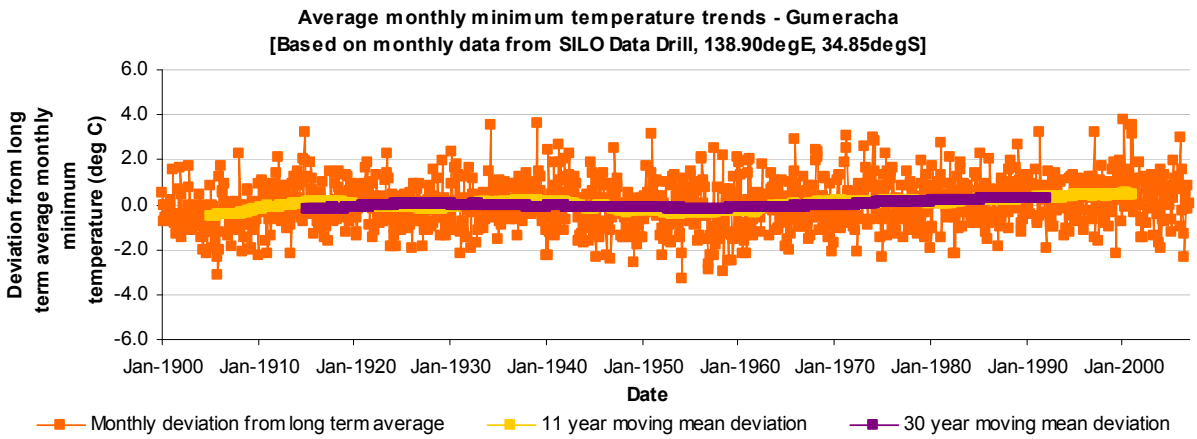


3. Gumeracha [138.90°E, 34.85°S]

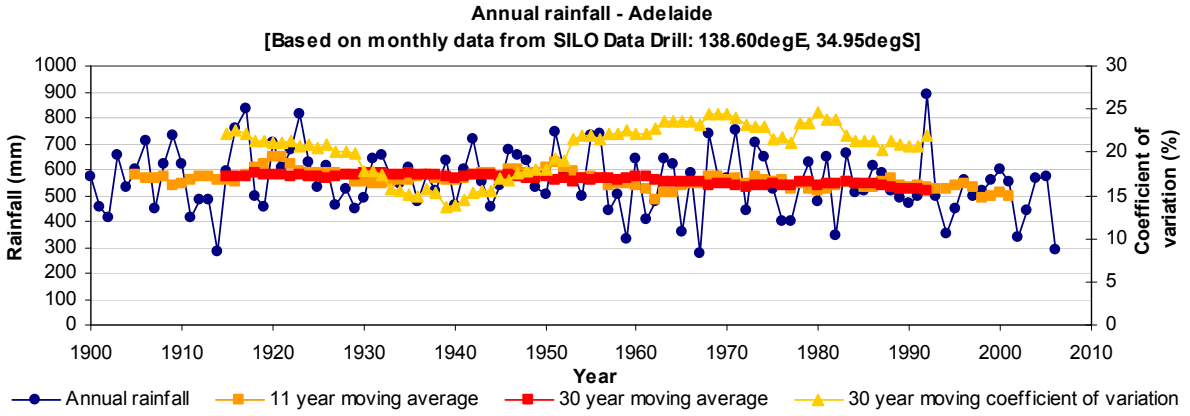


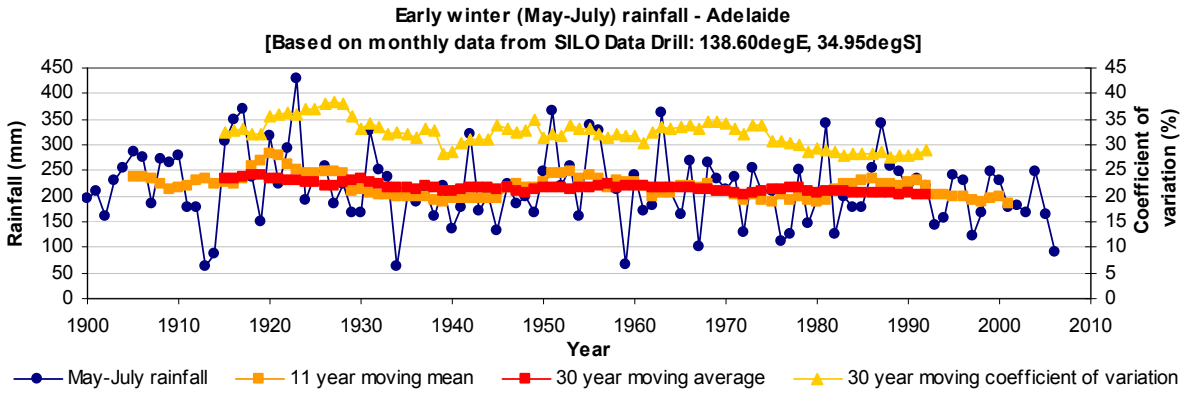


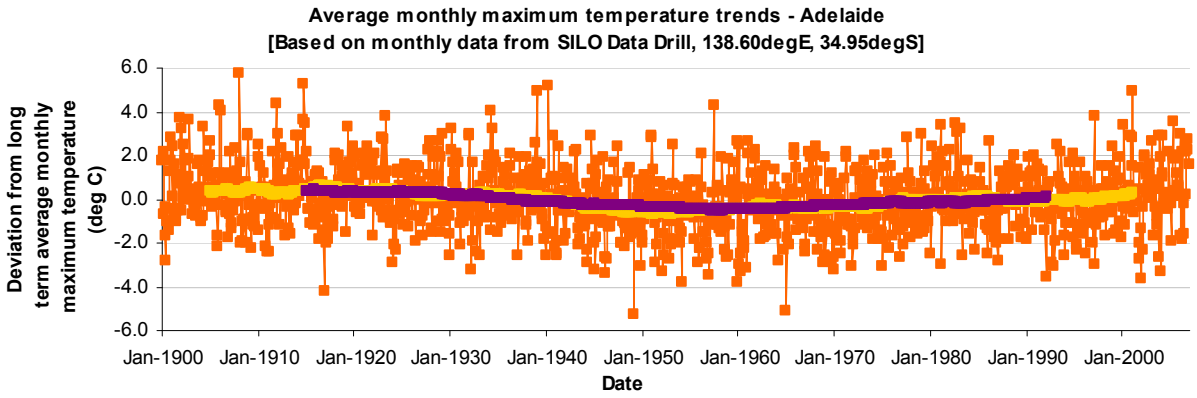


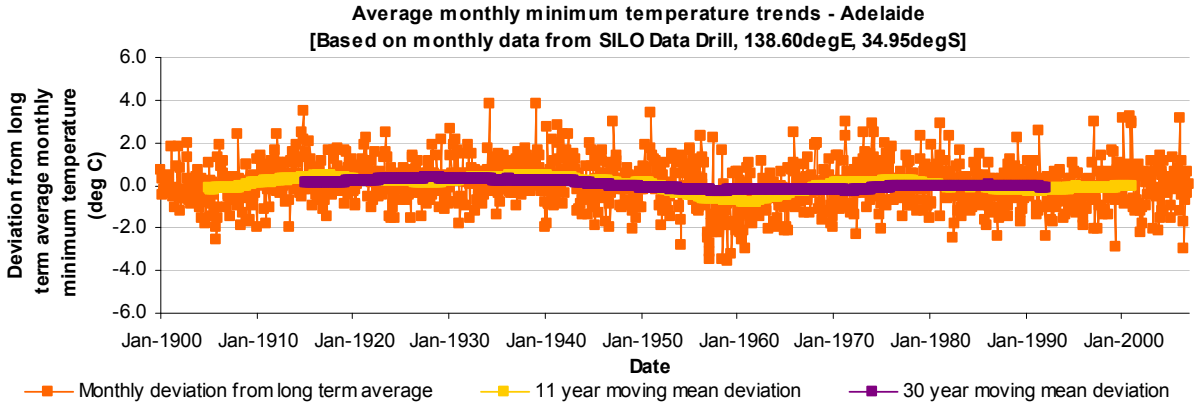


4. Adelaide [138.60°E, 34.95°S]

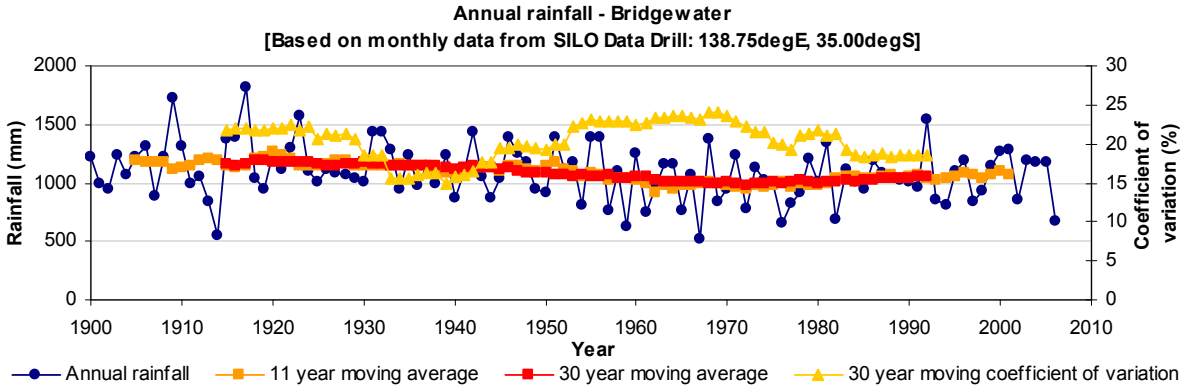


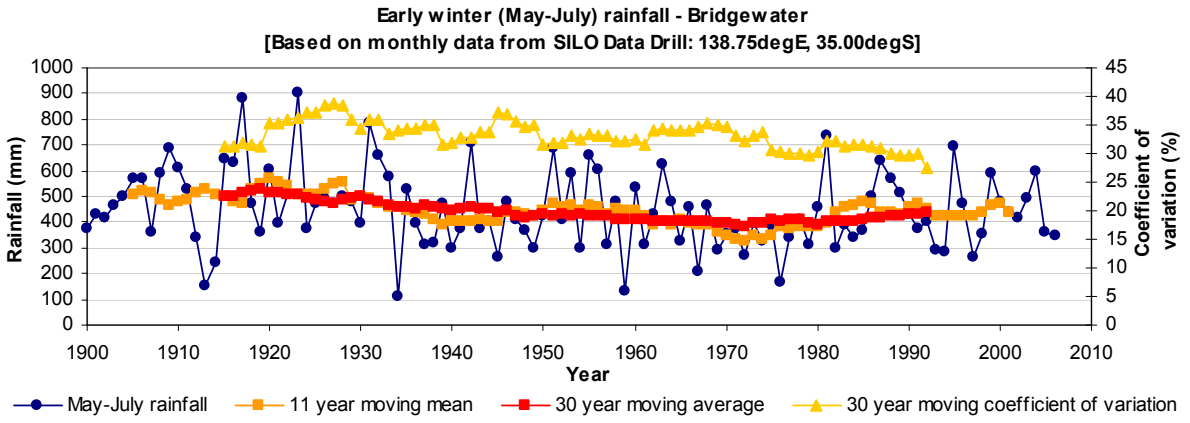


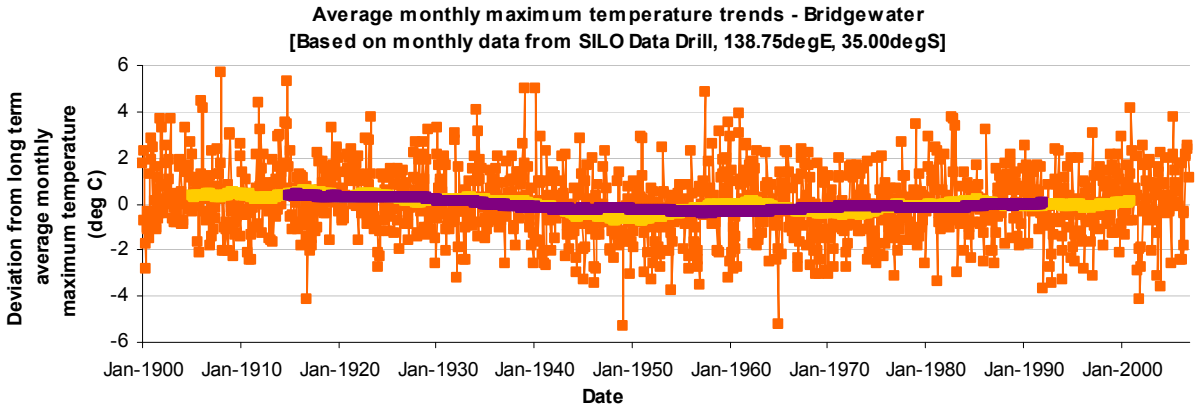


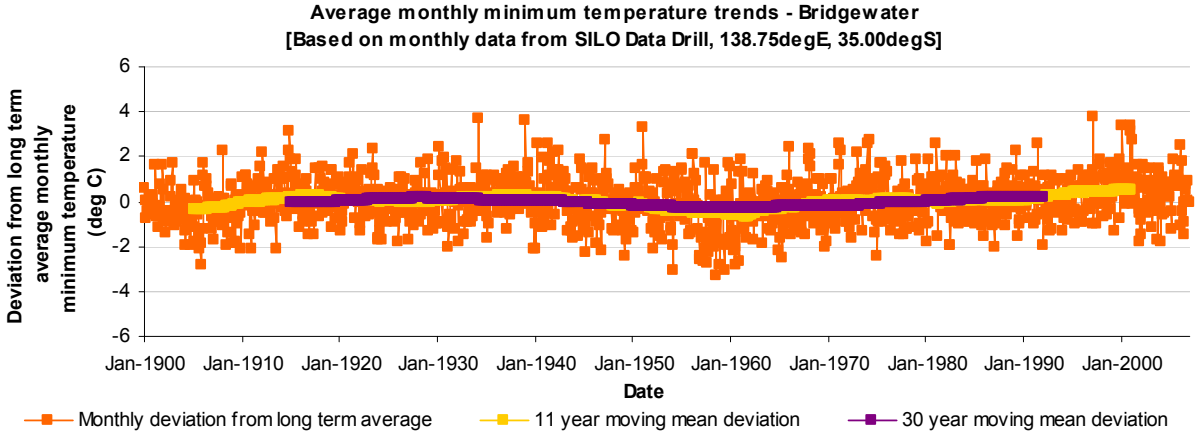


5. Bridgewater [138.75°E, 35.00°S]

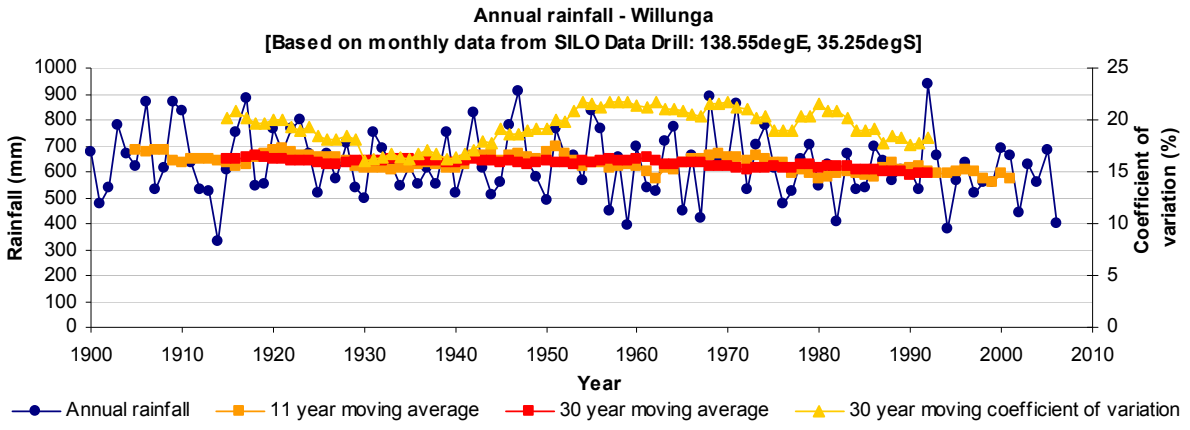


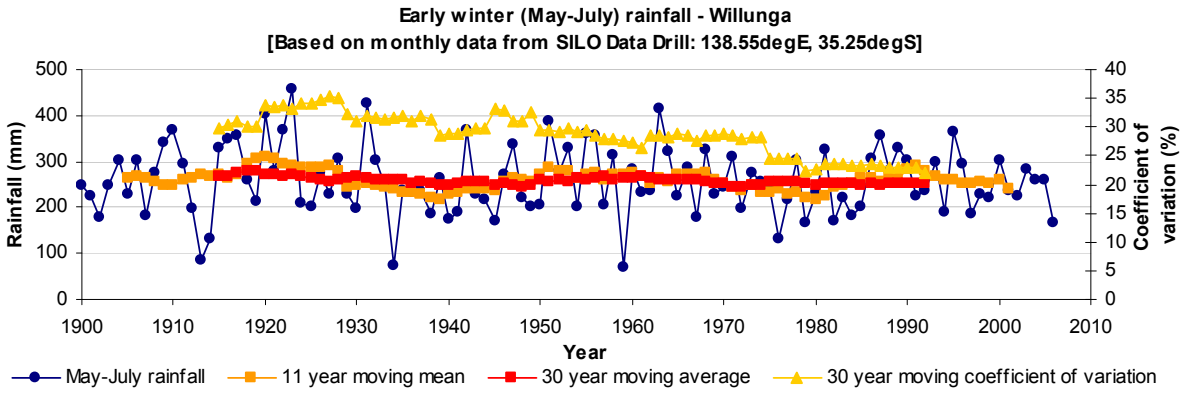


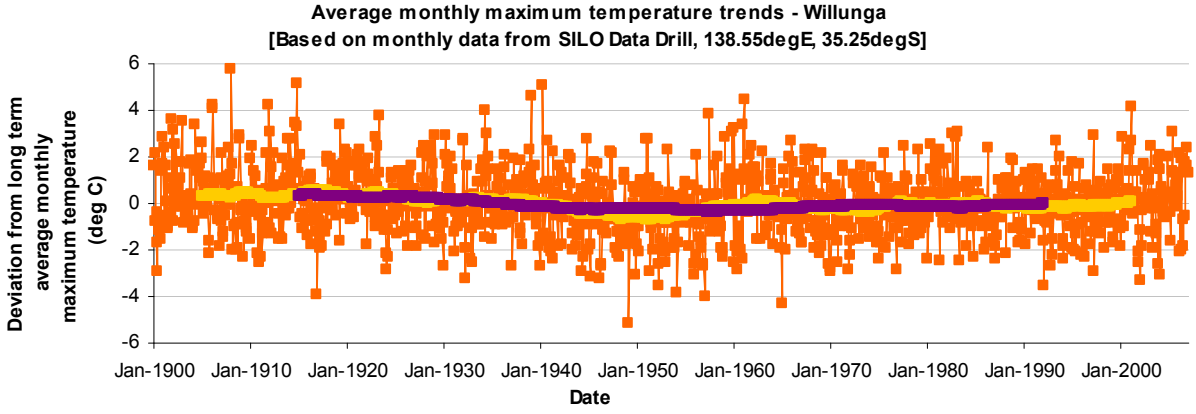


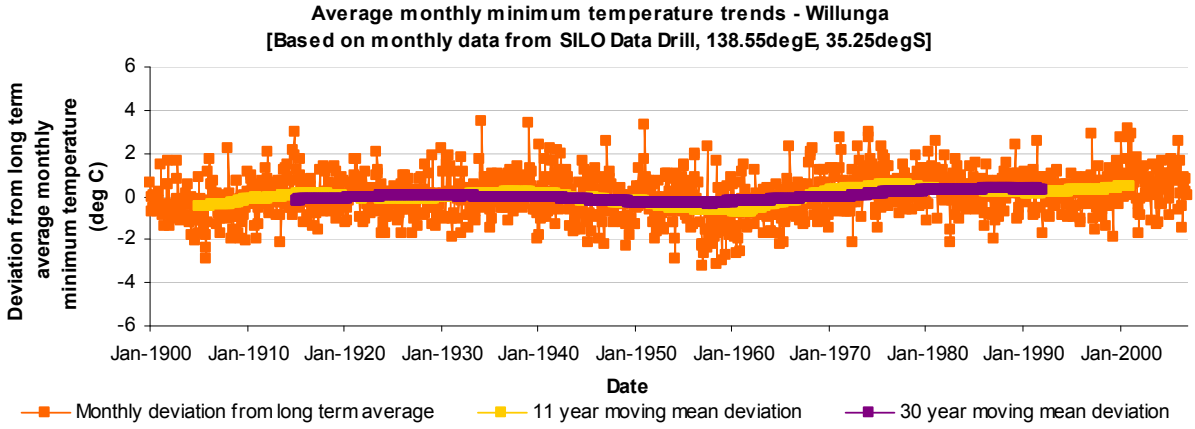


6. Willunga [138.55°E, 35.25°S]

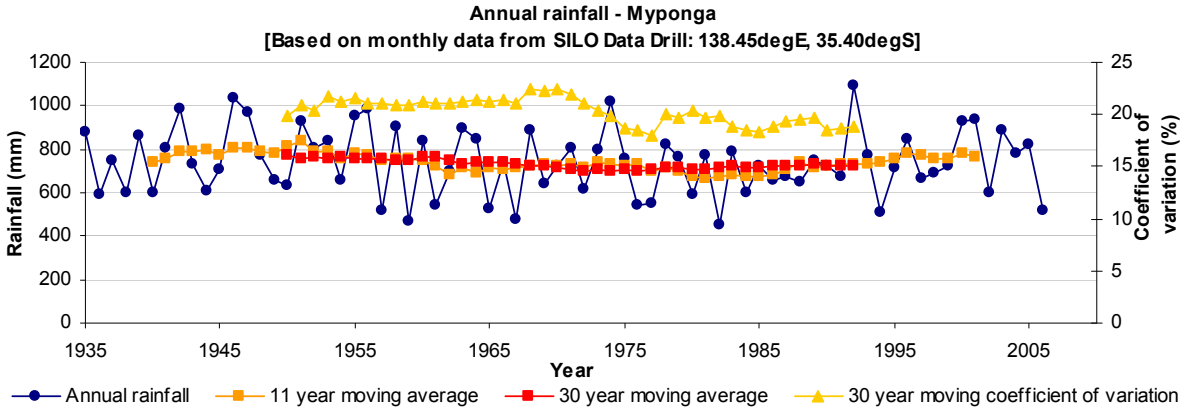


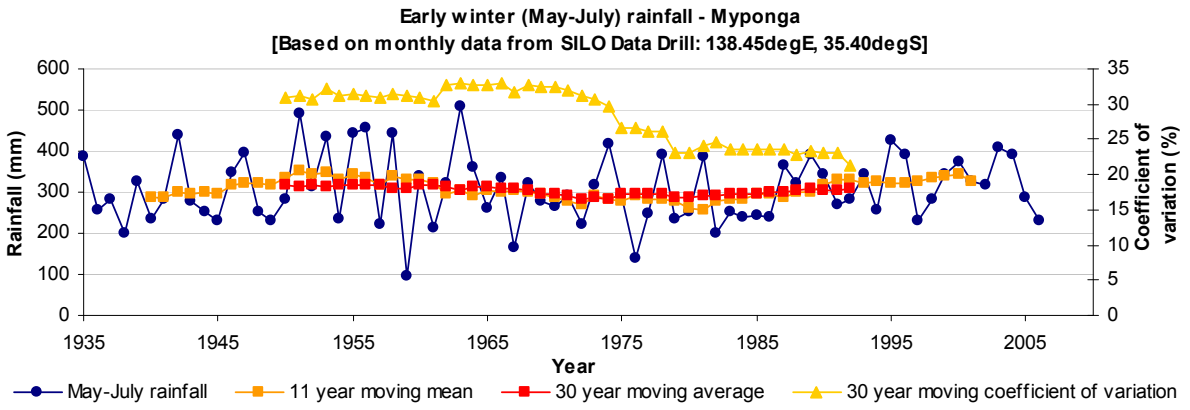


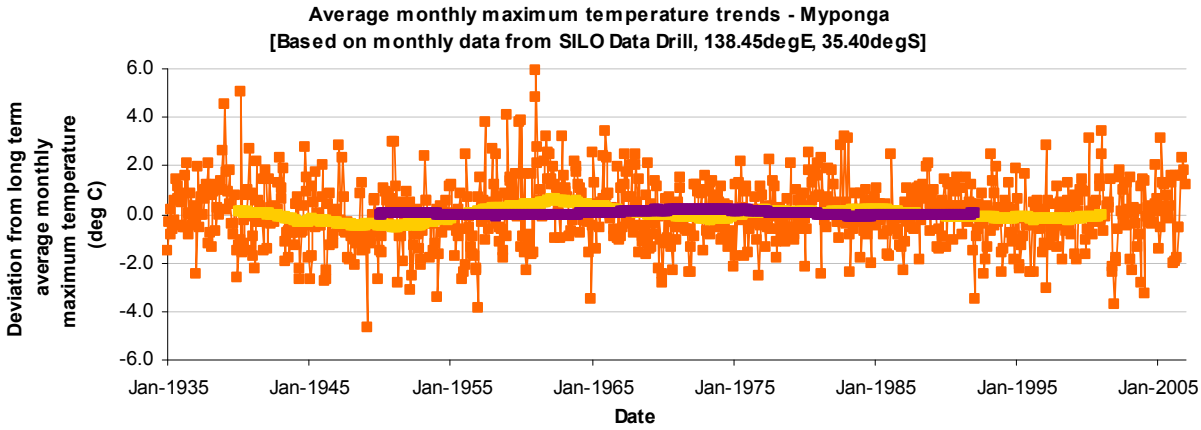


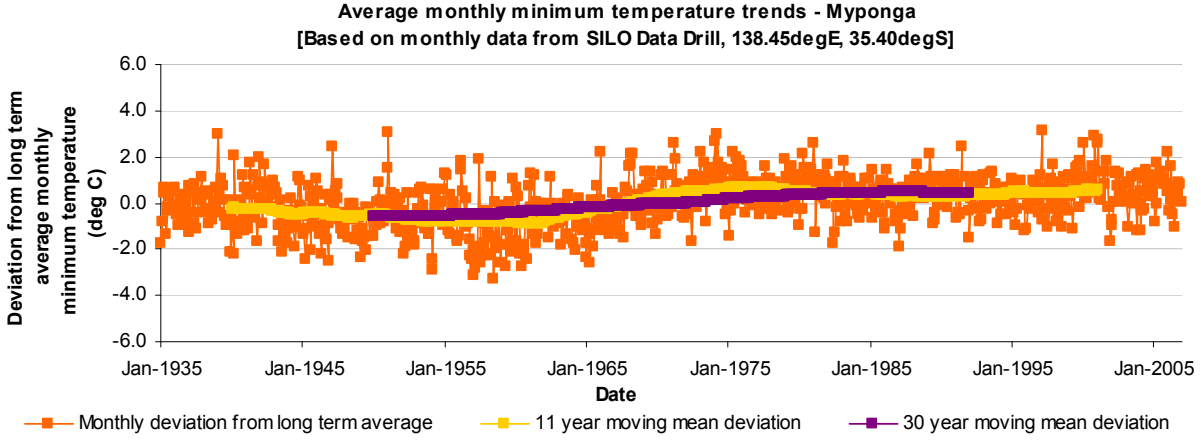


7. Myponga [138.45°E, 35.40°S]

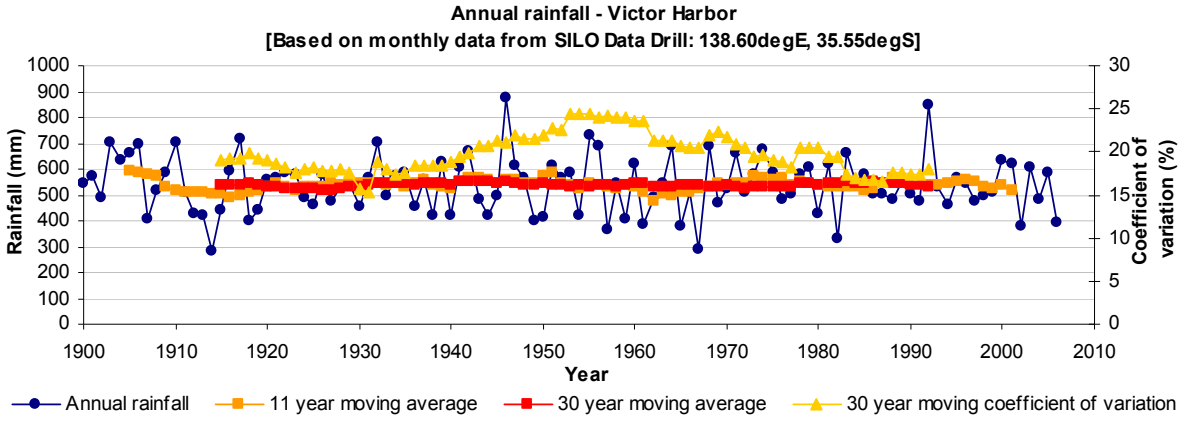


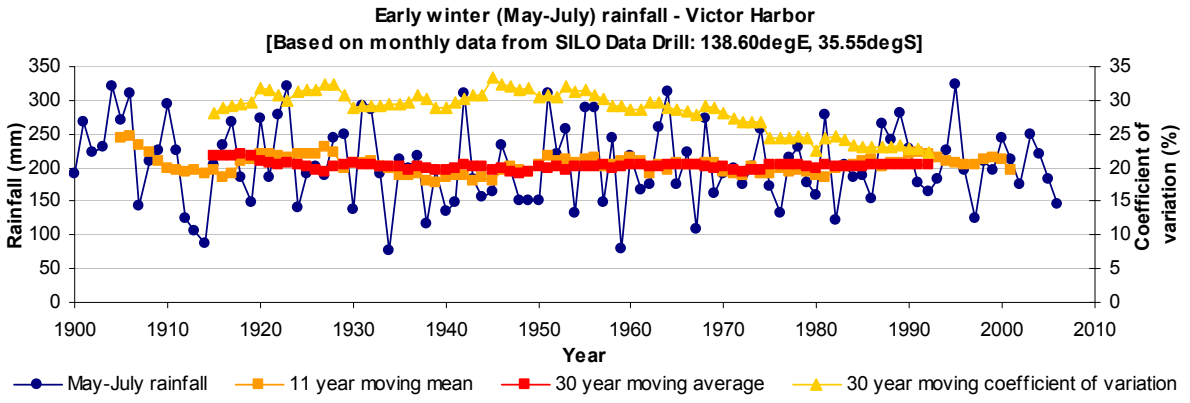


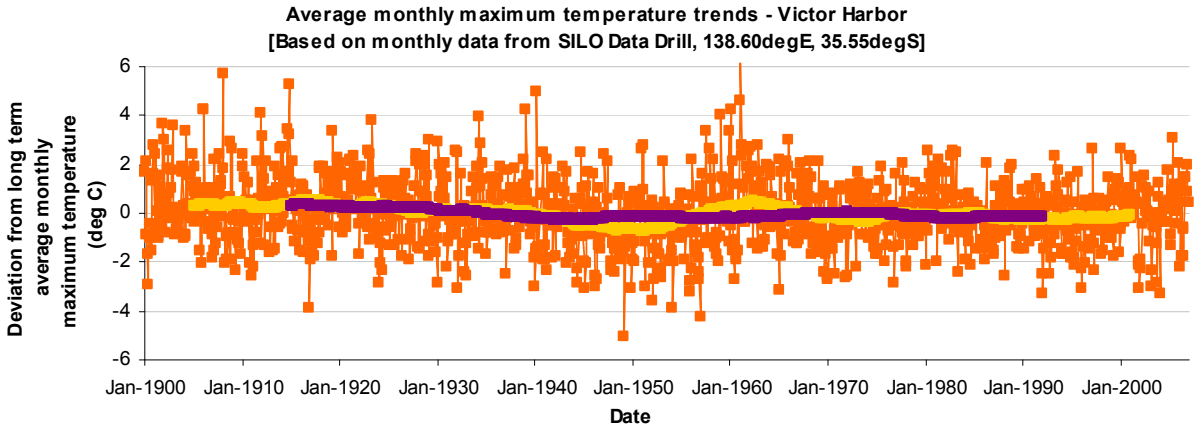


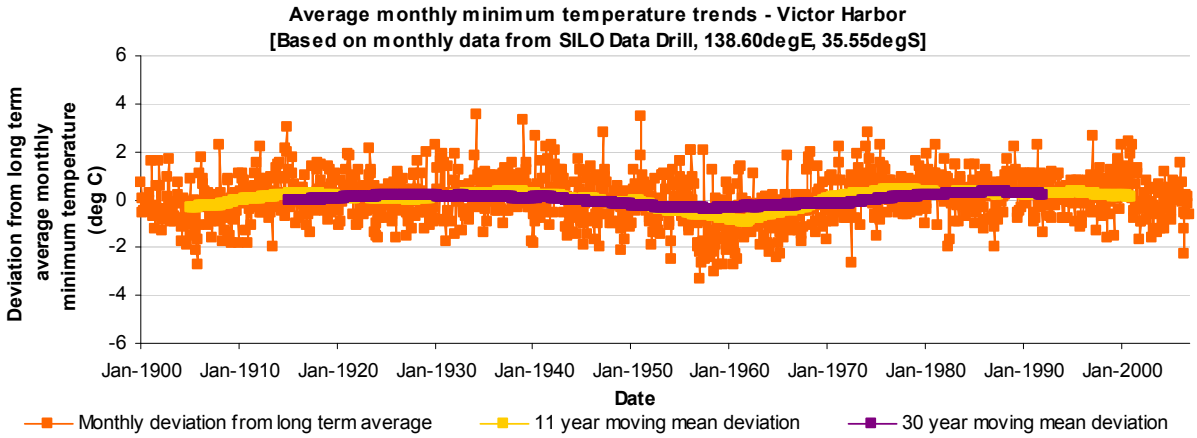


8. Victor Harbor [138.60°E, 35.55°S]









UNITS OF MEASUREMENT

Units of measurement commonly used (SI and non-SI Australian legal)

Name of unit	Symbol	Definition in terms of other metric units	Quantity
day	d	24 h	time interval
gigalitre	GL	10^6 m^3	volume
gram	g	10^{-3} kg	mass
hectare	ha	10^4 m^2	area
hour	h	60 min	time interval
kilogram	kg	base unit	mass
kilolitre	kL	1 m^3	volume
kilometre	km	10^3 m	length
litre	L	10^{-3} m^3	volume
megalitre	ML	10^3 m^3	volume
metre	m	base unit	length
microgram	μg	10^{-6} g	mass
microlitre	μL	10^{-9} m^3	volume
milligram	mg	10^{-3} g	mass
millilitre	mL	10^{-6} m^3	volume
millimetre	mm	10^{-3} m	length
minute	min	60 s	time interval
second	s	base unit	time interval
tonne	t	1000 kg	mass
year	y	365 or 366 days	time interval

Shortened forms

~	approximately equal to	ppb	parts per billion
bgs	below ground surface	ppm	parts per million
EC	electrical conductivity (μS/cm)	ppt	parts per trillion
K	hydraulic conductivity (m/d)	w/v	weight in volume
pH	acidity	w/w	weight in weight
pMC	percent of modern carbon		

GLOSSARY

Act (the) — In this document, refers to the *Natural Resources Management (SA) Act 2004,* which supercedes the *Water Resources (SA) Act 1997*.

Adaptation — Action in response to, or anticipation of, climate change to reduce or avoid adverse consequences or to take advantage of beneficial changes. Adaptation is usually distinct from actions to reduce greenhouse gas emissions.

Adaptive capacity — Reflects the capacity of a system to change in a way that makes it better equipped to deal with external influences via either autonomous or planned adaptation.

Adaptive management — A management approach often used in natural resources management where there is little information and/or a lot of complexity, and there is a need to implement some management changes sooner rather than later. The approach is to use the best available information for the first actions, implement the changes, monitor the outcomes, investigate the assumptions, and regularly evaluate and review the actions required. Consideration must be given to the temporal and spatial scale of monitoring and the evaluation processes appropriate to the ecosystem being managed.

AGO — Australian Greenhouse Office.

AMLR — Adelaide and Mount Lofty Ranges.

Biodiversity — (1) The number and variety of organisms found within a specified geographic region. (2) The variability among living organisms on the earth, including the variability within and between species and within and between ecosystems

Biological diversity — See 'biodiversity'.

Carbon trading scheme — Parties with emissions commitments trading their emission allowances with other parties.

Catchment — That area of land determined by topographic features within which rainfall will contribute to run-off at a particular point.

Climate change — A change in climate, which is attributed directly or indirectly to human activity, which alters the composition of the global atmosphere, and is in addition to natural climate variability observed over comparable time periods.

Climate projection — A projection of the response of the climate system to emission or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based upon simulations by climate models. Climate projections are distinguished from climate predictions by the more substantial degree of uncertainty in the underlying assumptions, e.g. regarding how future technological and economic trends may affect emissions.

Community — All South Australians including institutions and organisations.

CO_2 — Carbon dioxide.

CSIRO — Commonwealth Scientific and Industrial Research Organisation.

DEH — Department for Environment and Heritage (Government of South Australia).

DWLBC — Department of Water, Land and Biodiversity Conservation (Government of South Australia).

Ecological integrity — A measure of an ecosystems' functional (process) intactness and ability after a disturbance to a stable state.

Ecology — The study of the relationships between living organisms and their environment.

Ecosystem — Any system in which there is an interdependence upon, and interaction between, living organisms and their immediate physical, chemical and biological environment.

Ecosystem services — All biological, physical or chemical processes that maintain ecosystems and biodiversity and provide inputs and waste treatment services that support human activities.

Enhanced greenhouse effect — The greenhouse effect is the process where gases in the lower atmosphere such as carbon dioxide, methane and water vapour are warmed by radiation released by the earth's surface after it has been warmed by solar energy. These gases then radiate heat back towards the ground—adding to the heat the ground receives from the sun. The effect of naturally occurring greenhouse gases keeps the earth 33^{o}C warmer than it would otherwise be. The enhanced greenhouse effect refers to increases in the earth's atmospheric temperatures as a result of increased atmospheric concentrations of greenhouse gases due to human activities.

Environmental flow — Any managed change in a river or watercourse's flow pattern intended to maintain or improve the health of the river or watercourse.

EPA — Environment Protection Authority (Government of South Australia).

Erosion — Natural breakdown and movement of soil and rock by water, wind or ice: the process may be accelerated by human activities.

Estuaries — Semi-enclosed water bodies at the lower end of a freshwater stream that are subject to marine, freshwater and terrestrial influences, and experience periodic fluctuations and gradients in salinity

Exposure — Relates to the important weather events and patterns that affect the system and broader influences such as the background climate conditions against which a system operates and any changes in those conditions. Exposure is influenced by a combination of the probability and magnitude of climate change.

Extreme event — Weather conditions that are rare for a particular place and/or time such as an intense storm or heat wave

Fire regime — The intensity, frequency and season of fire in the landscape.

Fragmentation — The division or separation of natural areas by the clearance of native vegetation for human land uses, isolating remnants and species and affecting genetic flow.

Greenhouse effect — The balance of incoming and outgoing solar radiation which regulates our climate. Changes to the composition of the atmosphere, such as the addition of carbon dioxide through human activities, have the potential to alter the radiation balance and to effect changes to the climate. Scientists suggest that changes would include global warming, a rise in sea level and shifts in rainfall patterns.

Greenhouse gas emissions — The release of greenhouse gases into the atmosphere. A greenhouse gas is an atmospheric gas that absorbs and emits infrared or heat radiation, giving rise to the greenhouse effect (e.g. carbon dioxide, methane, nitrous oxide, etc.).

Groundwater — Water occurring naturally below ground level or water pumped, diverted and released into a well for storage underground: see also ‘underground water’.

Habitat — The natural place or type of site in which an animal or plant, or communities of animals and plants, live.

Hazard — A situation or condition with potential for loss or harm to the community or environment.

Indigenous species — A species that occurs naturally in a region.

Integrated natural resources management (NRM) — A holistic, long-term approach to natural resources management that, while retaining the benefits and efficiencies of sectoral management and associated expertise, also brings together the considerations and expertise of all sectors.

Intensive farming — A method of keeping animals in the course of carrying on the business of primary production in which the animals are confined to a small space or area and are usually fed by hand or mechanical means.

Invasive species — An animal, plant or pathogen that is a risk to indigenous species, ecosystems and/or agricultural ecosystems and/or human health and safety.

IPCC — Intergovernmental Panel on Climate Change.

Irrigation — Watering land by any means for the purpose of growing plants.

Landscape — A heterogeneous area of local ecosystems and land uses that is of sufficient size to achieve long-term outcomes in the maintenance and recovery of species or ecological communities, or in the protection and enhancement of ecological and evolutionary processes.

Long-term — No strict definition, although in this study normally refers to a period of 10–100 years (see also short-term).

Model — A conceptual or mathematical means of understanding elements of the real world that allows for predictions of outcomes given certain conditions. Examples include estimating storm run-off, assessing the impacts of dams or predicting ecological response to environmental change.

Natural resources — Soil, water resources, geological features and landscapes, native vegetation, native animals and other native organisms, ecosystems.

NRM — natural resources management: all activities that involve the use or development of natural resources and/or that impact on the state and condition of natural resources, whether positively or negatively.

NatureLinks — A vision and framework for an ecologically sustainable future for South Australia, through planning and the development of partnerships, to integrate landscape scale biodiversity management with regional development and NRM (DWLBC 2006).

Pasture — Grassland used for the production of grazing animals such as sheep and cattle.

Peak oil — The theory that the world's oil production rate (e.g. barrels of oil produced per year) will reach an all time maximum and then decline. This has potential implications for inflation of energy prices if oil production falls behind growing global demand.

Peri-urban — Areas around the edge or fringe of urban areas.

PIRSA — Primary Industries and Resources South Australia (Government of South Australia).

Precautionary principle — Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

Prescribed water resource — A water resource declared by the Governor to be prescribed under the Act, and includes underground water to which access is obtained by prescribed wells. Prescription of a water resource requires that future management of the resource be regulated via a licensing system.

Projection — See 'Climate projection'.

Radiative forcing — The change in the net vertical irradiance at the tropopause due to an internal change or a change in the external forcing of the climate system, such as, for example, a change in the concentration of carbon dioxide or the output of the Sun.

Regional NRM Board — A body established under Chapter 3 Part 3 and includes a body appointed under that Part to be a regional NRM board under The Natural Resources Management Act (South Australia) 2004.

Reserve area — An area of land and/or sea especially dedicated to the protection and maintenance of native biodiversity, and associated natural and cultural resources, that is managed through legal or other effective means.

Resilience — The ability of a system to withstand and recover from stresses and disturbances.

Riparian zone — That part of the landscape adjacent to a water body that influences and is influenced by watercourse processes. This can include landform, hydrological or vegetation definitions. It is commonly used to include the in-stream habitats, bed, banks and sometimes floodplains of watercourses.

Risk — A probable measure of the consequence of a threat acting on an asset, typically expressed as a product of likelihood and consequence. Risk can also be a measure of the probability of management actions not delivering the desired outputs and outcomes.

SA — South Australia.

SARDI — South Australian Research and Development Institute, a division within PIRSA.

Sensitivity — Reflects the responsiveness of systems to climatic influences and the degree to which changes in climate might affect it in its current form; the threshold points at which affects will be exhibited, whether change will occur in trends or steps and whether they will be reversible.

Short-term — No strict definition, although in this study normally refers to a period of 0–10 years (see also long-term).

Stormwater — Run-off in an urban area.

Surface water — (1) water flowing over land (except in a watercourse), (a) after having fallen as rain or hail or having precipitated in any another manner, (b) or after rising to the surface naturally from underground; (2) water of the kind referred to in paragraph 1 that has been collected in a dam or reservoir.

Sustainability — The ability of an ecosystem to maintain ecological processes and functions, biological diversity, and productivity over time.

Vulnerability — The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes

Water allocation plan — A plan developed to manage prescribed water resources through providing a system for the allocation and transfer of water via water licences at a sustainable rate of use that establishes an equitable balance between environmental, social and economic needs for the water. Water allocation plans may also set up rules to regulate water affecting activities such as the drilling of wells and construction of dams through permits.

Water-dependent ecosystems — Those parts of the environment, the species composition and natural ecological processes, that are determined by the permanent or temporary presence of flowing or standing water, above or below ground: the in-stream areas of rivers, riparian vegetation, springs, wetlands, floodplains, estuaries and lakes are all water-dependent ecosystems.

Water sensitive urban design — The aim of water sensitive urban design is to ensure that development is designed, constructed and maintained to minimise negative effects of urban development on natural hydrological regimes and water quality while minimising water consumption and maximising opportunities for water harvesting and re-use

Wetlands — Defined by the Act as a swamp or marsh and includes any land that is seasonally inundated with water. This definition encompasses a number of concepts that are more specifically described in the definition used in the Ramsar Convention on Wetlands of International Importance. This describes wetlands as areas of permanent or periodic to intermittent inundation, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salty, including areas of marine water, the depth of which at low tides does not exceed six metres.

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