Limits to Adaptation

Climate change adaptation in the Coorong, Murray Mouth and Lakes Alexandrina and Albert

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Synthesis and Integrative Research Program

NCCARF Synthesis and Integrative Research Program
The Limits to Adaptation

Climate Change Adaptation in the Coorong, Murray Mouth and Lakes Alexandra and Albert

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

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Preface

The National Climate Change Research Facility (NCCARF) is undertaking a program of Synthesis and Integrative Research to synthesise existing and emerging national and international research on climate change impacts and adaptation. The purpose of this program is to provide decision-makers with information they need to manage the risks of climate change.

This report on "***Climate change adaptation in the Coorong, Murray Mouth and Lakes Alexandrina and Albert***" forms part of a series of studies/reports commissioned by NCCARF that look at the limits to adaptation. The notion of 'limits to adaptation' is fundamentally concerned with identifying the thresholds at which actions to adapt cease to reduce vulnerability. Much of the research on adaptation avoids the question of what adaptation cannot achieve. It is therefore implied by omission that adaptation can avoid all climate impacts. Yet this is clearly not going to be the case for many systems, sectors and places at even modest rates of warming, let alone at the more rapid rates of warming that now seem almost inevitable. Understanding the limits to adaptation is an emerging frontier of climate change research. It is important for decision making about adaptation for three reasons.

Firstly, it helps to determine which responses to climate change are both practicable and legitimate, and the time scales over which adaptation may be considered to be effective. Secondly, it helps to understand how people may respond to the damage to, or the loss of, things that are important to them, for which there may, in some cases, be substitutes or ameliorating policy measures. Thirdly, it can help prioritise adaptation strategies, refine their intentions, and identify communities that will be served by them.

This report identifies and documents limits to adaptation and adaptation pathways for the Coorong Wetlands. It seeks to determine the extent to which acceptable substitutes can be found for things that are lost, for example because of climate change. It uses participatory approaches to ensure local knowledge, perspectives and information take their place alongside scientific knowledge when examining limits to adaptation and adaptation pathways. In this manner the project provides substantial support for capacity building and exchange of knowledge between community-based and technical organisations.

Other reports in the series are:

- *Limits to climate change adaptation in the Great Barrier Reef: scoping ecological and social limits;*
- *Climate change adaptation in the Australian Alps: impacts, strategies, limits and management;*
- *Limits to climate change adaptation in floodplain wetlands: the Macquarie Marshes;*
- *Limits to climate change adaptation for two low-lying communities in the Torres Strait;* and,
- *Limits and barriers to climate change adaptation for small inland communities affected by drought.*

To highlight common learnings from all the case studies, a brief synthesis has been produced which is a summary of responses and lessons learned.

All reports are available from the website at www.nccarf.edu.au.

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1. EXECUTIVE SUMMARY

The Coorong and Lakes Region offers critical lessons for adapting to climate change because it is at the end of the iconic River Murray, and comprises a large and complex wetland system of international environmental importance by the coast. It is the traditional country of the Ngarrindjeri Nation and supports vibrant communities. The Region has been subject to continual environmental change, from a range of natural drivers in prehistoric times to the more recent human drivers of change, including a succession of environmentally damaging semi-permanent technological interventions created since the time of European settlement.

This research project investigates adaptation to climate change in the Coorong and Lakes Region from a number of angles and perspectives. It is one part of the National Climate Change Adaptation Research Facility (NCCARF) program of seven Australian geographically-based projects exploring the "limits to adaptation" and adaptation options in ecologically sensitive areas, such as wetlands, alpine areas and coastal areas. In this context adaptation includes social adaptation to changing climatic conditions as well as ecological adaptation. Climate change adaptation has been investigated from a holistic perspective that examines connections between the social, institutional and ecological elements of this complex system. The research explores limits to adaptation, adaptation options, vulnerability, resilience and environmental health from an historical perspective and by examining the current situation to assess future adaptation options. The project delivers findings in two main areas. First, at a localised regional level the project answers specific climate change research questions related to the Coorong and Lakes Region and offers conclusions and recommendations to enhance adaptation. Second, at a broader level, the research delivers findings for the research community in relation to notions of adaptation and limits to adaptation.

Our key findings regarding adaptation are that:

1. There are many local adaptations and adaptation options which to a greater or lesser extent concern water availability, the bigger picture of national water policy, water sharing arrangements at the state level and impacts due to climate change. A key "limit" or barrier to climate change adaptation in the Region concerns the availability of water and arrangements for sharing water;

2. These local adaptation options have not been openly discussed or put "on the table" for discussion at the same time. This is due, in part, to bureaucratic and political constraints; inadequate community engagement; prior episodes of social conflict and division; several parallel, but generally unconnected planning initiatives and lack of institutional arrangements to develop a truly long-term perspective. An important "limit" or barrier to climate change adaptation in the Region concerns a lack of institutional capacity to create trust and effective working relationships between communities, governments and scientists;

3. For each adaptation option there is a set of anticipated and unanticipated consequences some of which will be seen as positive adaptation and others as maladaptations. Other adaptations will only work with a limited range of conditions. Decisions about these can be informed by better scientific knowledge, but will involve societal value judgements on managing risk, tradeoffs between ecosystem services, and the desired future. An approach is required in which these can be discussed and in which all perspectives are respectfully considered in determining the most appropriate outcome. Another "limit" or barrier is an inability to learn from the past and consider all perspectives for future adaptation options;

4. A new regional institution is recommended, one in which local communities, including the Ngarrindjeri Nation, are respected for their local knowledge and capacity for innovation, and can play a major part in formulating a vision for the area, ongoing management, including for climate change adaptation. Therefore we recommend an institutional arrangement that is based on an adaptive management approach because there are many unknowns in adapting to the impacts of climate change: long-term planning can benefit from an understanding of what has gone on before and a continuing reminder of lessons learned from prior adaptive experiences. While we understand that there may not be political support for the establishment of a new institution, major changes are required in current institutions and community-oriented practices to enhance planning and adaptive management.

Summary of recommendations:

1. Planning for climate change adaptation and water management:
    - Climate change adaptation should be mainstreamed into water management.
    - The Federal government's proposed Murray-Darling Basin plan is an opportunity to integrate non-climate and climate induced reforms into water management: large reallocations for environmental flows would greatly aid the Region;
    - A genuinely anticipatory and long-term approach to management of the Region with climate change is required. Dedicated institutions are required to develop, implement and adaptively manage long-term plans;
    - A long-term plan should consider the two major long-term drivers of change in the Region: inflows from the Murray-Darling Basin and ongoing climate change impacts.

2. Establish institutions that can better manage the Region with climate change:
    - Include the Ngarrindjeri Nation in influential roles in ownership and management structures for the Region;
    - Develop and sustain ongoing relationships with the community;
    - Consolidate planning in the Region and reinforce scientific research;
    - Enhance governance institutions for better management of the Region - options include: increasing investment in state government agencies; enhancing Natural Resource Management Boards; establishing a consensus-based Council; and setting up a regional Coorong and Lakes statutory authority.

3. Enhance support for adaptation to climate change through effective implementation of the Ramsar Convention on Wetlands.

4. Implement new adaptation measures and better assess other options for the Region. These include: adoption of an adaptive management vision for the desired environmental state; development of assessment guidelines; initiation of community engagement on a long-term basis to consider adaptation options; and implementation of clearly beneficial adaptation measures such as increasing environmental flows from the River Murray.

Response to Research Questions:

1. *Assuming there will be no planned adaptation, what are the likely impacts of climate change (in association with other known drivers of vulnerability)? For whom will these impacts be a problem?*

    The impacts of over extraction of water in the Murray-Darling Basin and climate change are inextricably linked. Without increased environmental flows desiccation events will increase in frequency in the Lakes and the Coorong would become increasingly saline leading to loss of biodiversity and fisheries. The values for which the Region was designated as wetland of international importance under the Ramsar

Convention would be lost. Cultural and recreational values and natural resource based industries would decline. Maintaining the Barrages against desiccation then sea level rise would become increasingly difficult. High sea level rise would overtop the Barrages.

2. *What adaptation strategies are available? Will (can) these strategies address all the climate risks that concern all potential stakeholders?*

   The primary adaptation strategy that would maximize environmental and socio-economic benefits in the Region under all conditions is to increase environmental flows from the River Murray, and to a lesser extent, the South Australian catchments. Better catchment management in South Australia is a 'no regrets' measure that would provide modest additional benefits. A suite of engineering interventions have been proposed. Some would be most beneficial, such as restoring the historic width of the Narrung Narrows and increased inflows from the South East Drainage System. Other "environmental works and measures" have substantial costs as well as possible benefits, are contested and require better knowledge and societal consent if they are to be considered further. It is unlikely that the Barrages can be maintained in the long term with sea level rise and this means that environmental flows will be required in the lower River Murray to maintain estuarine conditions and access to consumptive water. "Translucent" operation of the Barrages is one option that should be considered. Under all these conditions more effective institutions are required for regional adaptive management.

3. *Assuming climate stabilises at 1.03oC above pre-industrial levels, what seem to be the likely residual impacts of climate change after adaptation has taken place? For whom will these impacts be a problem?*

   This low level of climate change is an unrealistic scenario as past emissions have committed the world to around a 2oC warming now. If warming was reduced to this level then sound reallocation of an additional 4,000 GL pa or more for environmental flows through a Basin Plan could maintain moderately healthy ecosystems.

4. *Assuming warming exceeds 1.6oC above pre-industrial levels, what seem to be the likely residual impacts of climate change after adaptation has taken place? For whom will these impacts be a problem?*

   CSIRO modelling of this scenario suggests that inflow from the River Murray into the Region could increase by up to 20% or decline by as much as 69% by 2030, but less inflows are anticipated. At this level of moderate climate change the effectiveness of adaptation depends on reallocating substantially more water to environmental flows, which will become more difficult as the cheaper reallocation options are exhausted. The Guide to the Murray-Darling Basin Plan suggested that 7,600 GL were required for a low risk of degradation of key ecological assets. Reallocation of less water risks more frequent desiccation as experienced in the Millennium Drought, increasing salinity and substantial loss of biodiversity. Desiccation episodes would be felt through the loss of the Ngarrindjeri's cultural and economic base, as well as reduced fishing, constricted boat movements, loss of tourism and reduced water for livestock. The extent of sea level rise is difficult to forecast with this degree of warming, in particular, whether it would overtop the Barrages.

5. *Assuming warming exceeds 4oC above pre-industrial levels, what seem to be the likely residual impacts of climate change after adaptation has taken place? For whom will these impacts be a problem?*

   This high level of climate change would see substantial sea level rise that would overtop the Barrages and see the Region transition to a more marine state. Inflows from the River Murray have not been modelled with this level of warming, but with much greater evapotranspiration less water could be anticipated. Environmental flows will be required in the lower River Murray to maintain access to consumptive water and estuarine conditions in the lakes. Many species and ecological communities would be lost due to higher salinity. The Ngarrindjeri would suffer from loss of traditional economic resources and cultural sites. Some agricultural enterprises would be inundated or lack sufficient access to freshwater to continue. Some sectors of the community may be maintained by a marine lakes system, including the boating, fishing and tourism sectors.

6. *Given anticipated losses, are there substitutes for things that are lost that would be acceptable to affected parties?*

   The capacity to adapt and substitute varies considerably. It may be possible to maintain small refugia for some biodiversity, for example for some freshwater species in Currency Creek and the Finniss River. Other biota would almost certainly be lost, for example, Ruppia sp. aquatic communities and wading bird habitat in the south lagoon of the Coorong. It is unlikely that the traditional economic base of cultural resources of the Ngarrindjeri people could be replaced to their satisfaction. Displaced people and agricultural businesses could potentially move elsewhere if their finances allowed.

2. PROJECT INTRODUCTION

2.1. The project location and aims

The Coorong and Lakes Alexandrina and Albert are located at the terminus of the River Murray in South Australia where the river discharges to the Southern Ocean (Figures 1 and 2). More particularly, the often called “Coorong wetlands” were investigated to determine “where there may be limits to adaptation that seeks to sustain the health of ecosystems, and the businesses, communities and cultures that depend on it” as part of a suite of seven Australian geographically-based projects to “deliver insights around the national understanding of limits to adaptation” as part of the National Climate Change Adaptation Research Facility (NCCARF) program.

Within this context this work aims to: determine which responses to climate change are both practicable and legitimate, and the time scales over which adaptation may be considered to be effective; understand how people may respond to the damage to, or the loss of, things that are important to them, for which there may, in some cases, be substitutes or ameliorating policy measures; prioritise adaptation strategies, refine their intentions, and identify communities that will be served by them (NCCARF Call for Proposals: http://www.nccarf.edu.au/node/483).

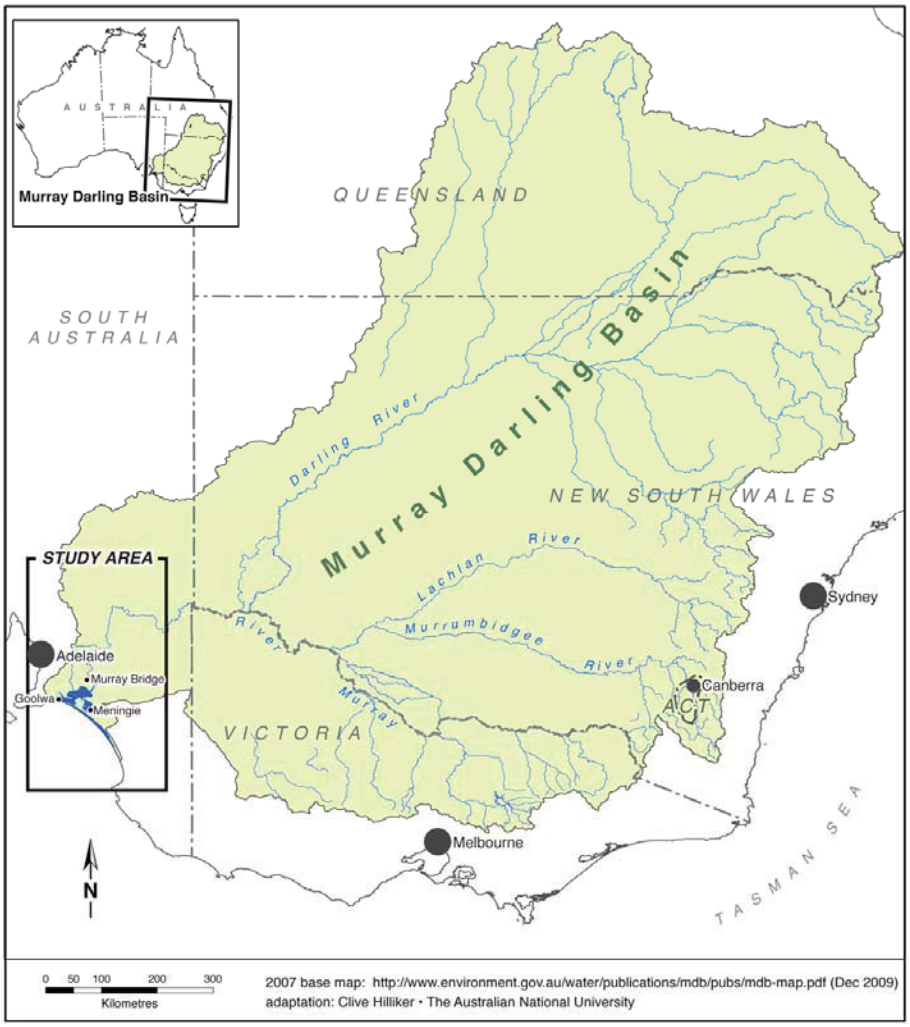

Figure 1. Location of the study area in the Murray-Darling Basin

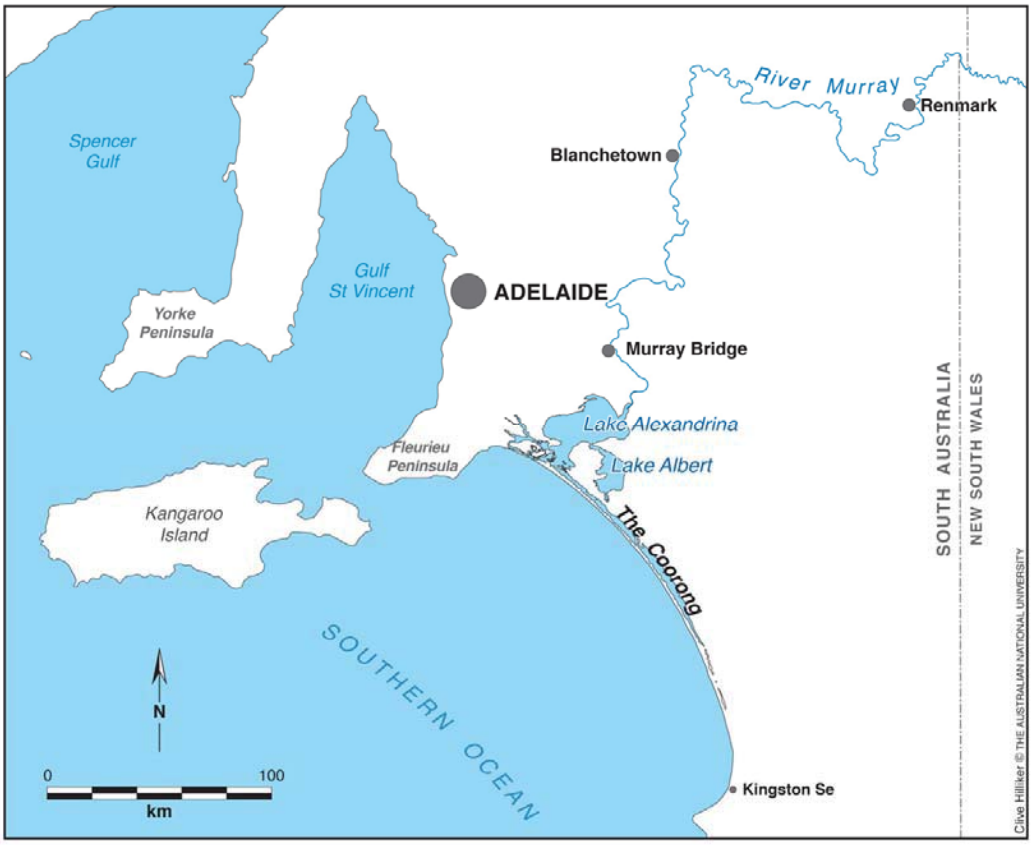

Figure 2. Location of the Coorong and Lakes Alexandrina and Albert in South Australia

Colloquially, “the Coorong” is often, but geographically inaccurately, used to describe a much larger, interconnected wetlands system that forms the focus of this project. The Region is often called the “Coorong, Lower Lakes and Murray Mouth” or “CLLaMM”, and is referred to as the “Region” or “Coorong and Lakes” in this report. The geographical area covered includes: the mouth of the River Murray, the Coorong – a back-barrier lagoon; Lakes Alexandrina and Albert further inland – that have been managed as freshwater systems’ and the lower end of the River Murray channel below Lock 1 at Blanchetown (Figure 2). The main part of the Region, including The Coorong National Park and the Coorong and Lakes Alexandrina and Albert, is designated as a Ramsar Wetland of International Importance (Figure 3) (Phillips and Muller 2006).

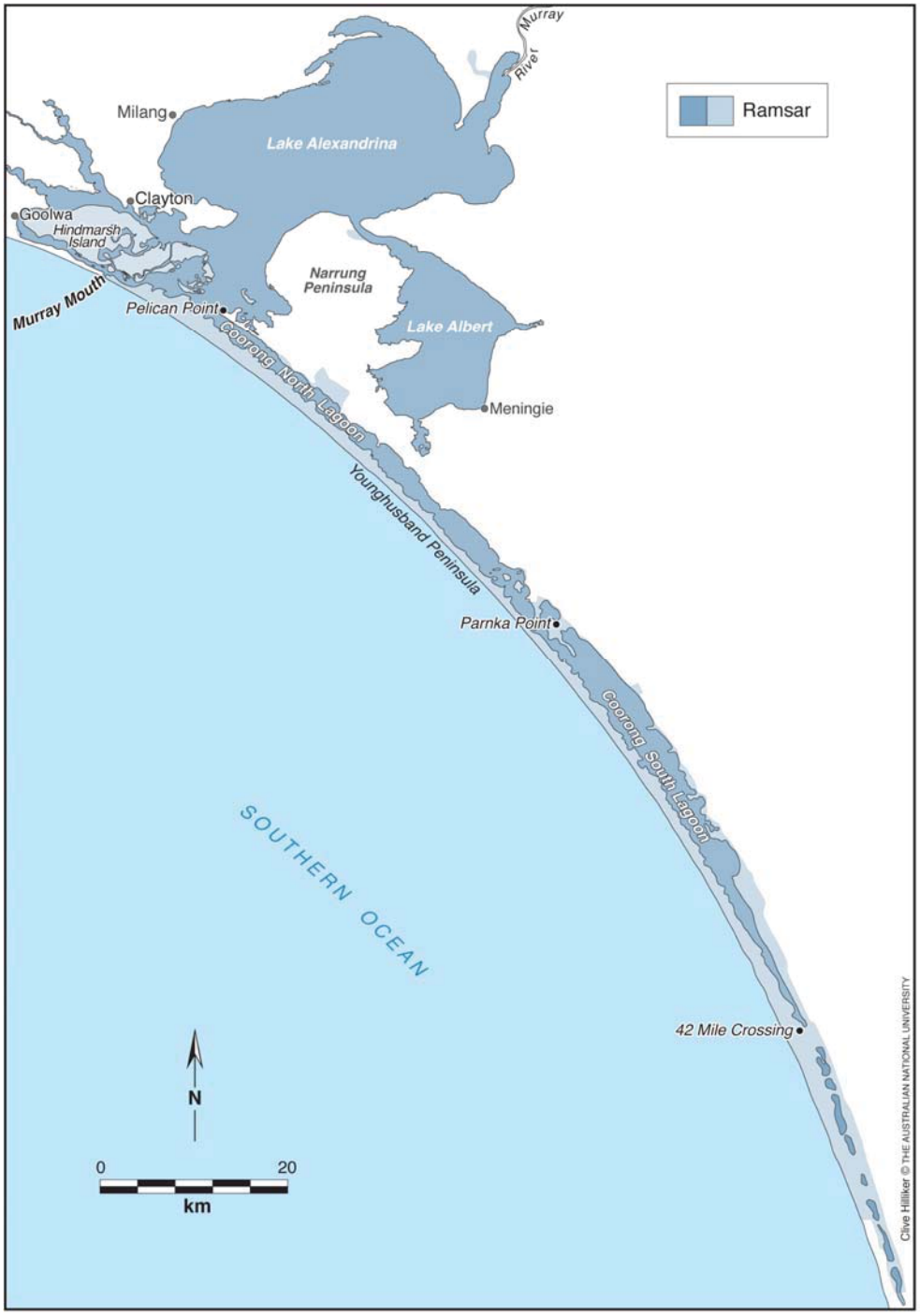

Figure 3. Map of the Coorong and Lakes Region. The dark blue shaded land and waters form the Ramsar site

2.2. The research context and questions

The Region is a particularly poignant location for assessing adaptation in its broadest context because it:

1. Has been subject to interventions to manage environmental, including climatic, variability since European settlement (Sim and Muller 2004, Phillips and Muller 2006), and provides a challenging and possibly unique opportunity to investigate the lessons from these interventions as a basis for developing and implementing adaptations to climate change (see 2.3.3);
2. Is culturally, environmentally and economically significant to many sectors of the local community (DEH, 2010), further afield throughout the Murray-Darling Basin, nationally (Connell, 2007), and internationally as a Ramsar site (Phillips and Muller, 2006);
3. Is at the end of a major river system and thus highly sensitive to changes in freshwater inflows due to both non-climate changes and climate variability, change in the catchment and changes in governance and institutional practices at multiple levels (CSIRO, 2008);
4. Has geographical and to some extent social-economic similarities with the many other coastal barrier lagoon and estuary systems around the Australian coast (Kench, 1999);
5. Was under immense pressure (stress) during the 2002-2010 Millennium Drought which (arguably) may serve as an analogue for many climate change impacts (see 2.3.3);
6. Is the subject of major government policy developments through the national Water Act and the proposed Murray-Darling Basin water plan (MDBA, 2010).

The research team was contracted to answer the following questions (NCCARF Call for Proposals http://www.nccarf.edu.au/node/483):

1. Assuming there will be no planned adaptation, what are the likely impacts of climate change (in association with other known drivers of vulnerability)? For whom will these impacts be a problem?
2. What adaptation strategies are available? Will (can) these strategies address all the climate risks that concern all potential stakeholders?
3. Assuming climate stabilises at 2^{o}C above pre-industrial levels, what seem to be the likely residual impacts of climate change after adaptation has taken place? For whom will these impacts be a problem?
4. Assuming warming exceeds 4^{o}C above pre-industrial levels, what seem to be the likely residual impacts of climate change after adaptation has taken place? For whom will these impacts be a problem?
5. Given anticipated losses, are there substitutes for things that are lost that would be acceptable to affected parties?

The project team modified these terms by including the detailed climate change scenarios developed by CSIRO's Sustainable Yields Project (CSIRO, 2008) when considering the residual impacts from anticipated increases in atmospheric temperature. This included "three predictions of the temperature change by 2030 relative to 1990: a low global warming of 0.45 °C (low end of [Intergovernmental Panel on Climate Change scenario] SRES B1), medium global warming of 1.03°C (average of the low and high global warming scenarios), and high global warming of 1.60 °C (high end of SRES A1T)" (Chiew F.H.S. et al., 2008:15). These three climate scenarios were run through 15 global climate models and linked to hydrological models to identify 45 possible outcomes for water availability, presented as "extreme wet" for the second wettest, "median", and "extreme dry for the second driest model results. To ensure our proposal was aligned with the scenarios developed for the Murray Darling Basin Authority's (MDBA's) water plan, we adjusted the scenarios recommended through the

NCCARF project to dovetail with those developed by CSIRO for the Basin. Thus, we considered the following scenarios (detailed in Table 4):

1. +1.03 °C: The CSIRO median scenario for an average annual reduction of inflows of 37% into the Region and the apparent basis of MDBA policy development;
2. +1.6 °C: The CSIRO extreme dry scenario for an average annual reduction of inflows of 69% into the Region, which is similar to NCCARF's +2 °C brief;
3. +4°C: From NCCARF's brief, a scenario which has no modelling data to interpret outcomes.

We did not consider the CSIRO 2030 extreme wet scenario for an average annual increase of inflows into the Region of 20% based on a +1.6 °C scenario global climate model run for two reasons. Firstly, additional inflows into the Region would have environmental and socio-economic benefits and would not reach limits to adaptation: the focus of this research. This is appropriate since good risk management must consider how to respond to less likely but more catastrophic outcomes. Further, this outcome is inconsistent with MDBA planning. Other, non-inflow related climate change impacts with a +1.6 °C scenario are considered in this report with the analysis of an extreme dry outcome, for instance, sea level rise,
Our research consisted of three interlinked components:

1. A literature review that synthesized relevant information on adaptation and the Region;
2. An assessment of past and proposed adaptation measures against the likely impacts from three different climate change scenarios; and
3. In depth interviews with key stakeholders locally and nationally to document the spectrum of views on adaptation in the Region.

These three components were then synthesized to address the research questions on the limits to adaptation.

2.3. Key concepts in the research

In this project we seek to identify the limits to adaptation in the Coorong and Lakes to inform climate change responses locally and globally. A number of concepts concerning adaptation, adaptation and water, limits to adaptation, vulnerability, resilience and environmental health require elaboration as a basis for this assessment

2.3.1. Adaptation

In the context of the Intergovernmental Panel on Climate Change (IPCC), *adaptation* refers to "initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects" (Bates et al., 2008: 167). NCCARF defined adaptation as "actions taken to avoid actual or anticipated impacts from climate change, or to attain potential benefits arising from climate change" (NCCARF Call for Proposals – http://www.nccarf.edu.au/node/483), and Adger et al (2009: 337) as "… adjustments made to changed environmental circumstances that take place naturally within biological systems and with some deliberation or intent in social systems". However, there are drawbacks with these definitions as they are either overly focussed on climate change rather than also embracing changes due to non-climate drivers, and deliberation is over-emphasised. In this research we augment these with the definition from Brooks (2003: 8) that considers autonomous as well as deliberate measures, and places adaptation in its broader environmental context, namely: "adjustments in a system's behaviour and characteristics that enhance its ability to cope with external stresses".

We contend that when adaptation has a broader meaning beyond climate change there may be lessons to be learnt from adaptation to changes driven by non-climate influences. In the context of the Region these may inform potential responses to impacts from climate change. Therefore we have taken a broad approach in this study and have increased the scope of

the original questions to develop an *understanding* of adaptation in the Region as well as explore the notion of the "limits" to adaptation.

2.3.2. Adaptation to non-climate and climate drivers

Climate change will exacerbate existing pressures rather than bring a new set of threats. Environmental degradation is usually the result of a complex interplay of drivers, in the case of wetlands, that includes over-exploitation, pollution, habitat conversion, impacts of infrastructure and invasive species (MEA, 2005). In the case of the Murray-Darling Basin's freshwater ecosystems, over-extraction of water is considered a more severe impact than climate change induced reductions in run-off in the short to medium term (Pittock et al., 2010, Schofield, 2011), although in practice the two threats are negatively synergistic. Consequently strategies to adapt to climate change impacts must be mainstreamed into programs to manage threats holistically, for example in the case of the Murray-Darling and water, through the Basin Plan (MDBA 2010).

2.3.3. Adaptation and water management

As water management can be seen as comprising a set of adaptations to local climates it is an important field to examine in order to better understand adaptation and limits to adaptation (Pittock, 2009b). There is a substantial and growing body of academic analysis that water governance changes represent real time experiments in systemic and adaptive effectiveness that have lessons for climate change adaptation (Godden et al., 2011). The IPCC has accepted that current water management represents autonomous adaptation to climate variability, stating that: "Adaptation to changing conditions in water availability and demand has always been at the core of water management" (Kundzewicz et al., 2007: 196). *Autonomous adaptations* have been defined as "adaptations … that do not constitute a conscious response to climate stimuli, but result from changes to meet altered demands, objectives and expectations which, while not deliberately designed to cope with climate change, may lessen the consequences of that change" (Bates et al., 2008:48). However, this term has pejorative connotations that may discourage recognition that this type of action may be the most widespread type of adaptation and represent measures that should be actively encouraged (Dovers and Hezri, 2010, Dovers, 2009). If there is to be an optimum effort for adaptation, the autonomous and innovative instincts of people and institutions in society (for example, of farmers in adapting to declining terms of trade, climatic variability and change) should be supported with information and encouragement to channel these resources in the most propitious directions.

The extent to which the impacts of European management of water is comparable to the impacts of climate change, and whether adaptation to climate variability (including the Millennium Drought) is comparable to climate change is debated, including by reviewers of this report. We argue that non-climate changes to water flows have similarities to those that would be anticipated with climate change and are a basis for drawing lessons on impacts and adaptation. Abstractions of water for consumption reducing inflows into the region have increased gradually over a century (Phillips and Muller, 2006). European water management changed seasonality of inflows and climate change is also changing the seasonal precipitation patterns in the Basin (Kingsford, 2006, CSIRO, 2010). Deliberate government policy responses to climate change in the Basin are anticipated to further reduce the scale and pattern of flows, for instance, through greater water consumption due to carbon sequestration in plantations and due to changed dam operating rules in supplying environmental water that may reduce the prospects of large flood events (Pittock, 2011, CSIRO, 2011). Further, as this report details, European water use saw extensive water infrastructure works in the region: so too are adaptation measures for climate variability and change.

Australia has a long history of managing climatic and hydrological variability which can be considered anticipatory adaptive management. One example is the storage large volumes of water per capita; another is the rejection of US and European water entitlement doctrines of riparian rights and prior appropriation in favor of allocating a seasonal share of the available resource (Connell, 2007, Pittock and Connell, 2010). More recently, the establishment of a market for water entitlements has enabled water users to adjust better to hydrological change (Grafton et al., 2011, Grafton and Jiang, 2010). However, a number of conflicts are evident between government programs, for instance, those to buy back water entitlements for the environment (including to adjust to climate change) and those that subsidize irrigation enterprises during drought on the assumption that conditions will return to "normal" (Pittock and Connell, 2010). Further, extensive scientific and policy work has agreed on the need for environmental flows to manage the environmental impacts of changes in water availability (Davis, 2009, Arthington et al., 2006), yet implementation of such policies has been disappointing (NWC, 2009). Consequently there is a lot of knowledge and experience of managing climatic and hydrological variability in the Basin and some of it is yet to be fully applied, especially with respect to sustaining wetland ecosystems. Better management of drought and other variability in the Basin should be a key strategy for adaptation to climate change.

The question of whether climate variability in the Region is an analogue for future climate change is complex. Obviously variability refers to short term events whereas much of the climate change modeling for the Region has forecast long term average conditions. A major prediction for the Region is a change in average inflows from the River Murray ranging from +20 to -69% by 2030 (CSIRO, 2008). The frequency of extreme events such as drought is anticipated to increase with climate change. The severity of the Millennium Drought in the Region is in part now attributed to climate change (CSIRO, 2010). In that the short term water availability in the Millennium Drought was more severe than the average dry extreme suggested by CSIRO for 2030 we contend that there are lessons to be learnt from society's responses to the drought for climate change adaptation (Pittock and Finlayson, 2011a) (Table 3).

2.3.4. Limits to adaptation

'Limits to adaptation' is fundamentally concerned with identifying the thresholds at which actions to adapt cease to reduce vulnerability (Adger et al., 2009). These thresholds exist in four domains:

1. Ecological and physical thresholds beyond which unplanned or planned responses fail to avoid climate change impacts.
2. Economic thresholds, which are where the costs of adaptation exceed the costs of impacts averted (that is, it is more expensive to adapt than it is to experience climate impacts).
3. Technological thresholds beyond which available technologies cannot avoid climate impacts.
4. The points at which social groups judge adaptation actions to have failed. These social limits arise when the goals of adaptation decisions, and the proposed measures of their success, fail to consider the values and views of different groups that may be affected.

The societal component of adaptation is important as it incorporates the inconvenient truth that diverse groups often value things differently; thus, what may be perceived as a successful adaptive response from one point of view may not be perceived the same way by others. To a large degree the above limits to adaptation substantially revolve around judgements made by specific groups in society about changes that are unacceptable to them based on their values, livelihoods and needs. Given the importance of societal and community views on adaptation, and environmental management more generally, we

incorporated a substantial social research component in this project alongside a biophysical assessment of adaptation and limits to adaptation.

Understanding the limits to adaptation is important for decision making about adaptation for three reasons. First, it helps to determine which responses to climate change are both practicable and legitimate, and the time scales over which they may be considered to be effective. Second, it helps to understand how people may respond to the damage to, or the loss of, things that are important to them, for which there may, in some cases, be substitutes or ameliorating policy measures. Third, it can help prioritise adaptation strategies, refine their intentions, and identify communities that will be served by them.
In developing the project outline we were not convinced that the phrase "limits to adaptation" best represented the social and biophysical constructions that have been publicly developed and debated in many forms of media as well as in the more specific research literature (e.g. Kingsford et al. 2010). In particular the word "limits" was not seen as useful as "constraints, barriers, or hurdles" with a preference for "barriers" because people in the Region have and could further adapt to substantial changes even though the costs are high. This point is explored further later in this report (Section 8).

The Region provides a particularly sensitive setting for understanding environmental change and constraints to adaptation due to the significant changes experienced historically (Table 1), as well as the vulnerability of the social and biophysical environment to reduced freshwater inflows from the River Murray and sea level rise, as elaborated below. The complexities of the social and biophysical environment in relation to the heavily politicised local and national debates over water management, in particular to the allocation of environmental flows and the reallocation of water to the rivers and wetlands across the Murray-Darling Basin, has been played out in the national media and provides a stark case for any consideration of constraints to adaptation in the Region (see the following: Connell and Grafton, 2011, Kingsford et al., 2009, Pittock et al., 2010, Phillips and Muller, 2006, Sim and Muller, 2004, Connell, 2007, Kingsford et al., 2011).

2.3.5. Vulnerability

In this project we have used the framework for vulnerability assessment recommended for use by the Ramsar Convention on Wetlands (Gitay et al., 2011). Therefore, vulnerability assessment is an approach for providing information for maintaining the ecological character of wetlands which are subject to adverse change as a consequence of climate change, whilst recognising that climate change will interact with many other pressures on wetlands. Under this approach, vulnerability is the degree to which a wetland is sensitive to and unable to adapt or moderate the consequences of climate change and other (anthropocentric) pressures on its ecological character. Vulnerability is closely associated with risk assessment and risk management where risk assessment is based on determining the extent of a particular hazard and its potential effect or impact on the system and is expressed in terms of the probability of the extent and effect of a hazard impacting on a system.

Vulnerability assessment includes the following steps:

- Determining the probability of a risk event occurring;
- Assessing the effect of this on the system, given its sensitivity and adaptive capacity;
- Developing options that can reduce the adverse impacts from that event; and
- Formulating the desired outcome for the system within an adaptive management framework to ensure that the response options being implemented are achieving the desired outcomes.

Given the absence of specific data it is often necessary to make subjective judgements, particularly when dealing with risk assessment and perception. Changes in the information

available for these steps would be addressed through an adaptive approach that encouraged learning and the development of new knowledge that would feedback into the assessment.

2.3.6. Resilience and environmental health

Another important concept that is inter-related with vulnerability is r*esilience,* namely "the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self organization, and the capacity to adapt to stress and change" (Bates et al., 2008: 179). As we outline below, a number of environmental changes in the Region appear to have crossed ecological thresholds for resilience with ecological systems having changed from one ecological state to another. As many such changes in state can be irreversible, or near irreversible, this provides both a societal and ecological quandary for managers and policy-makers.

Environmental health is a commonly used but ill-defined term that may be interpreted in many ways, including the scientific, legal and social approaches that are described here. The term is often used explicitly or implicitly to refer to a past or desired *reference condition* that is judged as "healthy".

In Australia, scientifically a pre-European environment has often been considered as a suitable and socially acceptable reference condition, including by many scientists, and interpreted as the maintenance of specific components of the natural biodiversity and ecosystem processes that existed in 1788. As a coastal system influenced by a large river catchment, the Region underwent substantial pre-historical changes (McKirdy et al., 2010, Cann et al., 2000, Fluin et al., 2007). The construction of the Barrages from 1935-1940 (and other likely changes as a result of European settlement) substantially changed the state of the Region for example, changing the lakes from a system of fluctuating water levels with occasional saline water incursions into a freshwater system maintained at a constant level (until the onset of severe drought from 2002) resulting in major changes in biota (Barnett, 1994). Consequently a pre-European state of environmental health does not now exist and is not possible to re-establish even if it could be reliably characterised.

Legally, as a result of the listing of the Coorong and Lakes Alexandrina and Albert as a Wetland of International Importance under the Ramsar Convention on Wetlands in 1985, and because the Australian Government did not specify a different reference condition, the ecological character of the site in 1985 is the state that Australia is obliged to maintain under international law (Pittock et al., 2010, Phillips and Muller, 2006). This 1985 condition included operation of the Barrages to maintain the lakes as freshwater systems at a constant water depth, and which could be considered un-natural or modified. *Ecological character* is defined as: "the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time" (Ramsar, 2008) and, in this context, ecosystem benefits are defined as "the benefits that people receive from ecosystems" (Ramsar, 2005). In the absence of further guidance from the Ramsar Convention it could be decided that the described ecological character of the Ramsar site equates to a state of environmental health (Horwitz and Finlayson 2011).

A further approach to defining or describing the environmental health of Region could be to consider this within a social context whereby the Region's environment has the capacity to support valued socio-economic activities, such as water extraction, fishing and boating (see section 3.4 on ecosystem services). One option for managers could be to work with the local communities to develop a shared view of the desired future state, or reference condition for the Region, to guide management interventions and adaptation, as is being promoted elsewhere and discussed within the Ramsar Convention (Finlayson and Weinstein, 2008, Horwitz and Finlayson, 2011). This approach is likely to be required in the Region where it is

not be possible to restore the pre-European state, substantial action is needed to restore the 1985 Ramsar ecological character, and where further climate change impacts may limit management options for attaining particular states. Different segments of the community are likely to value different attributes of the Region's environment, and consequently identifying a shared view of a desired environmental state may be difficult. For instance, different segments of the community argue for a "freshwater solution" (see River, Lakes and Coorong Action Group: http://hurrysavethemurray.com/fresh-water-embassy/; Sim and Muller, 2004) and they are often local residents. They are opposed by proponents of "opening the Barrages" to enable inflows of sea water who view the Lakes as an "artificial freshwater oasis" (see Myth and the Murray: http://www.mythandthemurray.org/ and Lakes Need Water: http://www.lakesneedwater.org/facts; Marohasy, 2010): a number of these commentators are proponents of agricultural water use.

This type of management challenge has been described as a *wicked issue* or problem, namely "issues with particularly incomplete, contradictory, and changing requirements. Complex inter-dependencies, difficulties in defining the problems themselves, and difficulty in identifying – and often in reaching consensus on – solutions all contribute to wickedness" (Turnpenny et al., 2009). Such issues are characterised by: uncertainty; inconsistency of needs, preferences and values; an unclear sense of all consequences and/or cumulative impact of collective action; fluid, heterogeneous, pluralist participation in problem definition and solving. This is well illustrated in the Region by the scientific controversy over the extent to which sulfate sediments in the lake beds oxidise to form sulphuric acid when exposed to air and the risk these soils represent to water quality in the lakes (Kingsford et al., 2009, Geddes and Walker, 2009). The unanticipated consequence of management interventions are also evident, for instance, the silting of the bunds built at Narrung that separates Lake Albert from Lake Alexandrina, that have further restricted flows of less-saline water into Lake Albert (Phillips and Muller, 2006). These examples illustrate the difficulty of addressing complex problems, but the following quote does provide a signpost for a way forward "The effective long-term management of wicked issues is often considered hindered by traditional methods of scientific enquiry and governing" (Turnpenny et al., 2009). That is, it may be useful to consider the evidence and possible solutions from a different perspective, including, as referred to above, engaging more with local communities and experts to construct a shared understanding and vision.

3. THE COORONG, MURRAY MOUTH AND LAKES ALEXANDRINA AND ALBERT: HISTORY, STATUS AND ADAPTATION

Assessment of future adaptation in the Region needs to be based on an understanding of historical change and adaptation in the region and the current status of the system. The biophysical features or ecological character has been described by various experts with the last decade having seen far more attention given to documenting the ecological condition and health of the system (Brookes et al., 2009, Phillips and Muller, 2006, Kingsford et al., 2009, Kingsford et al., 2011). The Coorong and Lakes is a system of wetlands forming the lower reaches and outlet of the River Murray. The environmental history of the Region is one of considerable change with past and present ecological states outlined in Table 1.

3.1. Historical change and adaptation in the region

3.1.1. Prehistoric status and change

In pre-Quaternary times the area was a shallow sea. Ongoing uplift has resulted in a low-elevation basin with underlying and saline marine sediments and marked by a succession of former coastlines – paleo-barriers – trending to the south west to the youngest barrier, the current coastline at the Sir Richard and Younghusband peninsulas (Cann et al., 2000). During the succession of glacial and interglacials in the Quaternary period the Region was mostly an inland plain with sea levels as much as 140 m below present, punctuated at times of higher sea levels (like now) as a wetland system (Hill et al., 2009, Fairbridge, 1972, Cann et al., 2000, Lambeck and Chappell, 2001, Nakada and Lambeck, 1989). The Holocene saw sea level rise from ~18,000 BP to levels as much as 2.7 m above AHD in Lake Alexandrina at around 5,255+/- 60 yr PB when there was a strong marine influence (Nakada and Lambeck, 1989, Cann et al., 2000). There is debate as to the extent to which these higher than present water levels were due to sea level change or a hydroisostatic response to the postglacial Southern Ocean (Cann et al., 2000, Belperio et al., 2002). Nevertheless these higher water levels in the Region indicate the environmental changes that may be experienced with climate-induced sea level rise.

Water levels then fell to create the current system of freshwater lakes and other wetlands with more restricted estuarine – lagoonal conditions between 5255+/- 60 BP and 3605 +/- 70 yr BP before greater influence of coastal waters was finally seen (Fluin et al., 2007, Cann et al., 2000). The wetlands were dynamic, for example, with the main channel of the River Murray through the lakes Albert and Alexandrina changing over time and with the location of the mouth of the Murray changing by many kilometres (Hill et al., 2009).

Sea level change must have significantly impacted the Ngarrindjeri people, whose oral history records their links to off-shore areas like Kangaroo Island (Phillips and Muller, 2006, Ngarrindjeri, 2006). The Holocene environment was driven by inflows from the River Murray and was particularly biodiverse and supported a large Ngarrindjeri population. The River Murray has highly variable annual river flows (Walker, 1986, Walker et al., 1995), and its biota requires both flood pulses and dry periods to thrive (Overton et al., 2009, Walker and Thoms, 1993). During major floods the Region's wetlands are mainly fresh and a freshwater plume from the mouth of the Murray may extend out to sea.

The extent to which the Lakes and Coorong were fresh, brackish and saline is disputed and has major implications for management aspirations today and consequently, the desired outcomes and measures for adaptation. The paleo-environmental evidence from wetland sediments outline above indicates periods of greater and lesser marine influence during the Holocence (Cann et al., 2000). In the past 3,500 years the Lakes were mainly fresh with

limited sea water intrusion during major low flow periods (Fluin et al., 2007, Barnett, 1994, Cann et al., 2000), and that the Coorong south lagoon, fed by inflows from the south east region, had salinities lower than seawater, much lower than present (McKirdy et al., 2010, Krull et al., 2009). In work that has not been peer-reviewed, advocates for irrigated farming interests contend that the Lakes were more often saline (Marohasy, 2010), a position rejected by experts in this field (Bourman, 2010). The alternative fresh and saline water theories are strongly supported by different groups in society, including local people who want the Lakes managed as freshwater ecosystems (Sim and Muller, 2004), and interstate water users who seek to open the system to the sea to reduce the demand for environmental freshwater inflows.

3.1.2. Historic status and change

The Region is the traditional country of the Ngarrindjeri people and they retain a close association with this land (Phillips and Muller, 2006, Ngarrindjeri, 2006). European settlement began in 1836 with conversion of surrounding lands for agricultural production for livestock production, then drainage for cropping, resulting in an influx of sediment that degraded the wetlands along the River Murray. The Ngarrindjeri Nation was displaced from much of its traditional country but the Nation maintained its connection to the land and sea and has continually asserted its rights to play major roles in the ownership and management of the Region (Ngarrindjeri, 2006).

The post colonial history of the Region is one of adaptation as European settlers sought to change the hydrology of the system to deliver particular services, but often with perverse impacts. These adaptations are discussed in section 3.1. The waterways were significant for their fisheries which are now substantially diminished. Clearing of the surrounding lands for agriculture has had a number of ongoing impacts, including influxes of sediments and nutrients, mobilisation of salt as well as drainage of wetlands (Phillips and Muller, 2006). The colony of South Australia saw the River Murray as a major transport route, resulting in the construction of supporting infrastructure, including the lock at Blanchetown. From the 1860's, and accelerating in the 1950's and 1960's, the extensive wetlands of the south east region were drained, reducing surface and ground water inflows into the Coorong south lagoon (England, 1993, Department of Water, 2011). The loss of this freshwater inflow may have set the scene for the substantial increases in salinity and ecological decline seen in this significant habitat for water birds and other biota in the past decade (Phillips and Muller, 2006). Partial and ongoing plans to restore inflows from the south east to the Coorong south lagoon aim in part to undo some of the damage (Department of Water, 2011).

From the 1880's the growing upstream diversions of water for agriculture caused growing concern that sea water may intrude into the Lakes (Sim and Muller, 2004). The7.6 km long Barrages were constructed at 0.83 m AHD from 1935 to 1940 to isolate the Southern Ocean and the Coorong from the Lakes and so securing the use of the Lakes as a freshwater reservoir for water supply for agriculture and urban areas, including Adelaide (Sim and Muller, 2004, LMDRG, 2008). Operation of the Barrages at 0.45 to 0.75 m AHD kept the Lakes artificially high and at a constant level in comparison to pre-development variability, impacting on littoral ecological communities (Kingsford et al., 2009). In recent decades this constant lake level has supported the development of a canal-based marina estate and recreational boating facilities, particularly at Goolwa and Hindmarsh Island. The Barrages restricted the estuary to the Coorong north lagoon and in periods of very low flow largely eliminated brackish waters, as well as blocking fish migration, resulting in major changes to fish biota.

By the mid-1990's the construction of upstream storages enabled the retention of water equivalent to three times annual average flow of the River Murray (Kingsford et al., 2009). The imposition of a cap on issuing new water entitlements and establishment of a water market failed to prevent further water diversions due to policy failure (Young, 2010) that:

- Gave previously un- or under- used water entitlements great market value and saw them traded and activated;
- Did not cap groundwater extractions resulting in increased extraction from aquifers connected to the river system;
- Did not adequately regulate inflow interception activities such as “overland flows”, farm dams and forestry plantation establishment.

The streams draining the Eastern Mount Lofty Ranges into the Lakes provided limited water. Yet it is notable that while South Australia seeks reallocation of water to the environment in upstream states in the Basin, it is yet to finalise the Eastern Mount Lofty Ranges Water Allocation Plan to prevent increased diversions through inflow interception (SA MDB NRM Board, 2011). Good management of these streams, especially Currency Creek and the Finniss River, is important in providing habitat for threatened freshwater biota (Lester et al., 2010, Phillips and Muller, 2006).

In recent decades the western side of the region has seen population and economic growth from tourism and recreation – especially recreational boating – and retirees, resulting in urbanisation around Goolwa and construction of new infrastructure. The regional population is now 28,000 and the gross regional product of the lower Murray, Lakes and Coorong was estimated to be $700 million in 2006-07: the specific value of various industries in the Region are summarised by DEH (2010) and Kingsford et al. (2009).

Despite the environmental, social and economic importance of the Region over a long period of time there was virtually no Western science research to understand the ecological processes that drive the system until the 1980s (Geddes and Butler, 1984). Insufficient investment in research meant that there was inadequate knowledge on the measures needed to sustain chosen ecological states when the Millennium Drought began in 2002. An urgent, $5.3 million, three year CLLAMMecology Research Cluster involving CSIRO and South Australian research institutions between 2006 and 2009 provided key information on the functioning, environmental flows and thresholds in the Coorong and Murray Mouth but not the Lakes (Brooks et al., 2009). This research identified a number of thresholds between ecological states and concluded that the health of the Coorong depends primarily on freshwater flows through the Barrages, and secondarily in the case of the Coorong south lagoon, inflows from the south east (Brooks et al., 2009, Lester et al., 2009). This research advised that a modest increase in environmental flows would sustain more diverse biota in the Coorong (Lester et al., 2009). The ecosystem state model developed in this research for the Coorong identifies parameters and threshold values, such as the numbers of days without flow over the Barrages and the depth of water in the lagoon to predict outcomes ranging from a health marine system to a degraded hypersaline state (Brooks et al., 2009). However, this research began by examining a system that was already degraded. Traditional and historical ecological knowledge suggests that a more diverse range of positive ecological states existed prior to European settlement which included small estuarine areas associated with inflows from freshwater springs and streams from the south east, fringing reed beds and more extensive areas of *Ruppia tuberosa* seagrass community (Phillips and Muller, 2006, Ngarrindjeri, 2006). These would require even greater freshwater inflows to re-establish.

While there is now a sound platform of scientific knowledge to guide management of the Coorong there is still relatively limited knowledge available on the ecological processes of the Lakes (Brookes et al., 2009). The funding for CLLAMMecology ended in 2009. The establishment in 2011 of the multi-partner Goyder Institute for Water Research (http://goyderinstitute.org/) with $14 million in funding until 2014 to support water resource management in South Australia may help develop relevant knowledge, if sufficient effort is devoted to the Region.

3.1.3. Recent management and adaptation to extreme water scarcity

The 2002 to 2010 Millennium Drought was similar in terms of precipitation levels to two historical droughts, but average temperatures were higher and inflows fell precipitously to record low levels (CSIRO 2010; Schofield, 2011), pushing the Region's wetlands into an unprecedented state. Low river inflows were caused by low rainfall and greater evapotranspiration, poorly regulated inflow interception activities and diversions that increased as a portion of the available water as supply levels decreased (Schofield, 2011). The crisis sparked institutional reform with the Federal Government asserting more direct control over water management in the Murray-Darling Basin, based in part on implementing the Ramsar Convention on Wetlands, through the Water Act 2007 (Commonwealth of Australia, 2008) and proposed Basin Plan (MDBA, 2010), to return water extraction to ecologically sustainable levels (Connell, 2007). The Federal Government allocated $200 million for management of the Region as part of around $2.2 billion in foreshadowed expenditure to treat the symptoms of the Millennium Drought in the Region (Kingsford et al., 2009). This also resulted in a number of water management interventions – adaptations – in the Region, including adoption of the South Australian Government's regional "Securing the Future" and "Water for Good" plans (DEH, 2010, Office of Water Security, 2010).

The Barrages were closed and the Murray Mouth was only connected to the Southern Ocean through constant dredging. Low inflows into the Lakes failed to exceed rates of evaporation, and with the Barrages closed, lake levels fell, increasing salinity levels and exposing local areas of sulfate sediments on the lake bed causing acidification. The State Government led emergency interventions in response to the crisis remain controversial within the scientific and local communities. The State Government believes that there is a high risk from acid generation (DEH, 2010) whereas a number of researchers contend that the risk is less severe and acid would naturally be buffered with water in the environment (Kingsford et al., 2009, Geddes and Walker, 2009). A number of crude structures, inoperable bund walls, were erected, ostensibly to manage acidification (Kingsford et al., 2009, Geddes and Walker, 2009):

- Lake Albert was separated by a bund from Lake Alexandrina, initially to enable water to be pumped into Lake Albert to maintain it at a higher level to submerge sulfate sediments, but when water levels in Lake Alexandrina fell lower, to concentrate the remaining resource in the larger lake;
- The Goolwa Channel was separated from Lake Alexandrina by the Clayton regulator and water levels were restored through pumping, an intervention criticised by communities that did not benefit as supporting boat use more than preventing environmental harm; and
- Currency Creek was separated from the Goolwa Channel by a low level bund with a view to preventing acidification and maintaining a refuge for freshwater fauna should water availability have been reduced even further.

The bund walls were criticised by some scientists for further fragmenting the wetlands ecosystem, for example, blocking fish passage, where communities were divided between those where water was retained versus those adjoining the desiccated lake area (Kingsford et al., 2009, Geddes and Walker, 2009). Following flood inflows from December 2010 the short term need for the bunds passed. While the Narrung bund has been breached it has not been completely removed, the Clayton regulator is being removed to the depth that a back hoe can reach, whereas the Currency Creek regulator is submerged. The State Government, which had promised that all bunds would be removed as soon as lake water levels were re-established, now says that technical and funding limits prevent full and prompt restoration (Caggiano, 2011a, Caggiano, 2011b).

Other interventions were more widely supported, including management of sulfate sediments on the lake bed through liming and sowing plants, and fencing out of some of the shoreline

from livestock. Construction of piped irrigation water supply from the River Murray channel above Wellington along the western side of Lake Alexandrina removed the dependence of many towns and agricultural businesses on water from the Lakes (SA Water Corporation, 2009); water for human use and stock watering was piped to the eastern side of Lake Alexandrina although this was insufficient for a number of dairy farmers on the Narrung Peninsula to maintain their enterprises. The South Australian Government proceeded with a major program to diversify water supplies with $2.1 billion allocated over four years from 2009/10, including the construction of a desalination plant at Port Stanvac to reduce Adelaide's dependence on water from the River Murray (Office of Water Security, 2010). A broader range of adaptations were proposed and remain as potential future interventions, as detailed in Table 7. Contingency plans adopted should water levels in Lake Alexandrina have declined below a threshold height of -1.5 AHD included the construction of the Wellington / Pomanda Island weir, to protect a new freshwater weir pool in the River Murray channel above Wellington to support diversions to local communities and Adelaide (DEH, 2007). This would have enabled inundation of the Lakes with sea water.

Table 1. Past and present ecological states of the Coorong and Lakes region (drawn from Cann et al., 2000, Ngarrindjeri, 2006, Kingsford et al., 2011, CSIRO, 2010)

#	Time	State	Drivers of change	Condition	
				Biophysical	*Socio-economic*
1	up to ~18,000 BP	Pleistocene glacial. Sea levels ~ 140 m below present	Changes in river geomorphology.	Colder, drier, riparian corridor in plains.. The Region was a flat plateau with a river floodplain across the continental shelf	Indigenous society
2	~18,000 to ~5,200 BP	Rapid sea level rise	Climate warming and resulting sea level rise	Rapid inundation of the continental shelf then the Coorong and Lower Lakes by sea level rise. Lake Alexandrina was around 2.7 m above AHD and influenced by marine waters	Indigenous society is likely to have been greatly disrupted, as indicated by the Ngarrindjeri speaking for their sea country and Kangaroo Island
3	~5,200 BP to 1788	Holocence, pre European. Sea level near present	Climate, water level change, changes in river geomorphology.	River Mouth, estuary, Coorong and Lakes Alexandrina and Albert geography similar to present. Fluctuating hydrology and climate, including more restricted estuarine – lagoonal conditions between 5255+/- 60 BP and 3605 +/- 70 yr BP then greater influence from coastal waters	Indigenous society
4	1788 to 1880	European, pre Barrages; no irrigation	Livestock grazing and vegetation clearing; beginning of displacement of Indigenous peoples; in the Region European settlement began in 1836	Extensive erosion induced by hard-hooved European livestock and by clearing for cropping greatly increased rates of sedimentation and nutrient inflows into the Region's wetlands.	Indigenous society increasingly being impacted by European settlement, widespread livestock grazing and early dryland farming
5	1880 to 1940	European, pre Barrages; increasing irrigation	Climate, water level change, river avulsion, development of agriculture resulting in drainage of freshwater away from the Coorong and extensive clearing and erosion.	Similar climate to today, lake systems, fluctuating hydrology. Diminishing freshwater inflows to the Coorong south lagoon.	Livestock, cropping, fishing, shipping. Indigenous society undergoing change
6	1940 to 1985	Increase in irrigation diversions	Water storage capacity in the Basin increases to three times the average annual river flow. Proportion of outflows decreases	Major changes as the Barrages hold the Lakes at a more constant and unnaturally high level, and create a barrier to movement, changing the fish and fringing ecological communities; estuary restricted to the Coorong north lagoon	Agriculture and urban development facilitated by freshwater diversions directly from the Lakes. Change and decline in fisheries. Increasing tourism and recreational uses

7	1985 to 2002	Post-Barrages	Constant lake level, increasing water diversions (including inflow interception activities), water quality decline, invasive species. 1994 cap on surface water entitlements results in increased groundwater extraction	Similar climate to today, lake systems, stable hydrology, restricted connectivity, declining water quality, invasive species. Biodiversity loss. Decline in inflows of ~59% due to diversions	Irrigated agriculture and tourism and recreation increased, shipping and fishing in decline
8	2002 to 2010	Millennium Drought	Low lake level, water diversion, water quality decline. As water availability decreased water sharing rules increasingly favoured agricultural users over the environment	Drier, hotter climate (0.8°C increase). Extreme water level decline, exposure of acid sulfate soils (ASS), increasing salinity. Loss of connectivity. No outflows - Murray Mouth kept open by dredging. Extensive biodiversity loss in parts of CLLMM region	Irrigated agriculture lost or converted to piped water supply. Fishing and tourism in decline. Ecological cultural values severely impacted.

3.2. Current state of the Coorong and Lakes Region.

The Coorong and Lakes wetlands system has four main freshwater components and three saline components with substantially different characteristics that we now describe (Phillips and Muller, 2006) (Figure 4).

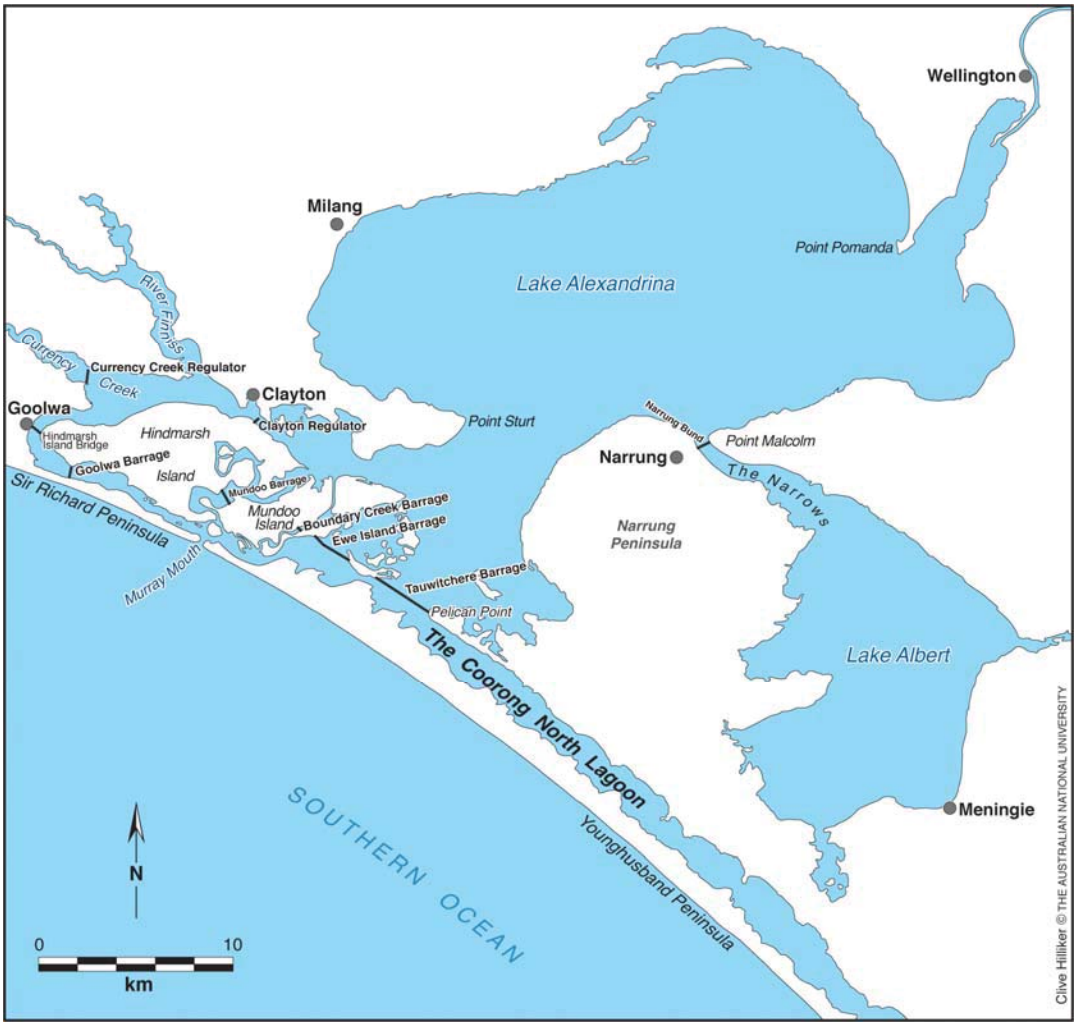

Figure 4. Map of the Coorong and Lakes Region showing six of the seven main wetland components (Coorong south lagoon not shown)

The seven components are:

1. Lower River Murray channel.

The 274 km of river below Lock 1 at Blanchetown (Figure 2) is a major river channel flanked by areas of oxbow lakes and floodplain wetlands. These have been substantially altered by development of the dairy and irrigated agriculture industries. Since construction of the Barrages water levels had been held constant at the expense of the ecosystem that would benefit from more variable hydrology. Low water levels during the Millennium Drought saw extensive areas of riverbank collapse (GSA, 2011). The river channel provides an important connection with the lakes, but there are limited data on the interactions between these. While the lower River Murray channel is connected to the Lakes, we have not considered its management in this research any further due to limited data and resources.

2. Lake Alexandrina.

Lake Alexandrina is the largest waterbody in the system at approximately 76,000 ha and has been largely freshwater throughout the late Holocene (Cann et al. 2000, Fluin et al., 2007, Barnett, 1994). The Lake is separated from the Coorong by a series of islands (a former coastal barrier) now linked by five barrages. The Barrages have largely held the Lake level at a constant target level of 0.75 m AHD resulting in loss of variability and habitat, and simplification of fringing vegetation (Phillips and Muller, 2006). In particular, freshwater submerged aquatic plant communities have been restricted to near-shore areas.

3. Lake Albert.

Lake Albert, at approximately 16,800 ha, is now an inland terminus of the River Murray and is connected to Lake Alexandrina by the Narrung Narrows. Historically the Narrows was around 500 m wide but it has been constricted to around 230 m wide by the causeway for the car ferry and consequent siltation and reed growth (Phillips and Muller, 2006). As a shallow and terminal wetland system, Lake Albert proved particularly vulnerable to salinity and desiccation during the Millennium Drought.

4. Tributary wetlands

The tributary wetlands associated with the Finniss River, Tookayerta Creek and Currency Creek, form part of the eastern Mount Lofty Ranges watershed with an area of just 1,488 ha (Phillips and Muller, 2006). Parts of the watershed are ungauged, however peak inflows are likely to exceed 100 GL pa (Phillips and Muller, 2006). These wetlands are diverse and support threatened species, such as the Mount Lofty Ranges Southern Emu-wren, the Yarra pygmy perch, the southern pygmy perch and the Murray hardyhead. The three streams are barely ‘permanent’ and runoff from their catchments may be vulnerable to inflow interception activities, such as farm dams and afforestation.

5. Murray Mouth and estuary

The Murray Mouth between the Goolwa Barrage and Pelican Point comprises approximately 3,400 ha. Prior to European settlement, flows of River Murray water out of the Mouth exceeded 2,000 ML per day 95% of the time. The form of the Murray Mouth was finalised around 6,000 years ago and its location has varied by 6 km over 3,000 years, and by 1.4 km over the last 160 years (Phillips and Muller, 2006). Due to declining freshwater outflows the Mouth closed in 1981 for the first time since European settlement, and between October 2002 and December 2010 dredges operated to keep two channels open to enable seawater to flow to the Coorong lagoons. Without seawater inflows, declining oxygen levels and increasing salinity and temperature may be beyond tolerance levels for some Coorong biota (Phillips and Muller, 2006).

6. Coorong north lagoon

This coastal lagoon between Pelican Point and Parnka Point (Figure 3) is approximately 50 km long and averages 3 km wide and covers roughly 11,069 ha (Phillips and Muller, 2006). Under natural conditions the north lagoon was dominated by River Murray inflows and tidal seawater movement through the Murray Mouth. The completion of the Barrages in 1940 greatly reduced the extent of the estuarine habitat and formerly extensive areas of aquatic vegetation dominated by *Ruppia megacarpa* recorded in the 1980s (Geddes and Butler 1984) have been lost as the salinity and turbidity have increased. The loss of this keystone aquatic vegetation may represent the crossing of a threshold to a new ecological state that could be very difficult to reverse. Consequently, there has been a considerable change and loss of macroinvertebrate, fish and waterbird populations, as well as reedbed and paperbark swamps (Phillips and Muller, 2006).

7. Coorong south lagoon

This southernmost and terminal arm of the Coorong between Parnka Point and 42 Mile Crossing (Figure 3) covers around 9,440 ha. Parnka Point protrudes into the Coorong and the narrowness and sand shoals restrict flow between the south and north lagoons. The south lagoon is a saline to hypersaline wetland that has extensive areas of mudflats that support large numbers of waterbirds, and especially international migratory waders. Water levels are important as the lagoon is bounded by calcrete cliffs and dunes, and the mud flat habitats would be largely eliminated if water levels were to rise. The historical hydrology of the area is not well documented. Historically inflows from the south east wetlands and groundwater were ecologically significant and maintained low salinities (Geddes and Butler, 1984, Phillips and Muller, 2006), however, from the 1880s drainage for agriculture directly to the sea has reduced such inflows (Department of Water, 2011, England, 1993). In particular, the Ngarrindjeri report ecologically and culturally significant freshwater soaks and estuaries that are now degraded or lost (Ngarrindjeri, 2006, Phillips and Muller, 2006). From the 1990's, the extension of the Upper South East Drainage Scheme has provided between 5 and 15 GL pa inflows into the south lagoon via Salt Creek. In expectation of unrealised greater runoff excessively freshening the south lagoon, discharges were legally capped at 40 GL pa. Currently planned extensions of the drainage scheme may further increase discharges, potentially up to 157 GL pa (Department of Water, 2011). Since 1985 populations of many bird species in South Lagoon (Coorong) have declined, including Black Swan (59%), Fairy Tern (82%), Australian Pelican (77%), Curlew Sandpiper (94%), Sharp-tailed Sandpiper (63%) and Red-necked Stint (68%). During the Millennium Drought the south lagoon proved particularly vulnerable to increased salinity – reaching levels above four times that of sea water - due to reduced water inflows. Extensive loss of seagrass ecosystems, fish and water bird species occurred.

3.3. Environmental significance of the Region

The environmental significance of the region is recognized nationally and internationally (Phillips and Muller, 2006, Kingsford et al., 2009, Brookes et al., 2009, DEH, 2010). The Region supports a range of threatened species and ecological communities The Coorong and Lakes area supports many nationally and internationally significant flora and fauna (Phillips and Muller, 2006). It provides habitat for nationally threatened species, including:

- orange-bellied parrot
- mount lofty ranges southern emu-wren
- murray hardyhead
- hooded plover
- freckled duck
- southern pygmy perch
- murray cod
- southern bell frog.

The Region also contains the critically endangered swamps of the Fleurieu Peninsula, the threatened Gahnia sedgeland ecosystem and a number of threatened plant species. A diverse range of migratory and local waterbirds use the Region, particularly in summer. It is a particularly important breeding site for the Australian pelican, crested tern, fairy tern, and the rufous night heron. Several migratory waders use the Region over summer and are listed for protection under international treaties. The Region was listed under the Ramsar Convention as it fulfils 8 of 9 criteria for wetlands of international importance (Phillips and Muller, 2006). This biota and the Ramsar site are each matters of national environmental significance enabling Federal Government regulation under the Environment Protection and Biodiversity Conservation Act (Australian Government, 1999). A description of the ecological character of the Ramsar wetlands is provided in Appendix 11.1. This is based on the information provided in Phillips and Muller (2006) and the Ramsar Information Sheet formally

submitted by the Australian Government to the Ramsar Convention in 1998 (http://ramsar.wetlands.org/Database/Searchforsites/tabid/765/language/en-US/Default.aspx).

3.4. Ecosystem services provided by the wetlands

A comprehensive analysis of ecosystem services provided by the Coorong wetlands is not available, despite the site being a Ramsar site with the requirement to maintain its ecological character, including its ecosystem services (Pittock et al., 2010). Whether or not this reflects governmental ignorance or indifference to the requirements accepted under the Convention is difficult to ascertain. A comprehensive description of the ecological components of the wetlands was provided (Phillips and Muller 2006), and while including some information on ecosystem services it does not represent a comprehensive assessment based on information collated from the wetlands. The Ramsar Information sheet submitted by the Australian Government in 1998 is out-of-date and precedes the requirement to include ecosystems services within the description of the ecological character of Ramsar sites. A summary of available information on ecosystem services is provided in Appendix 11.1. This is seen as an important gap that could bring immense benefits to the management regimen if closed; namely, by providing an analysis of the benefits that people derive from the wetlands, and by demonstrating how these are interconnected with and dependent on the biodiversity elements of the wetlands. By fulfilling the requirements of the Convention the management authorities could provide an opportune link to the human communities that depend on or value the Coorong wetlands and enhance the management, including the identification of potential adaptation options with tangible benefits for people, and links to the biodiversity that comprises the wetlands.

Within the limitations of the information resources an initial listing of ecosystem services provided by the wetlands is provided below.

- *Cultural services* – science and education; cultural heritage and identity; contemporary cultural significance; aesthetic and sense of place; spiritual, inspirational and religious, including those of the Ngarrindjeri.
- *Provisioning services* – water for drinking, irrigation, tourism activities; food from fishery; wood, reed, fibre and peat, as well as medicinal products used by the Ngarrindjeri.
- *Regulating services* – groundwater replenishment; water purification and flushing of nutrients and salt; coastal shoreline and riverbank stabilisation; carbon storage; local climate regulation.
- *Supporting services* – nutrient cycling; primary production; physical habitat for key biota.

A comprehensive listing and evaluation of ecosystem services is required before a complete description can be provided, as outlined under the provisions of the Ramsar Convention and contained within Australian legislation (Pittock et al., 2010). Further evidence of the importance of the ecosystem services provided by the Coorong wetlands is provided by the Australian Conservation Foundation (O'Connor, 2011, O'Connor, 2010) analyses of ecosystem services from the rivers and wetlands across the Murray-Darling Basin, as well as by the investigations by Morrison and McDonald (2010) on the value the Australian public places on these. The importance and benefits obtained by considering the ecosystem services provided by wetlands, such as those in the Coorong and Lakes, is outlined by the Ramsar Convention and supported through national legislation (see Pittock et al., 2010), and also documented in recent commentary on the Murray-Darling Basin plan (Norris, 2011, Pittock and Finlayson, 2011b).

3.5. Ecological change processes

The determinants of the environmental state and ecological changes to the Coorong and Lakes have been summarised by (Phillips and Muller, 2006:19). The specific ecosystem processes are not well understood for the Lakes but detailed research by CLLAMMecology has identified thresholds and management options for the Coorong (Brookes et al., 2009, Lester et al., 2009).

The primary determinants of the ecological state of the Region's wetlands are the climate, geomorphology and hydrology. As a consequence, the management interventions that most influence the Coorong and Lakes are: regulation of the River Murray, water extraction, operations of the Barrages, dredging of the Murray Mouth, inflows from the Upper South East Drainage Scheme, and discharges to land, water and air. These influence ecosystem components and processes, namely: water regime; physio-chemical environment; keystone species and assemblages; habitat availability; nutrient and carbon cycling; competition and reproduction. In turn these influence the generation of the ecosystem services summarised above.

In terms of the primary determinants the main scope for management interventions – adaptation - in the region to positively influence the environmental state are through changes in hydrology by enhancing the volume, quality and timing of water flows. Through barrages and canals the geomorphology of the Region's wetlands has and could be further influenced, but as we discuss, these measures have high risks as well as opportunities. Further, sea level rise induced changes to the geomorphology and climate change itself are largely beyond the scope of local managers to influence. Some important exceptions are discussed later in this report.

3.6. Recent management institutions

In recent decades the significance of the region has led to a number of management initiatives, although the effectiveness of these could be questioned, largely due to ineffective implementation rather than inherent deficiencies in the plans. Designation of large parts of the coastal areas and lakes as state conservation reserves, including the 48,075 hectare Coorong National Park and 140,500 hectares (which overlap) as a Ramsar Wetland of International Importance (in 1985) has not stemmed the degradation of the wetlands ecosystems which seems to have accelerated from the 1960s and continued into the present (Phillips and Muller, 2006). A succession of management and other government plans have been prepared for the region, which include:

- Coorong National Park Management Plan (NPWS, 1990);
- Coorong and Lakes Alexandrina and Albert Ramsar Management Plan (DEH, 2000);
- 2005 Fisheries Management Plan (Sloane 2005) Management Plan for the South Australian Lakes and Coorong Fishery (Sloan, 2005);
- Ecological Character of the Coorong, Lakes Alexandrina and Albert Wetland of International Importance (Phillips and Muller, 2006);
- The Lower Lakes, Coorong and Murray Mouth Icon Site Environmental Management Plan 2006–2007 (MDBC, 2006); and
- Securing the future. A long term plan for the Coorong, Lower Lakes and Murray Mouth (DEH, 2010).

Further the Ngarrindjeri people have published their "Ngarrindjeri nation yarluwar-ruwe plan" for management of their land and sea country and culture (Ngarrindjeri, 2006). However, it is apparent that neither the state nor federal governments have effectively engaged with the Ngarrindjeri Nation for its implementation; a situation that seems at odds with the rhetoric of community-oriented consultation and acceptance by Australian governments of the

principles of community engagement and entitlement as espoused under national and international legal instruments (see, for example, Pittock et al., 2010).

It is not clear how these different plans relate to each other and how they will be effectively implemented. The adoption of the Water Act 2007 (Commonwealth of Australia, 2008) and requirement for the preparation of a Basin Plan by 2011 (MDBA, 2010) could significantly influence the future state of the Region's wetlands ecosystems. The Plan is required to conserve ecological assets like the Region's wetlands and to set a sustainable diversion limit for water extractions which is to incorporate consideration of climate change impacts and adaptation. However, the initial policy proposals for the Basin Plan have been criticised as inadequate and not meeting their remit and hence compromising the ecological health of assets such as the Region (Pittock and Finlayson, 2011b, Kingsford et al., 2011).

The "Securing the Future" plan was developed by the South Australian Government in the peak of the Millennium Drought, ostensibly as the primary guide for long term management of the Region and in part to access $200 million allocated by the Federal Government to deal with the lack of inflows (DEH, 2010). "Securing the Future" is set within the very short time frame of five years from 2010. It does not present a vision for the longer term of the region. Most consideration is given to the consequences of the Millennium Drought and what emergency mitigation measures can be put in place to minimize its effects. The key important longer term issues such as "How much freshwater is required" (section 6.3) and "What future climatic scenarios" (section 6.4) are not well developed. The section (6.3; pp74-76) on how much freshwater is required outlines the process by which this question might be assessed but does not establish targets for end of system flows. Targets for environmental watering and end of system flows should have been identified so that "Securing the Future" can inform the MDBA Basin Plan with specific long-term goals and targets for the Region. "Securing the Future" is looking to the MBDA Plan for environmental flows to sustain the system but does not give sufficient direction to that Plan.

The section (6.3 pp 77-79) of "Securing the Future" which deals with future climate considers only changing system inflows and their effect on end of system flows, and then notes the consequences for the Region. This is a reactive position where future crises may have to be met with further emergency measures. A more useful approach would be to highlight the environmental flows that need to be returned to the system in a drier future. This section says nothing on sea level rise associated with global warming - a significant oversight. There are other topics on which there is little direction. There is no information on the important fishing industry in the Section 5.5, Social Impacts, nor 5.7, Economic Impacts. The Section 10 on Priority Management Actions outlines the role of the MDBA Plan in securing environmental water for the Region. There is little about management of the local Eastern Mount Lofty catchments by South Australia.

Adaptations local to the Region in "Securing the Future" include managing the Lakes to varying water levels, managing fishways and diverting water from the south-east of the state to the Coorong. These proposals will have long term benefits. However many of the measures proposed were emergency actions that were already underway, including dredging of the Murray Mouth, while others are short-term emergency measures such as limestone dosing, installation of sub-surface seepage barriers, planting on exposed sediments, Meningie lakefront "restoration" and pumping water into Lake Albert. These measures have been made unnecessary by recent river flows into the Region. Few of the actions have long term benefits.

In summary, naturally the Coorong and Lakes are a highly variable and changeable system due to their coastal location and dependence on freshwater inflows from the River Murray and south east. European settlement resulted in interventions to adapt the Region's wetlands to achieve particular water-based economic objectives, but each of these

interventions has had unanticipated, perverse impacts on the state of the wetlands. Limited and largely ineffective investments in science have meant that there was insufficient knowledge to manage the impacts when the unprecedented 2002-2010 Millennium Drought worsened. Nor had sufficient community debate been facilitated for there to be a large degree of understanding and possibly agreement on what ecological state was both desirable and practical. Consequently some of the adaptation measures implemented to manage the drought lacked scientific agreement, were divisive in the community and may have had perverse, but not entirely unexpected impacts. These lessons from managing past adaptation to climatic and hydrological variability need to be applied to the challenges of adapting to climate change. However current institutions are poorly linked and inadequate for long term adaptive management.

3.7. Water in the context of the Murray-Darling Basin

Excessive water diversions upstream in the Murray-Darling Basin have severely impacted the Region. From a pre-development average of 12,430 GL per year, the volume of outflows through the Murray Mouth have declined to just 41% (CSIRO, 2008, Pittock et al., 2010)(Table 2, Figure 5). More importantly, the numbers of years that the Murray Mouth has closed has increased from 1% before development to 40% of years now with major ecological impacts from the lack of connectivity across the Barrages (CSIRO, 2008). From 2002 to 2010 a dramatic decline of inflows due to water diversions and reduced runoff required dredging to keep the mouth open to the Coorong while evaporation resulted in the Lakes – isolated from the sea by the Barrages – falling below sea level. Reallocation of 4,000 GL of water on average per year (~37% of current diversions) or more from agriculture to the environment in the Murray-Darling Basin would provide enough water to sustain the Lakes and their inherent benefits for people under most conditions (Kingsford et al., 2009, Pittock et al., 2010, CSIRO, 2011, MDBA, 2010, Kingsford et al., 2011).

Water flows into the region's wetlands primarily come from the River Murray, with lesser volumes from streams draining the Eastern Mount Lofty Ranges, and also from the south east (Figure 5). South Australia has a minimum annual entitlement flow of 1,850 GL from upstream states and 900 to 1300 GL pa is required for river (salt) dilution or is lost (LMDRG, 2008). Below Lock 1 in a typical year 800 GL is lost to evaporation and 150 GL is diverted to Adelaide. Hence flows greater than about 950 GL per year are needed to sustain lake levels (LMDRG, 2008, DEH, 2007). Considering the water in the Basin under South Australia's control, currently South Australia diverts:

- 665 GL pa from the River Murray (MDBA, 2010:211);
- 11 GL pa from the Mount Lofty Ranges (MDBA, 2010:211);
- It could also add up to 25 to 35 GL pa from the south east drainage scheme (Phillips and Muller, 2006).

This totals 701 - 711 GL pa of additional water under South Australian control compared to 5,105 GL pa in pre-drought outflows from the Mouth (~ 14% of outflows). Consequently South Australia has a limited capacity to increase environmental flows, although the streams draining the Eastern Mount Lofty Ranges and also the inflows from the southeast may sustain small areas of significant wetlands habitat that could form refugia for freshwater biota.

Increasing environmental inflows from the River Murray through reallocation of water interstate is a particularly important option for improving the health of the Region's wetlands. The amount of water needed to improve the health of the wetlands in the Basin has been estimated as ranging up to 7,600 GL pa to achieve a high probability of success (MDBA, 2010, Pittock and Finlayson, 2011a, WGCS, 2010). In October 2010 the Murray-Darling Basin Authority in its "Guide to the Basin Plan" proposed reallocating between 3,000 and 4,000 GL pa from consumptive uses to the environment (MDBA, 2010) and 688 GL in

average annual entitlements had been purchased by April 2011 for the environment under the “Restoring the Balance in the Murray-Darling Basin” program (DSEWPAC, 2011). At the time of writing, the political debate on the reallocation has seen proposals for this reallocation to be reduced to less than 3,000 GL pa with implementation deferred to 2019-2024 (MDBMC, 2011). In Table 2 (summarised in Figure 5) the water inflows and outflows are shown for each of the three sources of water for the Coorong and Lakes, as well as the Basin as a whole. Four scenarios are shown: a) the situation before development, b) the current state with development, c) with a 3,000 GL pa reallocation to the environment, and d) with a 4,000 GL pa reallocation to the environment. The data illustrates that a reallocation of 3,000 to 4,000 GL pa from consumptive users to the environment would greatly increase outflows and thus connectivity.

Table 2. Water inflows and outflows under our scenarios, for each of the three sources of water for the Coorong and Lakes, as well as the Basin as a whole. Data derived from (MDBA, 2010:211-222, Department of Water, 2011).

#	Water body	Inflows (GL pa)	Water used by environment and losses (GL pa)	Diversions (GL pa)	Outflows (GL pa)
1	Murray downstream of Wentworth – without development	14,150 (100%)	1,720	0	12,430 (100%)
	Murray downstream of Wentworth – with current development	7,269 (51%)	1,524	704	5,038 (41%)
	Murray downstream of Wentworth – with +3,000 GL pa SDL	9,163 (65%)	1,646	521	6,992 (56%)
	Murray downstream of Wentworth – with +4,000 GL pa SDL	9,804 (69%)	1,664	459	8,488 (72%)
2	Eastern Mount Lofty Ranges – without development	120	47	0	73 (100%)
	Eastern Mount Lofty Ranges – with current development	120	40	11	67 (92%)
	Eastern Mount Lofty Ranges – with +3,000 GL pa SDL	120	43	8	68 (93%)
	Eastern Mount Lofty Ranges – with +4,000 GL pa SDL	120	43	7	68 (93%)
3	South east drainage scheme – current	5-15	n/a	n/a	5-15
	South east drainage scheme – cap	40	n/a	n/a	40
	South east drainage scheme – maximum possible increase	157	n/a	n/a	157
4	Basin outflows – without development	31,781	19,278	0	12,503 (100%)
	Basin outflows – with current development *	32,778	13,996	13,677	5,105 (41%)
	Basin outflows – with +3,000 GL pa SDL *	32,778	15,041	10,677	7,060 (56%)
	Basin outflows – with +4,000 GL pa SDL *	32,778	15,356	9,677	7,754 (62%)

* Includes inflows from interbasin water transfers into the Basin.

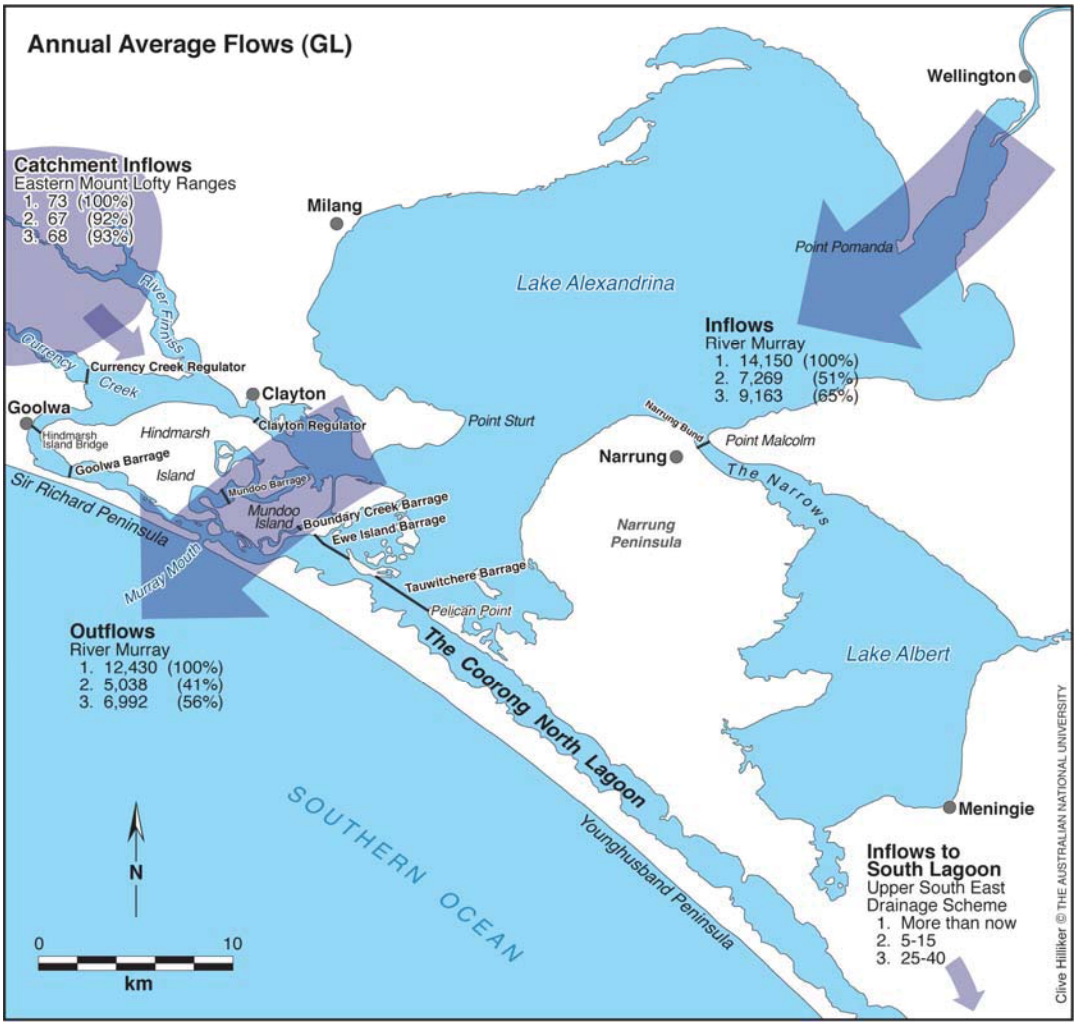

Figure 5. Lower lakes and Coorong inflows and outflows of freshwater. Freshwater flows into the Lower lakes and Coorong from the River Murray (data here for flows below Wentworth), the Eastern Mount Lofty Ranges catchment, and the Upper South East Drainage Scheme (USEDS). Data is shown here in annual average flows in GL from CSIRO (2008) and Philips and Muller (2006). Three situations are shown: 1. Flows before development, 2. Flows with current levels of development, and 3. Estimated flows with the reallocation of 3,000 GL pa to the environment under the Basin Plan. Data is poor for the USEDS. Prior to development large natural inflows are reported through surface and ground waters that significantly influenced the south lagoon of the Coorong (Phillips and Muller 2006). Inflows with the proposed extension of the USEDS are uncertain but may be more than 40 GL pa.

Under current development conditions the river flows over the Barrages and through the Murray Mouth around 64% of the time (despite being closed for most of the period from 2002-2010) compared to 99% before development. This would rise to 90% of the time with a reallocation of 3,000 GL pa, and 92% with 4,000 GL pa (MDBA, 2010). This debate on reallocation of water to restore the freshwater ecosystems of the Basin, and the Coorong and Lakes in particular, has not thoroughly considered how to respond to changes in hydrology due to climate change, as discussed in the next section.

3.8. Summary

The Coorong and Lakes region has undergone substantial prehistoric environmental change and has been significantly changed historically with successive adaptations to climatic and hydrological variability. Its location at the end of the River Murray system makes it highly vulnerable to climatic and anthropogenic changes in the basin, and being on the coast it is at the mercy of sea level rise. As one of Australia's major coastal wetlands it is of the highest environmental significance, as well as being the land of the Ngarrindjeri Nation and other communities.

The complex geomorphology of the Coorong and Lakes means that the ecological process and values within the system differ greatly. Major degradation of the wetlands has occurred primarily due to reduced freshwater inflows and subsequent engineering responses (adaptations, although possibly better described as maladaptations). Environmental stress and community conflict has generated a plethora of local management initiatives, yet whole-of-Basin conservation measures are also required. Increasing environmental flows is the major response that could restore the Region's environment in the short to medium term. In this context we now consider the additional impacts of climate change.

4. CLIMATE CHANGE AND THE REGION

Our consideration of climate change begins with an assessment of international perspectives on adaptation before considering the Region in greater depth.

4.1. Climate change and adaptation: international perspectives

The climatic and hydrological cycles on Earth are inextricably linked. Climatic change is thus expected to have a wide range of impacts on water availability, timing and quality that are summarised here (Bates, 2008, Pittock, 2009a). While in different parts of the world water availability is expected to increase, in southern Australia decreases are anticipated. Higher temperatures are expected to increase evapotranspiration and reduce runoff. Seasonal changes in precipitation and snow melt will change the timing of flows. More frequent extreme events are expected, such as floods and droughts. The combination of extreme events and higher temperatures may increase erosion and diffuse pollution, reducing water quality and exacerbating cyannobacteria blooms. These changes are likely to impact on populations of many indigenous species and enable invasion by exotic species. Major impacts on societal systems based on historical climates, such as water infrastructure, are expected. In addition, many societal responses to climate change are consuming more water and having other negative impacts on freshwater ecosystems (Pittock, 2010, Pittock, 2011). Mitigation has been the primary focus to date in climate policy and involves a relatively limited number of centralised and tractable – if contested – policy measures to price emissions (Dovers and Hezri, 2010). However, the growing stock of atmospheric greenhouse gasses means that mitigation cannot now prevent climate change (IPCC, 2007, Rockström et al., 2009). In contrast to mitigation, adaptation involves almost every facet of society in actions that must ultimately be local to adapt to the different circumstances of each region (Dovers and Hezri, 2010).

Earlier, we described how adaptation was ideally seen as a planned response to vulnerability resulting from exposure and sensitivity to climate change impacts (Adger, 2006, Adger et al., 2009, Adger et al., 2005). Although the terminology is defined differently by various authors, adaptive responses to climate change could be categorised as: resisting change; resilience, which is returning to a pre-existing state after an impact; or changing to a new state (Nelson, 2010, Dovers and Hezri, 2010). Adaptation often involves undertaking proven measures that our societies know that we should be doing anyway as they provide other environmental or socio-economic benefits – “no and low regrets” measures (Dovers and Hezri, 2010, Dovers, 2009). Historical experience of extreme events (as in the Coorong and Lakes) provides a solid basis for many adaptation measures, and the autonomous adaptation experience of people and institutions should be harnessed (Dovers and Hezri, 2010). However all adaptation strategies carry risks as well as providing opportunities, and careful consideration is required to spread risks through adoption of different but complementary measures (Dovers and Hezri, 2010, Pittock and Finlayson, 2011a). Adaptation measures in different sectors may conflict (Pittock and Connell, 2010), and have perverse impacts amounting to maladaptation (Barnett and O'Neill, 2010). Water infrastructure in particular is engineered to meet a set range of conditions and may fail with hydrological change, and thus risks being over-specialized adaptation (Milly et al., 2008, Nelson, 2010, Bates et al., 2008) unless cyclical adaptive management systems are adopted (Pittock and Hartmann, 2011). Some ways of managing infrastructure under changing conditions include focussing on reoperating existing structures, staged development and reversible infrastructure (Hallegatte, 2009).

4.2. Climate change in the context of the Murray-Darling Basin

The Murray-Darling Basin is anticipated to be particularly vulnerable to climate change because of its mid-latitude which is expected to dry as the Sub-tropical Ridge pushes rain bearing storm fronts further south, greater evapotranspiration, more frequent droughts, over-exploitation of groundwater and declining water quality (CSIRO, 2008, Pittock, 2009a, Cai and Cowan, 2008, Timbal, 2009, Murphy and Timbal, 2008, Leblanc et al., 2009, Nielsen and Brock, 2009, CSIRO, 2010). Increased temperatures and seasonal changes in rainfall have been observed in the southern Basin (Schofield, 2011, Cai and Cowan, 2008, CSIRO, 2010). There is considerable uncertainty, with the possibility of similar or increased levels of summer rainfall in the northern Basin, however the southern Basin is expected to get drier (CSIRO, 2008, CSIRO, 2010).

CSIRO's Sustainable Yields Project undertook modelling for three scenarios for changes in water availability in the Basin for 2030 (CSIRO, 2008), as summarized in Table 3. A wide range of possible hydrological outcomes was identified ranging from a modest increase in surface water through to a substantial decline, with lower water availability the most likely outcome in the southern Basin. The range of possible outcomes highlights the challenge in designing effective adaptation measures. Further, the much more severe, short term impacts experienced in the Millennium Drought in the Region compared to the average conditions for 2030 under CSIRO's extreme dry scenario illustrates the potential impacts of extreme events. In this context we consider the short term impacts of the Millennium Drought as one potential analogue (excepting sea level rise) for severe climate change impacts in the Region. The CLLAMMecology Cluster also predicted moderate climate change impacts on the state of the ecosystems of the Coorong, and identified a number of thresholds that could inform management (Lester et al., 2009).

Table 3. Scenarios for changes in water availability in the Murray-Darling Basin due to climate (CSIRO 2008).

CSIRO scenario	Average surface water availability in 2030	End of system flows in 2030
2008 Extreme wet	+7%	+20%
2008 Median	-12%	-24%
2008 Extreme dry	-37%	-69%
Situation in early 2010	-63%	(No outflows)

To counter potential water losses due to climate change the Murray-Darling Basin Authority in the Guide to the Basin Plan proposes a 3% reallocation of water to the environment, apparently on the assumption that the Plan's ten year life is a quarter of the 40 year span of CSIRO's median scenario for 2030 (CSIRO, 2008)(Table 3). There are three aspects to the proposed Plan that may help manage water scarcity with climate change, namely: a) water entitlements which are proportional to water availability (but currently discriminate against environmental allocations); b) the proposed 3% reallocation for climate induced losses; and c) the ten year iterative planning cycle (Schofield, 2011, CSIRO, 2008). This approach has been criticized as inadequate for managing the risk of more severe climate change, especially when much more severe, short term impacts were experienced in the Millennium Drought (Pittock and Finlayson, 2011b). Climate change is also expected to contribute to sea level rise, as discussed below.

In addition to climate change impacts on the volume of water inflows into the region there is the question of impacts on water quality. Water temperatures in the Lakes and Coorong vary seasonally from 11 C to 26 C (Geddes 1984, Geddes and Butler 1984). Increased water temperature may affect the composition of ecological communities in the Region however

research in southern Australia has focussed on streams and there is no data available on the impact of future water temperature regimes on the Lakes. Salinity and acidification are issues that arise with lower freshwater inflows and are assessed throughout this report. It has been suggested that climate change may increase erosion and nutrient inflows into freshwater ecosystems (Pittock 2009), however this may be offset if drier conditions lead to less intensive agriculture requiring less fertiliser use in the catchment. Although streams in the Basin regularly suffer from cyannobacteria blooms there is no history of eutrophication in the Lakes and the mixing induced by wave fetch would reduce the likelihood of such blooms. Except with respect to salinity and also conservation of freshwater refugia in the Region, water quality issues are regarded as secondary issues in the remainder of this assessment. There is a need for investment in further research on water quality in this ecosystem.

For the purposes of this research, we have elaborated on the three climate change scenarios for the Region from section 2.2 in Table 4 drawing on the CSIRO median and extreme dry scenarios also the Millennium Drought as an analogue and interpreting the potential outcomes. As discussed, the CSIRO extreme wet scenario was excluded as it was inconsistent with the NCCARF brief to assess limits to adaptation with +2°C and +4°C warming.

Table 4: Future climate change scenarios for the Coorong and Lower Lakes region

Future 2030 scenarios		**Vulnerability assessment**						
#	***Scenario***	***Drivers of change***	***Condition***		***Sensitivity***	***Adaptive Capacity***	***Risk minimisation***	***Substitutes***
			Biophysical	*Socio-economic*				
1	CSIRO 2030 median +1.03°C	Climate change, sea level rise, fluctuating lake level, water diversion, water quality decline. Environmental flows attempted to keep lakes fresh.	Drier, hotter climate. Periods of salinity, acidification, and limited connectivity likely. Lake waters non-potable at times. Biodiversity loss. Sea level rise unlikely to overtop the Barrages in this timeframe and with moderate warming	Modest recovery of fishing and tourism and ecological cultural values. Degraded system subject to climate variability.	Modelled Basin inflows of -12% and outflows of -37% (CSIRO 2008) without reallocation of water to the environment.	High potential to adapt by reallocating water to the environment and through smarter management of infrastructure.	A target annual median flow of 3,800 GL, 700 GL (+6%) higher than before recommended at the Barrages (Kingsford et al. 2009). Infrastructure changes. Basin wide reallocation of up to 7,600GL suggested (MDBA 2010).	Operating a "virtual weir" at Wellington with e-flows and "transparent barrages" has been proposed to improve natural connectivity and variability in the lakes' environment (Geddes pers. comm.)

2	CSIRO 2030 dry extreme +1.6°C	Climate change, sea level rise, water diversion and water quality decline. Lakes either with low freshwater level or barrages open to sea water.	Much drier, hotter climate. Low quality water inflows. Extreme water level decline, salinity and acidification or conversion to a marine ecosystem. Southern Coorong hypersaline. Severe impacts on biodiversity. Loss of connectivity - mouth kept open by dredging. Past 2030 this degree of warming makes it more likely that the Barrages would be over topped by sea level rise	Fishing and tourism and ecological cultural values severely impacted. Local economies in decline if lakes dry and water quality declines.	Modelled Basin inflows of -24% and outflows of -69% (CSIRO 2008) without substantial reallocation of water to the environment.	Moderate potential to adapt by reallocating water to the environment and through smarter management of infrastructure.	A target annual median flow of 3,800 GL, 700 GL (+6%) higher than before recommended at the barrages (Kingsford et al. 2009). Infrastructure changes. Basin wide reallocation of up to 7,600GL suggested (MDBA 2010).	Operating a "virtual weir" and "transparent barrages" are options (Geddes pers. comm.) but they may become increasingly vulnerable to short term variability, equivalent to the Millennium Drought.

3	Extreme change +4°C	Severe climate change, sea level rise, water diversion and water quality decline. Barrages open to sea water.	Much drier, hotter climate. Extreme water level decline, salinity and acidification. Loss of connectivity. Change from freshwater to marine biodiversity. Mouth kept open by dredging. Large rises in sea level may occur after 2030 with +4°C warming overtopping the Barrages	Modest recovery of fishing and tourism and ecological cultural values based on a marine system. Lake level fluctuations require significant adaptation of lake shore activities. Natural water use for farming at risk and desalinized water too expensive: end of agriculture?	Extreme reductions of inflows, in the order of 60% (Cai & Cowan 2008), and consequent long-term cessation of outflows are likely. The 2009/10 reduction of inflows by 63% and cessation of outflows is a potential analogue.	Low potential to adapt with insufficient freshwater inflows to adequately maintain the lakes or a large estuarine area. Inflows may be of very low quality. Extensive salinization, acidification and loss of biodiversity is likely.	The loss of inflows under this scenario would make minimisation of risk improbable.	Opening the lower lakes to the sea may maintain a large water body for boating and fishing and tourism. Constant intervention may be required to keep the mouth open.

4.3. Risk and Vulnerability

The Coorong wetlands face increasing risk and vulnerability to climate change. It is anticipated that the wetlands will be subject to increasing risk from existing pressures, such as those imposed by water management across the wider Murray-Darling Basin, as well as local changes by the plethora of pressures for local development and supporting local interests. These are likely to revolve around or intersect with policies and changes due to water inflows, water quality and sea level rise. These issues in effect provide a summary of the reasons to develop adaptation measures that include wider environmental change as well as the anticipated consequences of climate change, including sea level rise.

The impact of changes to, or more likely, reduced water flows into the wetlands reflects both current governmental policy as well as the anticipated consequences of climate change (Kingsford et al., 2011, Pittock and Finlayson, 2011). Further droughts, especially those akin to the Millennium Drought, will drastically reduce flows and further increase vulnerabilities of both the wetlands and the communities that depend on the rivers and wetlands. As current plans to return water to the environment do not meet the requirements to maintain the ecological character of the wetlands in the Basin as a whole, it is anticipated that the vulnerability of the Coorong wetlands will only increase, not decrease or be mediated (Pittock et al., 2010; Pittock and Finlayson 2011).

At the same time the water quality of the Coorong wetlands is also expected to remain vulnerable to adverse changes given the influence of water allocation policy and anticipated changes in the climate. Any measure, whether driven by climate or catchment-oriented policy that reduces inflows, including the larger or more episodic flushing flows, will exacerbate water quality issues that are, arguably, already indicative of near-irreversible changes. Sea level rise, as measured over many years, will also increase the vulnerability of the Coorong wetlands through possible direct impacts, for example, by increased salinisation as a consequence of inundation by high tides or storm surges, or by limiting adaptation options, that is, by limiting operational responses in the areas likely affected by tidal inundation.

As discussed in section 2.2, CSIRO has identified a 2030 extreme wet scenario for an average annual increase of inflows into the Region of 20% based on a +1.6 °C scenario global climate model run. While this scenario may reduce vulnerability to inflow reduction and is less risky, it would only marginally, if at all, ameliorate the impacts of sea level rise.

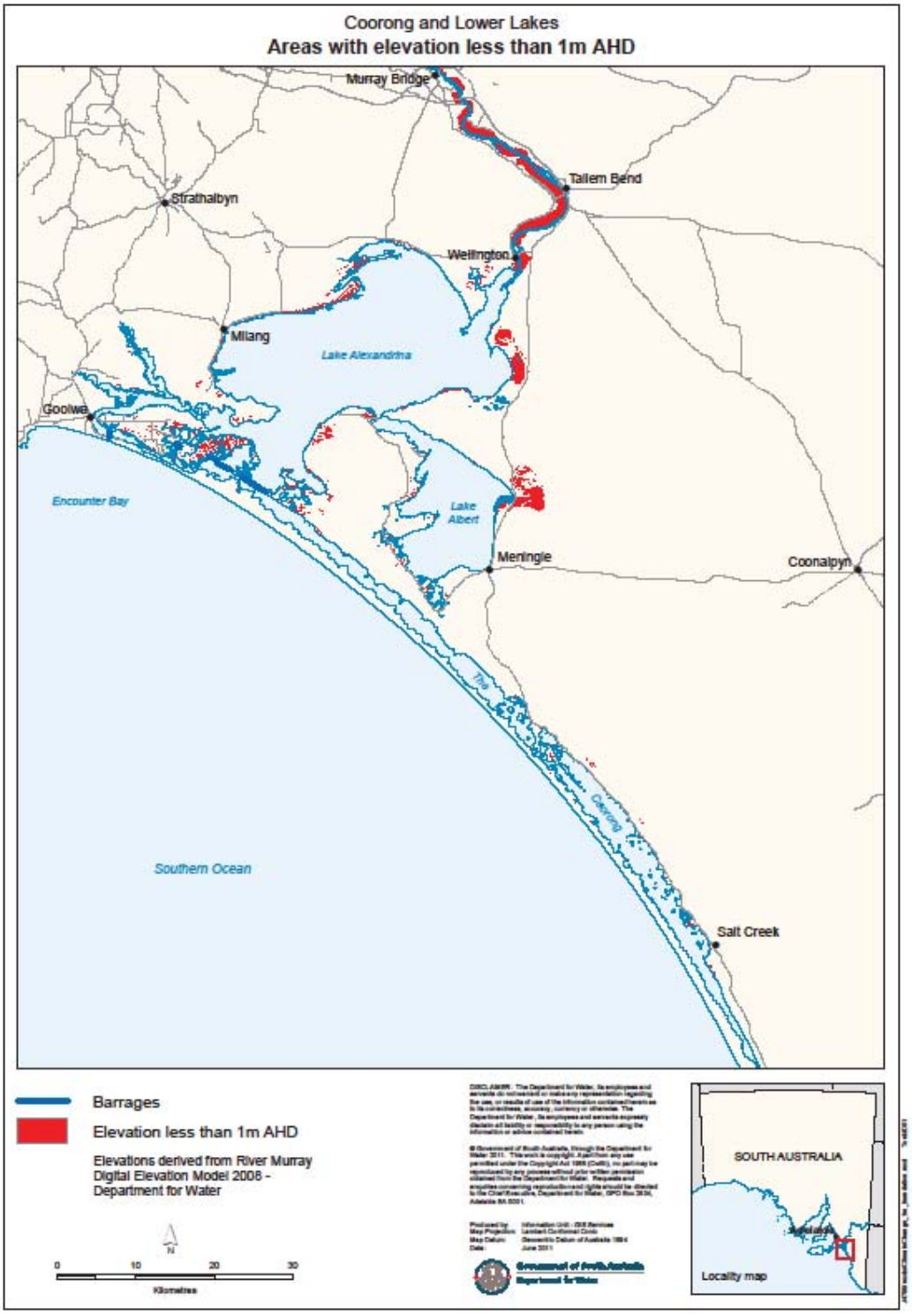

Figure 6. Sea level rise in the Region. Portions of the region (in red) below 1 m AHD that could be inundated with a 1 m rise in sea level. Some of these areas are not connected to current water bodies and may not be inundated. Source: South Australian Department for Water.

5. PROJECT METHODOLOGY

5.1. Research approach, assumptions and scope

By its nature this type of research requires a multidisciplinary approach in which a complex set of social, ecological and institutional arrangements and issues can be investigated. In this project we recognise that gaining an understanding of multifaceted problems within a highly complex context, such as the Coorong and Lakes area, requires a research approach that is itself multifaceted. Such a research approach is needed so that a range of different perspectives from a variety of knowledge sources within the study area can be explored. To make best use of these sources of local knowledge the project team brings a range of skills to the project. These skills areas include localised and contextual social and ecological knowledge, legal and institutional arrangements for ecosystems of national and international importance, climate change adaptation in wetlands, national and international water and climate change drivers and policies and the social aspects of complex problems.

As well as drawing on multiple sources of expertise and local knowledge, another important aspect of the research is the capability for reflection and learning as the research progresses. This is known as an adaptive research approach (Layder, 1998). While a research project generally adopts an overarching methodology and develops specific methods to conduct the research, in an *adaptive* research approach there is recognition of the value of a continuing engagement and reflection between the different parts of the research as the research itself progresses. Interactions of this type can be between theories and data within the research area (such as in the theory and practice of climate change adaptation) but can also be a reflection within the empirical findings as each stage of the work progresses. For example, findings from one area of the research, such as an interview with a stakeholder can influence the direction or choice of another set of interviews to explore an emerging theme from the earlier interview. This adaptive research approach encourages a broad and full exploration of the issues in complex problems, such as found in the Coorong and Lakes area. This approach can deliver insights into a complex problem that may not have been uncovered in a more rigidly structured research framework. For example, adaptive theory was helpful in understanding perceptions of injustice in conflicts over water allocation in the Murray-Darling Basin (Gross, 2010, Gross, 2011). An additional benefit of an adaptive research approach in the context of multidisciplinary team work exploring complex issues with roots in many different areas is that it stimulates a continual engagement between the different knowledge areas of the research.

The overarching methodology within which this research project was designed takes an inclusive or holistic approach to climate change adaptation in that the interconnectedness of ecosystems and social systems is seen as a fundamental aspect of the central problem. As researchers we recognise the importance of healthy communities and healthy ecosystems and the co-evolving nature of the region being studied. We use the term methodology here to describe the ideas which form the basis of the research approach (Midgley, 2000). The social and ecological linkages, interfaces and dependencies between ecosystems and social systems are an intrinsic feature of the complex system being studied (Berkes and Folke, 1998, Boyden, 2004). Thus the *scope* of the research project includes an exploration of the full range of factors that comprise the Coorong and Lakes area, including biophysical, institutional, social and political. This requires an understanding of how the current arrangements and current conditions have come about, and therefore includes the historical context as well as the current context. While the scope of the research is limited to the Coorong and Lakes, we recognise that this is but one set of interconnected systems in the much larger catchment area of the Murray-Darling Basin, and nationally as regards to water policy and regulation. Therefore, artificially limiting the scope to just the Region is not always possible and maintaining awareness of the larger context of the research is important.

Nevertheless, the focus and primary scope of the project is on climate change adaptation in the Region.

Given the overarching methodology the approach taken in this research study does not start with a broad set of assumptions. Rather, the research is exploratory in nature. The three main areas of the research method, project team meetings, literature review and stakeholder interviews, do not start with any specific assumptions about climate change adaptation. However, one general assumption adopted from the outset was that this type of complex research, both from a contextual and theoretical perspective, requires the type of broad-based and adaptive research approach described above.

5.2. Research methods

As mentioned above, we identify in this project three key areas of investigative methods. The first is recognising that the regular project team meetings, with either the whole team or a subset of the team, were important features of the research method. For example, although the team meetings were used at the outset to draw together information, determine the project approach and devise the project plan, there were also many wide-ranging and fruitful discussions throughout the project which were essential for idea development, exploration of emerging themes and the identification of implications and recommendations for climate change adaptation.

The second key research method was the ongoing exploration of the literature to investigate different aspects of the research. These aspects included wetland, estuarine and freshwater ecology in the context of the Region; international and national Ramsar Convention site initiatives and implications; climate change adaptation research and initiatives; vulnerability assessments and social-ecological linkages in complex problems. The literature review also focused on the socio-ecological context of the Region. Many different types of documentation were used in the review. These included peer-reviewed journal articles, government and scientific reports, unpublished commentaries and reports, website information including community action group reports, campaign communications and the like.

Semi-structured interviews comprised the third research method. Semi-structured interviews, conducted in-person and confidentially, were chosen as the best way to gather information directly from people involved in the area. These types of interview facilitate the use of "what" and "why" questions to explore people’s experiences and perceptions of adaptation and climate change in the area. Semi-structured interviews allow a flexible approach to information gathering: although a set of questions is developed prior to the interview, the interview questions are used more as a guide and can be adapted while the interview is underway to reflect an interviewee's different knowledge base and experiences of the issues being explored (Minichiello et al., 1995). This type of interviewing approach, in which the interview is conducted rather like a conversation, also allows for people to reflect on the questions and think about the topic without feeling the need to have answers at the ready. The confidential nature of these interviews supports this interview environment in which interviewees can feel at ease to describe their thoughts and experiences without fear of being identified or having their identity and views made publicly available. Thus the complex interactions between different stakeholder groups and individuals could be explored and an understanding gained of the range and diversity of these differing perspectives.

5.3. Research tools, interviews and dealing with the data

Prior to embarking on the fieldwork the ethical implications of the research were considered and approval for the research was gained from the Australian National University Human Research Ethics Committee (Protocol 2010/571 approved on November 1 2010, with a variation approved on May 4, 2011). As part of the initial approval process three research tools were developed: an information sheet on the research to give to interviewees (Appendix, 11.2.1); a consent form for interviewees to sign (Appendix, 11.2.2) and a set of questions to guide the interview (Appendix 11.2.3). An additional research tool that was used in the first round of interviews was a number of 3 x 5 cards, placed in front of interviewees, with the terms "Adaptation: adaptation possibilities"; "Limits to adaptation"; "Maladaptation" and "Impact: material, social and personal". These were helpful during the interviews to draw interviewee's attention to these concepts and keep the interview on track as the conversations progressed.

The interviews were conducted in two main rounds. The first round took place early in the research process (November 2010 to January 2011) and was designed to gather basic information and perspectives about the Region and adaptation to climate change in that context. This first round of 29 interviews comprised people from different stakeholder groups primarily living in the Region and surrounding areas, including Adelaide, although one university interviewee lives outside South Australia (interviewed in March). Interviewees were selected primarily through two methods: either recommendation by a member of the project team or through the snowball or networking method (Ritchie et al., 2003) whereby interviewees were themselves asked to nominate other people who they thought would be able to contribute significantly to the research. Interviewees were contacted by phone or by e-mail. The information sheet was either sent in advance prior to the interview or given to the interviewee at the time of the interview. All interviews in this round were conducted in person by Catherine Gross. The interviews were recorded (with the permission of the interviewee) and summary high-level notes made after each interview with up to 10 key points being identified. Interviewing continued until it was felt that no significant new perspectives or insights were coming up. This is known as "saturation" (Richards, 2005) whereby the researcher feels that adequate data gathering has taken place and that the key perspectives have been gathered.

The second round of seven interviews took place towards the end of the research process (May and early June 2011). The purpose was to discuss the draft conclusions and recommendations with key informants who were known for their experience and knowledge of the overall institutional and political context in which the report would be circulated. These interviewees were identified at a project team meeting. In addition to the information sheet interviewees were provided with a three-page document describing the draft recommendations. This formed the basis of the discussion. Interviews were conducted by either James Pittock or Catherine Gross. Again, the interviews were recorded and summary notes made immediately after the interview. The data from all interviews was stored securely under computer password.

Data analysis from all interviews took place immediately after each interview, with summary notes being recorded, and emerging themes and ideas identified. These themes were numerous and varied including for example, a particular belief about the Region, a source of tension, an idea about water management or use and experience of community engagement or involvement. This analysis continued throughout the interviewing process. After interviewing was complete the themes were summarised for project team review at the team meeting in April 2011 and in subsequent e-mail discussions in which conclusions and recommendations were drawn up. The themes are described in Section 7 in which data from individual interviews is used to illustrate the diversity and complexity of the interviewee perspectives.

5.4. Reflections: benefits and limitations of this research approach

There are many benefits of this research approach and also some limitations. It is clear from this project that a multidisciplinary team can devise a suitable project approach to untangle a complex socio-ecological problem. The three aspects of the research approach facilitated an exploratory and yet structured and rigorous research project. Significant insights and a broad set of conclusions and recommendations are the result. Discussions with key informants in the final round of interviews have already demonstrated the value and usefulness of the recommendations to people working in natural resource management and within the institutional context.

Similarly, in the first round of interviews the range of perspectives and clarity with which people recounted their experience of adaptation and institutional challenges shows the benefit of a confidential interview process that is conducted with sensitivity. Letting people speak about what is important to them and being guided by the interviewer and the research tools provides a richness of data that could not be gathered through other techniques such as questionnaires. However, it should be noted that there is disagreement and a sense of disquiet already in the Region around confidentiality and the lack of transparency. For example, one potential interviewee refused to be interviewed on the grounds that the person did not agree with confidentiality of research gathering processes. This person argued that research of this nature should be fully transparent and that the interviews should not be conducted confidentially. It seemed that this research approach tapped into some larger area of concern about the way government consultation processes had worked in the Region just prior to this research project. This is one limitation of an interviewing approach that places confidentiality as central design feature.

Finally, it would have been advantageous to the research to be able to explore the issue from an expanded scope. Two examples include being able to interview people further upstream about their views of the impact and limitations of climate change adaptation on the Region, and also to explore more fully the scientific pros and cons of the different adaptation options that have been put forward in recent years.

6. LESSONS FROM HISTORICAL ADAPTATION

Preceding the social component of this research into limits to adaptation is an assessment of the outcomes of historical adaptation measures in the Region to inform the subsequent discussion. The post-settlement management of the Region is a history of interventions to adapt to variable hydrological conditions. The location of key measures is shown in Figure 7 and they are detailed in Table 5.

In terms of those relevant to climate change adaptation, major impacts have arisen from the extraction of water upstream in the Basin for irrigation from the 1860's which reduced the flows needed to maintain low salinity levels and keep the Murray Mouth open (Sim and Muller, 2004). The risk of saltwater inflows into the lakes resulted in the decision to build the Barrages (completed in 1940 with a then anticipated lifespan of 60 years) to separate the lakes from the Coorong. This then enabled a series of industries to develop based on the artificially high and constant operating level of the lakes, including water diversions, stock watering canals, boating facilities and a marina development.

These two actions – irrigation extractions and the Barrages – have resulted in a cascade of unintended consequences, with each emerging problem resulting in another hard engineering intervention (Kingsford et al., 2009). The overly narrow operating ranges of this infrastructure were exposed with climatic variability, highlighting vulnerability to climate change and resulting in ever more desperate measures. The barrier to fish required the renovation of the Barrages to incorporate new fish passages. The loss of inflows into the Coorong contributed to the construction of the Upper South East Drainage Scheme to, in part, increase low saline water flows into the south lagoon. The total reduction of system inflows required the use of dredges between 2002 and 2010 to keep the Murray Mouth open. Similarly, the unintended impacts on the Coorong of the drainage of freshwaters to sea in the south east part of South Australia are being progressively addressed by redesigning the system to put low salinity water into the Coorong via Salt Creek. Growing freshwater scarcity was also a catalyst for reoperation of irrigation farms on the lower Murray to enable more efficient water use and reduce salinity.

These water management problems escalated when river Murray inflows fell below levels required for sustenance of the lakes, and as they desiccated (falling below sea level) an increasingly more desperate series of adaptation measures were implemented and planned (DEH, 2010, DEH, 2008, DEH, 2007, SA Water Corporation, 2009). The lack of adequate scientific knowledge of the lakes' ecological processes contributed to uncertainty and dispute over adaptation measures. Falling lake levels required construction of pipelines to supply water to towns and farms, but the more remote farms were not supplied with sufficient water for their dairy herds and the businesses closed. Lake Albert was fenced and the sulfate sediments on its dry bed were dosed with limestone and sown with plants to stem acidification.

A number of crude, inoperable bunds were built in order to maintain freshwater refuges and keep acid sulfate sediments submerged (Geddes and Walker, 2009, Kingsford et al., 2009). As Lake Albert dried a decision was taken to isolate it with a bund and pump water into it, a measure that was then abandoned as Lake Alexandrina fell to precipitously low levels. The Clayton regulator isolated the Goolwa Channel and enabled pumping of water into it to maintain higher levels, and a low level bund across Currency Creek was built to form an emergency refuge for freshwater biota. The bunds further fragmented the lake system, offended the beliefs of the Ngarrindjeri people and were contested by those communities which did not benefit from inundation of their sections of the lakes. Despite promises for their full removal once adequate lake levels were restored through inflows – which occurred in

late 2010 – the South Australian Government subsequently said in 2011 that it did not have the technology or funds to fully remove the bunds (Caggiano, 2011a, Caggiano, 2011b). This highlights the risks from poorly planned adaptation measures. Further bunds and other measures were planned (Section 8) had water availability declined further.

The new Federal Government began purchasing water in 2008 and by June 2011 had acquired 750 GL of annual average water entitlements in the Basin (DSEWPAC, 2011). This is being used by the Commonwealth Environmental Water Holder to maintain aquatic biodiversity in the Basin, including, in part, in the Region. With the $3.1 billion is allocated under this program ultimately around 1,200 GL could be purchased (Pittock et al., 2010). This funding is not enough to buy sufficient water – estimated at 4,000 GL or more – to adequately restore and sustain the lakes and Coorong (MDBA, 2010, WGCS, 2010, Pittock et al., 2010). This history of adaptation in the Region holds a number of lessons. Large, hard engineering interventions such as the Barrages have unintended consequences or work in only an overly narrow range of operating conditions and can amount to maladaptation (Nelson, 2010, Barnett and O'Neill, 2010). These engineering measures have then required more and more complex interventions to manage their perverse impacts. Ideally adaptation measures would be implemented in a staged manner, operated flexibly and be fully reversible (Hallegatte, 2009), tests that the emergency bunds largely fail. Lack of rigorous scientific knowledge of the ecology of the lakes and rushed planning of the emergency measures at the peak of the Millennium Drought contributed to design problems and community division over implemented and planned adaptations. The opportunity cost of these hard adaptation measures needs to be compared to soft adaptation options, in this case purchasing greater environmental water entitlements, to identify more beneficial interventions (Kingsford et al., 2009, Grafton, 2011). It is with these lessons in mind that we further consider socio-economic aspects of adaptation in the region and options for managing more severe climate change.

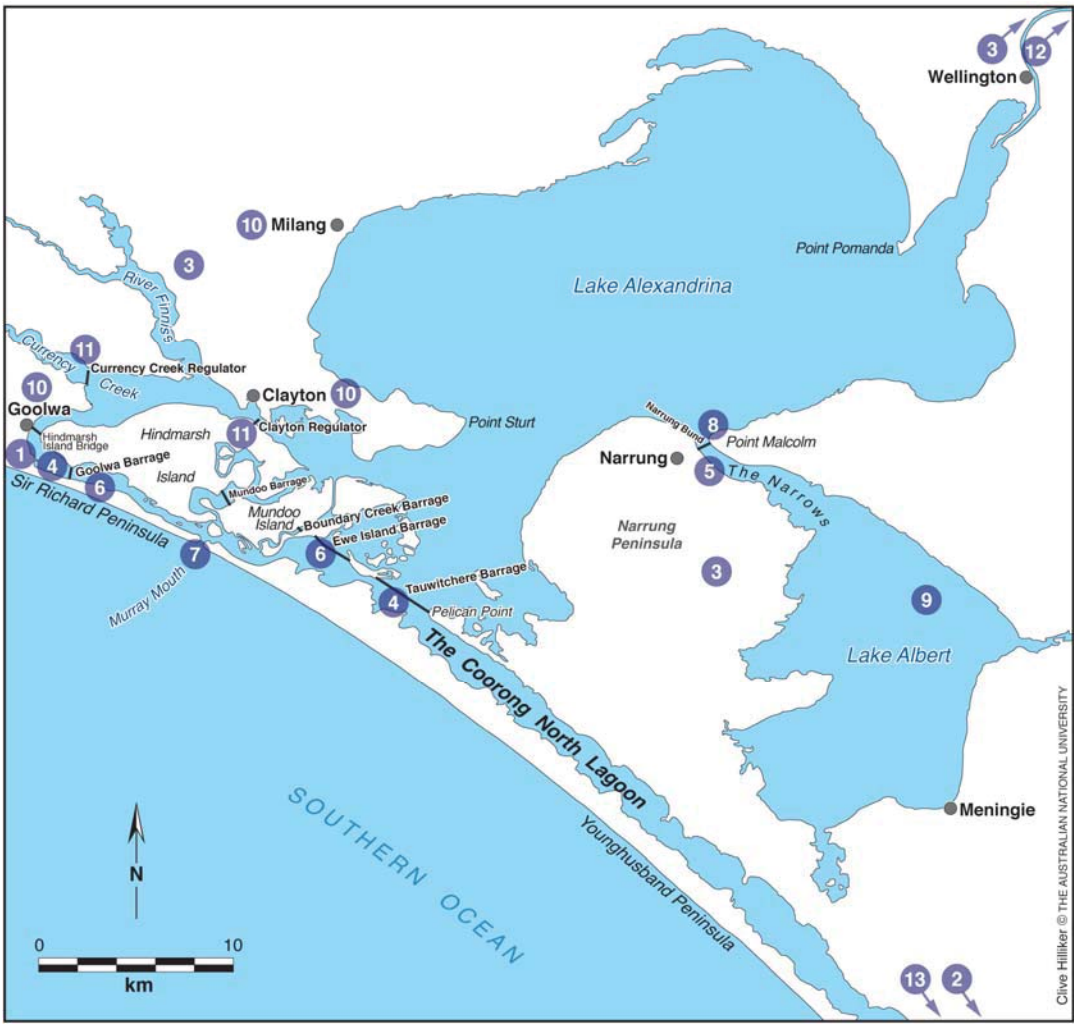

Figure 7. Historical adaptation measures in the Lower lakes and Coorong Since European settlement numerous measures to adapt to climatic and hydrological variability have been implemented in the Lower lakes and Coorong (see Table 5 for details).

These include:

1. Goolwa to Victor Harbour railway
2. Drainage of the upper south east lands to the sea
3. Irrigation and livestock water extraction
4. Barrages
5. Narrung Narrows car ferry
6. Addition of fish ladders to the Barrages
7. Dredging the Murray Mouth
8. Narrung bund and pumping water into Lake Albert
9. Fencing out, limestoning and planting dried lake beds
10. Piping water to users from the River Murray above Wellington
11. Clayton and Currency Creek regulators
12. Renovating irrigation areas on the lower River Murray
13. Upper South East Drainage Scheme (delivered to the Coorong South Lagoon via Salt Creek before flowing towards the North Lagoon)
14. Purchase of water entitlements for environmental flows (not shown)

Table 5: Key adaptation measures applied in the Region from 1915 to 2010
Sources: (DEH, 2010, DEH, 2007, DEH, 2008, Kingsford et al., 2009, SA Water Corporation, 2009)

#	Date	Vulnerability	Adaptation	Benefits	Costs	Limits / maladaptation
1	1887	Loss of shipping in the Murray mouth, in part due to low flows.	Goolwa –Victor Harbour railway – Cockle Train.*	Enabled transport of cargo around the Murray mouth, which was dangerous for ships.	Triple handling of cargo.	River shipping was replaced by rail.
2	1860s onwards	Wetlands and seasonal flooding reduced agricultural production potential.	Drainage of freshwater to the sea from the south east region of South Australia (England, 1993)	Increased the land area available for farming.	Reduced freshwater inflows into the Coorong's southern lagoon. Reduced groundwater recharge. Reduced area of wetlands and associated resources like water birds.	Diversion of freshwater has increased salinity in the Coorong's southern lagoon, decreasing flora and fauna populations.
3	1860s onwards	Crops and livestock impacted by climatic variability, especially inconsistent rainfall.	Beginning in Victoria, increasingly large volumes of water were extracted for irrigated agriculture (Sim and Muller, 2004). Around the lakes, stock watered directly from channels of the lakes' edges.	Increased the reliability and volume of agricultural production by reducing reliance on immediate rainfall.	Increasingly severe environmental impacts from water diversions that are magnified down the River Murray. Increasing salinity. Water levels in the lakes need to be maintained at a constant level for livestock access.	Increasing diversion entitlements to 1994 and a variable and changing climate have reduced reliability of water access. Rising salinity is ruining some areas of farm land and threatens freshwater supplies.
4	1935-1940	Loss of access to fresh water from the Lakes during low flows and seawater ingress.	Barrages between the Coorong and lakes (Sim and Muller, 2004).	Prevented saltwater ingress into the lakes, enabled freshwater supply to be drawn directly from the lakes.	Changes in fisheries and loss of biota due to constant water levels and loss of connectivity. Greater sediment accumulation, including of acid sulfate sediments.	The Lakes are not sustained with reduced inflows from extreme droughts or climate change.

5	?	Very long transportation distances for residents of the Narrung Peninsula around Lake Albert to Adelaide.	Narrung Narrows car ferry constructed, including causeways serving as ferry abutments that narrow the width of the water passage by about half.	Improved road transport for local residents to key services at Murray Bridge and Adelaide.	Ferry abutments have enhanced silting of the Narrows, greatly constricting water exchange between lakes Albert and Alexandrina leading to reduced water quality in Lake Albert.	Impacts are unnecessary as a different ferry abutment design could restore water passage. Car ferry and water flows may be cut with reduced inflows from extreme droughts or climate change.
6	2004	Insufficient opportunities for migratory fish to pass over the Barrages resulting in population declines.	Addition of fishways to the Barrages+.	May allow migratory fish to pass from the sea to the River Murray.	Part of $25 million. Effectiveness of the fishways is yet to be proved.	Does not change the artificial sea-freshwater barrier at the Barrages; lakes need to be full to operate the fishways.
7	2002-2010	Low inflows saw the Murray Mouth silt up, stopping water exchange and decreasing water quality in the Coorong.	Dredging the Murray Mouth.	Maintains an open channel to the sea to maintain wildlife passage and dilute hypersaline waters in the Coorong.	$32 M / 5 yrs Ongoing expense.	Requires ongoing work while ever inflows are low.
8	2008-2011	Desiccation of Lake Albert.	Narrung bund between lakes Alexandrina and Albert, enabling pumping water into Lake Albert. Bund built as a non-operable structure, eg. in terms of fish passage.	May limit ASS oxidation in two different modes of operation. When first built it was used to pump water from Lake Alexandrina into Lake Albert to maintain higher water levels. When inflows into Lake Alexandrina remained too low, the bund was operated to isolate Lake Albert to reduce evaporative loss of water that could impact on Lake Alexandrina.	Up to $14 M. May accept loss of wetlands habitat in Lake Albert.. Following inflows to the lakes the SA Government breached the bund but now says it cannot afford to fully remove it.	Lakes naturally disconnect at -0.3 AHD; did not work with low inflows. Bund constructed as a temporary structure.

9	2009-2010	Acidification of desiccated lake bed sediment and its wind borne transport as dust.	Limestoning and planting of grasses and semi-aquatic plants to control acid sulfate sediments. Livestock fenced out of Lake Albert.	May reduce acidity. Possible biodiversity gains through riparian plantings. Can reduce wind erosion. Introduces carbon to stimulate sulfate reducing bacteria.	$10 M. Ongoing expense. Accepts some loss of wetlands habitat.	Indefinite maintenance of dry lake beds is unlikely to be publicly acceptable
10	2009	Loss of access to freshwater with the desiccation of the lakes and decline in water quality.	Piping water to many CLLAMM communities (Narrung, Meningie, Milang, Point Stuart) from the River Murray above Wellington.	Remove reliance of some local communities on water supply from the lakes. More efficient water supply. Could enable more variable management of water levels and quality in the lakes.	$127 M. Some farms not supplied resulting in loss of production.	Supply of most far-flung farms considered too expensive. Limited volumes that can be supplied.
11	2009	Desiccation of the Goolwa Channel and Currency Creek estuary.	Emergency installation of non-operable Clayton and Currency Creek regulators to maintain high freshwater levels in the Goolwa Channel, and if that failed, the Currency Creek estuary.	Possible reduction of acidification of the bunded-off waterbodies and establishment of refugia for freshwater aquatic species. Potential to help manage freshwater releases to the estuary. Enabled boating to continue on limited areas.	$26 M. Accepts some loss of wetlands habitat. Reduction of connectivity and transport of nutrients and sediments. Community conflict	May not work with low inflows. Weirs were constructed as temporary structures and with the return of inflows the SA Government says that it now cannot afford to fully remove them.
12	?	Inefficient water use in irrigation and induction of salinity.	Renovating irrigation areas on the lower Murray: laser-levelling fields and upgrading infrastructure.	More efficient use of water in agricultural production, lower production costs and potential to expand agricultural production with 'saved' water. Reduced salinity.	$60-90 M. Greater energy use in new infrastructure. Considered an expensive mechanism to return water to the environment	With more and more efficient water use there is less room for error. More efficient water use can only provide limited water for either agriculture or the environment
13	1990s on	Increasing salinity and ecological degredation in the Coorong south lagoon due to low of inflows.	Upper South East Drainage Scheme and Reflows redirect freshwater and mildly saline runoff into the Coorong via Salt Creek.	Provided 5-15 GL pa in increased flows of less saline water to freshen the Coorong south lagoon. Some other SE wetlands also received water. There is a proposal to further extend the Scheme (see Table 7).	Cost? Some areas of indigenous vegetation were destroyed or bisected by the USEDS drains.	Runoff in the SE is likely to decline with increased evapotranspiration with climate change.

14	2008 on	Reduced environmental flows down the River Murray.	Federal Government purchased 750 GL of annual average water entitlements in the Basin from 2008 to June 2011 (DSEWPAC, 2011).	Purchased water to be used by the Commonwealth Environmental Water Holder to maintain aquatic biodiversity in the Basin, including, in part, in the Region. With the current funding the program may ultimately purchase around double this amount (Pittock et al., 2010).	$3.1 billion is allocated under this program which may purchase around 1,200 GL (Pittock et al., 2010). The reallocation of water may constrain agricultural production.	The funding is not enough to buy sufficient water to adequately restore and sustain the lakes and Coorong (DSEWPAC, 2011).

* Cockle Train, http://www.steamrangerheritagerailway.org/index.php?option=com_content&view=article&id=3&Itemid=6, accessed 30 June 2011
+ Fish passage at the Barrages, http://www2.mdbc.gov.au/__data/page/65/BarrageFishway_long.pdf, accessed 30 June 2011

7. RESEARCH FINDINGS: PERSPECTIVES OF STAKEHOLDERS

Key findings from the interviews are presented in this section. The purpose is to give an overview of the range of different perspectives on the Region held by interviewees from different stakeholder groupings. These are arranged in three main areas: how people value and use the area; how people have worked with each other both within communities and with external agencies, and how government, scientists and communities have worked together. All the information presented in this section is taken from interviewee data, and represents a subset of the total data collected. The information presented here illustrates emerging themes about climate change adaptation and people's perspectives on past adaptation activities and decision-making processes.

7.1. Perspectives on the area: how people value and use the area

7.1.1. A diversity of livelihoods and perspectives

There is a wide range and diversity of perspectives held by people living in the Region. Livelihoods, cultures, beliefs, values, emotions, future plans, family roots, social networks, hopes and aspirations all featured strongly in the interview conversations about the way in which people use the area and value the area. People talked not only about how they themselves use and value the area, but also what they thought about the way *other* people in the Region use and value it. Controversy about different aspects of the Region centres on these differing perspectives about how people should or should not use the natural resources in the Coorong and Lakes area. Users of the area are highly diverse and include those who live there permanently and those who visit on a seasonal basis. Indeed, this diversity is a feature of the area: residents and visitors range from wealthy holiday-home owners who enjoy the area principally for recreational boating to farmers, tradespeople and tourism operators who make their living within the area. Thus many value the area because their livelihood and overall well-being is dependent on the health of both the ecosystem and socio-economic system, while others value the area mainly for recreational purposes. This creates a tension between those who perceive themselves as dependent on the area versus those who have an external income and are not dependent on the area for any aspect of their well-being. Such tensions are not limited to localised differences: there is also the ever-present interstate disagreement about use of water along the length of the River Murray and how much water is needed to keep the Region healthy.

People interviewed for this research project included vineyard owners/managers, farmers, environmentalists, traditional owners, community leaders, local government employees and councillors, retirees, local ecologists, fishermen, a marina operator, a doctor, state and federal government employees, scientists, and people with multiple interest areas, such as authors and artists who also work as local government employees and farmers. It is impossible to separate people into distinct stakeholder groupings because the majority have several different types of interest in the area, including how they value the area for their livelihood, and how they value the area culturally, socially and spiritually. For example, a farmer could be a conservationist as well as a local business owner benefiting from tourists interested in recreational boating. Similarly a vineyard owner or business manager may also benefit from the tourist trade, but have very strong opinions about the way water in the Region is managed, which would not necessarily be in line with another tourism operator. A key finding from these interviews is that people living in the Region have a very wide variety of experiences, knowledge and beliefs about how individuals, communities and governments have adapted to changing water levels, climate variability and government interventions in the face of perceived risk.

Opinions and perspectives about government activities, community activities and adaptation interventions vary greatly. It is not possible to predict what opinion someone might hold from

their settlement or position in the community. Even scientists disagree about the necessity of different types of interventions in the Region. Thus the area is characterised by a myriad of groups and communities with a patchwork of common interests and yet with strongly held opinions and beliefs that cause underlying tensions which can erupt into social conflict. However, there is one common element around which all life in the region coalesces: water. Water is the vital natural resource around which people of the Region pursue their livelihoods and their social lives. The health of communities and the health of ecosystems depend on water levels, water availability, water quality and the flow of water between the connected systems of the Region. Since the arrival of Europeans the principal driver of change has been water management to allow water to be diverted and stored for human use. Thus, adaptation activities carried out by people in the Region since European settlement have been primarily around the management of water. This includes local adaptation but, more importantly, adaptation to large-scale changes since the upstream diversion of irrigation water and the construction of the Barrages to prevent sea water entering the Lakes.

7.1.2. The Ngarrindjeri

For tens of thousands of years people have lived in the Region, with the Ngarrindjeri people being the traditional owners of the area. The Ngarrindjeri depend on their country for their food gathering, recreation, and spiritual and cultural well-being. In turn, they care for, protect and conserve their country through their traditional way of life. Thus, Ngarrindjeri life and their activities are intimately interconnected with the country that they live in. It is not a question of valuing the area or using the area: the Ngarrindjeri *are* an intrinsic part of their country.

The Ngarrindjeri people have seen the rapid change of their traditional country into a landscape in which water management for human use became the predominant driving force. The Ngarrindjeri people have suffered from what they perceive as the destruction of their lands and waters and also from the way they have been treated as a people. The lack of respect by local communities for Ngarrindjeri cultural beliefs and cultural sites came to a head with the building of the Hindmarsh Island Bridge in the 1990s. In 2003 Ngarrindjeri leaders submitted a proclamation to the State Government in which they pointed out that they had been conferred rights to the land on which they live by the South Australian Colonising Commission in 1836. Since that time they had been denied Constitutional recognition for this right and perceived that they had been treated inequitably since that time (see Ngarrindjeri Nation, 2007). One Ngarrindjeri interviewee drew attention to the ongoing problems with this lack of recognition and with a perceived lack of respect with which the traditional owners are treated. For example, the perceived inappropriateness of the latest Ministerial appointment for the portfolio of Aboriginal Affairs and Reconciliation was seen as disrespectful and plain "wrong", when taking into account aboriginal culture and how the Ngarrindjeri and governments work together. But, conversely, many people in government positions *do* understand the need and benefit of Ngarrindjeri participation in natural resource management. For example, one retired state government employee lamented the overall way in which the Ngarrindjeri people had been treated and said he felt that the Ngarrindjeri people had "come off worst" in the recent drought because the loss of water had a significant impact on their culture and traditional way of life.

7.1.3. Rural communities around the Lakes and Coorong

The legacy of settler agriculture from the 1840’s is apparent in the towns and communities around Lakes Alexandrina and Albert. Communities sprang up around the agricultural enterprises and many people in these communities are still dependent or semi-dependent on agriculture today. These include farmers themselves, farm workers, businesses selling farm equipment, tradespeople and service professionals such as nurses and teachers.

Farming varies from irrigated dairying, to less intensive dry-land beef and sheep grazing. Some long-standing farming families in which farms have been handed down from generation to generation still exist in the Region although there has been substantial change in the last decades. One dairy farmer near Meningie described the family farm dependence on water and how the dairy farming community has been dramatically reduced during the recent drought because of the lack of water quality and availability in Lake Albert. Even though dairy farming in the Lake Albert area has changed substantially with less use of irrigated pasture and a new reliance on piped water, which is more expensive than water pumped from Lake Albert, this interviewee suggested that dairy farming was part of the family history and the family would still like to see it part of the future. This farming family valued the area for the lifestyle of their livelihood as well as it being their historical roots and their current and future home. This sentiment was echoed by dry-land farming interviewees who also expressed their connection to the land and the Lakes as not only that of lifestyle and livelihood, but also as a type of emotional or spiritual connection. Many spoke of their personal sadness or anguish when seeing the Lakes dry out: not only because of the impact on their farming enterprise, but also because they value the area for its natural beauty, the health of the wildlife and their own place in it. Many were concerned about their children and grandchildren being able to experience the Region in the same way that they had and wondered if the changes wrought by human activities and climate change would make this an unrealistic aspiration.

Commercial fishermen also rely on the Region for their livelihood. Again, commercial fisheries have a long history in the area with some multi-generation fishing families being long-standing members of communities. Fishermen value the area not only for their ability to catch fish and make a living from this, but also for the way they can sustainably manage their fish stocks and enjoy the benefits of continuing a long tradition, with perhaps their children taking up the same settlement.

7.1.4. Scientists, naturalists and conservationists

Many people would classify themselves as a conservationist, naturalist or ecologist whether or not they made a living from conservation work. Many interviewees were involved in conservation work, to a lesser or greater degree. A retiree, who was also a dryland farmer, suggested that conservationist would be a good description for her because it neatly described her attitude to the area and the way she valued it: she would like to see it conserved. This interviewee suggested that the area should be considered as a "jewel in the crown" of the Murray-Darling Basin and was surprised that more people did not understand what the area offered in terms of its unique ecological characteristics. Another suggestion was that the way people referred to the area as the "Coorong and Lower Lakes" was rather derogatory and that it would be better to say "the Lakes and Coorong (Lake Alexandrina and Lake Albert)". Other interviewees suggested that the area should be valued, not only for its natural beauty and wildlife habitat, but also its function in the whole catchment of the Murray-Darling Basin. The Region carries out an important function in moving salt and excess nutrients out to sea and should be valued as such. In this light, the Region should also be valued for its interconnected nature and therefore any obstruction to water flow should be seen to diminish the ecological and functional value of the area. One ecologist, who did not live in the area, but worked in the area, values the area for its wildlife and habitat, including the Ramsar status. A scientist who also did not live in the area suggested that the area should be valued for its "unique wetlands" which have a high value as breeding and feeding grounds for water birds.

7.1.5. Businesses and communities around Goolwa

As well as primary industries such as agriculture and fishing many other business operators value the area for the natural resources which provide the basis for their livelihood and business operation. The area has been home to vineyards and wineries for many decades, and the industry is an attraction for tourists as well as a source of high-quality wine. New vineyards have become established in recent years and vineyard operators value the area for the climate, the soils, availability of water as well as the attraction of the area to tourists who are an additional source of income for the wineries. For example, one winery near Currency Creek markets its products in Goolwa through regular wine tastings and promotions, thus drawing on visitors to the area and residents of Hindmarsh Island and Goolwa. Residents, whether permanent or seasonal, value the area for the natural resources including the coastline, the Lakes, the Goolwa channel and opportunities for boating in the waterways of the Region. The Hindmarsh Island marina, a large complex of more than 500 waterfront homes, has been built to capitalise on the extensive waterways. Thus, the level of water in the channel has a significant effect on the value of these properties. During the recent drought the low water levels in the marina were thought by many to be a strong political driver behind the building of the Clayton regulator to maintain the water level in the Goolwa channel. Several interviewees commented on this persistent rumour. One interviewee described how he had decided to wait for more certainty about water levels before building his home on the marina. During the drought and low water levels at Goolwa many businesses declined and many boat-owners took their boats elsewhere. Thus, water availability and water levels are highly valued in the Goolwa area.

7.1.6. Key emerging themes about the Region

Role of the Region as part of a larger Murray-Darling Basin catchment

Many interviewees described the importance of seeing the Region as a fully connected and complex system with variability of climate, seasonal water in-flows, wind movement and other natural cycles. The imposition of the Clayton regulator and Narrung Bund were frequently used by interviewees as indications of a lack of understanding of the importance of this connectivity and the work that the Region does as part of the entire catchment of the Murray-Darling Basin. Many interviewees believe that people generally don't understand how the system works nor the importance of the system in terms of its ecosystem functionality. Thus many people in the region hold the view that the Region is not understood for its functional significance, is not appreciated for its importance to biodiversity, and is not valued for its unique natural attributes.

The freshwater perspective versus the estuarine perspective

There is a clearly palpable tension of perspectives between people in the region who emphasise that Lakes Alexandrina and Albert were predominantly freshwater prior to large-scale irrigation extraction, and those who argue that the Lakes were estuarine to some degree before the construction of the Barrages in the 1930s. This dichotomy of perspectives came out clearly in many interviews. The freshwater perspective has been documented in a booklet published by the River Murray Catchment Water Management Board (Sim and Muller, 2004). One interviewee explained his opinion as to why these two opposing perspectives have come to prominence in current day discussions about water in the Region. In his view people who support the "freshwater" perspective are concerned that if the "estuarine" perspective prevails then this supports recent suggestions to open the Barrages to let seawater in to the Lakes during times of drought and low River Murray flows, as had been recently experienced. Thus, he described the estuarine perspective as an "inconvenient truth" which is why there is such a strong move to show evidence for the Lakes being predominantly freshwater. Going further, the incentive for returning large volumes of water as environmental flows is reduced in an "estuarine" perspective of the

Lakes. He believed that there was an underlying fear among the residents of the Region that the Lower Lakes could dry up.

Perspectives on climate change and adaptation to climate change
Differences of opinion were also evident in people's perspectives about the realities of climate change and adaptation to climate change. One interviewee, an elected official with a local council, described how people were sceptical about the reality of climate change. He describes the profile of people in his area as being conservative and older than 50 years. In this category people feel that climate change is "just cycles". He recounts how the then Prime Minister, Kevin Rudd, visited Lake Alexandrina during the drought and announced that what he saw before him was "due to climate change" which offended the local community. In their opinion the cause of the dry lake bed was much more complicated than that, including over-allocation of water in upstream states. Thus he described how too much emphasis on climate change can cause political resistance and reinforce a belief about a political party. Thus politics has an influence on people's beliefs about climate change. This interviewee also believed that people in his area responded to climate change initiatives, such as the installation of solar panels, not because it was a "green thing to do" but rather because it made "economic sense" to them.

Many interviewees suggested that they were continually adapting their livelihoods and lifestyles to climate variability. Thus adaptation to climate change was not something entirely new: many adaptation measures that people had taken in recent years were due to lack of water and this was seen as a combination of climate variability as well as over-extraction of water from the River Murray by upstream users.

7.2. Perspectives about relationships: how people work with each other

7.2.1. Community perspectives

A significant amount of time in many interviews was spent discussing the way in which governments and communities interacted. This varied from generalised discussions about long-term community-government relationships to discussions about specific initiatives or examples of community consultation. Many interviewees in the community felt very strongly that governments failed to consult widely about important initiatives, such as the Clayton regulator or the proposed Wellington Weir. This was why people felt moved to form or join protest groups, such as the River, Lakes and Coorong Action Group Inc. One interviewee suggested that the government had lied about the Clayton regulator, suggesting that it had used the risk of acidification in the Lower Lakes as the rationale for building the structure, when in reality it was due to political pressure from the Goolwa "boaties" to keep water in the Goolwa channel for economic and business reasons. One Councillor, a resident of Goolwa, was also of this opinion, saying that he was sure that the Hindmarsh Island Marina development company had put pressure on the state government to build the regulator. Thus cynicism and concerns about the "misuse of information" about acidification grew amongst the community during the period prior to construction of the Clayton regulator.

In addition to failing to consult widely, some interviewees in communities that were badly affected by the loss of tourism and agriculture due to the low water levels in Lake Albert, felt that they had been largely "abandoned" by the government. A health professional said that the impact on the people had been enormous and he had worked hard to get funding for a mental health worker to assist those whose mental and physical health had suffered as a result of their economic circumstances. He added that he thought the government had been "utterly useless" in assisting the community and believed that it was mainly because their votes didn't count.

The impact on the community of the failure by the community and the government to come to agreement on adaptation interventions, such as the Clayton regulator, also had a detrimental impact on the community itself. People developed entrenched positions and this split communities between those in favour and those against certain initiatives. This affected people in many different ways, some becoming depressed, some changing their day-to-day habits in order to avoid meeting people, some becoming very wary about topics of conversation in order to remain "friends". Ironically, the formation of protest groups also brought different parts of the community together united in a common cause. One interviewee described how she used to shop in Goolwa and now went to Victor Harbour, as a result of her strong feelings about the campaign. However, she and her husband were now contemplating leaving the area, in part as a result of the Clayton regulator episode.

A community leader, working in a community centre, was concerned about issues of social justice in terms of government decision-making. She was critical of the "decide and defend" strategy which she thought governments used frequently when making difficult decisions and felt that much consultation is a "sham". She felt that government has no "clear idea of what community *is*" or the capacity of the community to be engaged in making and implementing decisions. She described several perceived limits of government's ability to work with communities. These include the inability of government to treat community as an equal partner; the fact that government has the dollars which gives it the power and puts the community at a disadvantage in terms of power relations; the government doesn't trust the community and vice versa; government gets defensive if community criticises the government; the government does not understand that a "decide and defend" strategy doesn't work and that the community will get "snippy"; and that the government often has staff changes and is too busy dealing with their own internal issues to deal with local community issues. This interviewee also felt that the government lacks specific local knowledge, but on occasion does recognise that the local community has the capability to develop ideas and implement initiatives. This is manifested when the government "takes" ideas to use as their own, as they did on several occasions in her experience. This is an example of government not giving credit to local community for their capabilities or innovation.

Along similar lines an environmental project officer talked about the government lack of appreciation for such work as environmental monitoring carried out by the community. She was concerned about the way government staff treat people in local communities, suggesting that many government employees see those in the country as "hicks" and do not appreciate that they are under-utilising the considerable resources of the community. Not only does the community have local knowledge, and can be the "eyes and ears" for the local area, but it is also good for the community in terms of their own confidence and their ability to make a recognised contribution. One example of this is the "Save the turtles" campaign carried out by school students and members of the community on the shores of Lake Alexandrina. Turtles living in the lake suffered from the weight of tubeworms growing on their backs due to rising salinity levels. The plight of turtles and campaign to rescue them received national media attention. The campaign was seen by local people to be helpful to members of the community themselves as well as the turtles because they could do something to help the wildlife even in the face of natural disaster. However, one person active in the campaign felt that the government had not appreciated how important this type of self-help initiative was to the community and had even blocked some of the community activities within the campaign. Another aspect of tension between government and community is the release of grant money: delays in payments due to perceived bureaucracy or "red tape" merely frustrates the community who cannot reliably plan seasonal environmental initiatives, such as shrub plantings.

7.2.2. Government perspectives

A local government councillor was also critical of state government decision-making and the "decide, announce and defend" strategy. He believed that communities need to be prepared for these decisions and that state governments should listen more to communities. In his opinion local government was the "most sensitive and most powerless", being close to the community, but not having the power to intervene or influence decision-making. In his opinion the "battle" was not with elected politicians, but was rather with the public servants. One example was the embargo of a report regarding the impact of the Hindmarsh Island Bridge. This report identified important sites to the Ngarrindjeri people but the report was not released. A local government employee involved in strategic planning suggested that politicians and senior government officials are often more concerned with the "photo opportunity" rather than "really listening". Another local government employee involved in strategic planning made the point that "we cannot seem to have an honest discussion until there is a level of chaos" referring to the Queensland floods in the Brisbane area. When there is a crisis it "becomes okay" to talk about tough issues such as development in floodplains and insurance, which were not discussed before the flood. To this interviewee it is impossible to have an "honest debate" within the government. He also thought South Australia generally does not get heard in the larger scheme and that many federal dollars do not get down to the community level, being "dissipated" into the state agency.

A retired state government employee talked at length about the community consultation initiative in the development of the “Securing the Future plan”. In this strategic planning exercise community engagement was a central part of the overall plan with a five-level model being utilised. He described the importance of data and information being available and how people will not accept decisions in the absence of good information. He felt that in this exercise the government had done all it could to design and conduct an effective engagement strategy. He recognised the value of ongoing community engagement but made the point that realistically state government does not have enough funds for enduring community engagement. Another state government employee expressed frustration that members of the community will say that they have not been listened to, even though some specific projects, such as the one described above, do include well-planned and thorough community engagement.

7.2.3. Scientists perspectives

One ecologist interviewee talked in general about the way governments miss opportunities for learning or for further research, during periods of crisis, because of the perceived imperative to "act" and to be seen to be doing something. He felt that this was at the expense of controlled experiments, such as could have been done during the period when the acid sulfate soil problem was being evaluated. He felt that the acidification crisis became the prominent driver for management of the problem and that the government themselves exacerbated the problem in their quest for a quick "fix". In his opinion governments like to be seen to be doing things and not necessarily to learn. However, a state government scientist was very clear about the real threat of acidification to the lakes and that there was a real risk. Therefore, in his opinion there was a real need to act quickly. In his opinion, scientists didn't agree about the risk because they didn't understand the risk of acid sulfate soils. In terms of relationships between scientists, state government and community it seemed to him that in a crisis everyone comes out and it seems that "everyone is an expert". But as soon as the crisis is over then people go away again, which is frustrating because they need to be involved on a continual basis. This interviewee recognised the importance of being empathetic with community people and trying to help them, but he also recognised that this is a bigger question of how society functions as a whole. He felt that the local community was not adequately voicing their passion about the return of environmental water to the system, which was the ideal solution for the Region.

Another scientist felt that governments move to make decisions without fully considering all the options. He felt that he should have been consulted and that a wider set of options with innovative ideas could have been considered at the time of the acidification crisis.

7.2.4. Key emerging themes about community, government, scientist relationships

A key theme emerging from this interview data is that good relationships between different groups of people are not only vital in developing plans and responding to problems, but also for community well-being and achieving decision acceptance. But, the perspectives and experience of many in the local communities of the Region show that their expectation of state government to consult with communities and engage communities is seen to be unmet in many different ways. An underlying theme is the perceived lack of government recognition of knowledge and capabilities within local communities, and the feeling of disconnection between community people and government staff. This lack of connection is also felt by scientists who observe that governments are more motivated to act, than consult, consider options and learn.

These themes are critical in understanding how different parts of society work together to understand and address common problems and work out adaptation options and preferred solutions.

7.3. Emerging themes about adaptation and the limits to adaptation

While the main objective of the interviews was to gain understanding about people's thoughts about adaptation and the perceived limits to adaptation, many of the conversations revolved around people's experience of past adaptation, which included their own specific ways of adapting as well as their experience of regional initiatives. Since many of these initiatives were controversial, it is understandable that the way in which people work together, or fail to agree, becomes a focus when discussing limits to adaptation. Thus, the interviews tended to follow a common path in which discussions initially revolved around what interviewees wanted to say about their recent experiences with adaptation initiatives and then the conversation could move on to different aspects of adaptation, including theoretical ideas and what people saw as limits or barriers to adaptation.

Few interviewees talked in very specific terms about their ideas and plans for climate change adaptation. An exception was a winery business development manager who was well aware of the potential impacts of climate change on his business. He thought that rising temperatures due to climate change would turn the area into one that is similar to the Riverland region in the North. In his view temperature was the key climate change limiting factor. However, he described how his business was in a process of continual adaptation. For example, he sold all his permanent water and now leases it back (for economic reasons); he uses sophisticated weather monitoring technology and has three sources of water for resilience purposes. In his opinion the limits to adaptation are rising temperatures, cash availability (to purchase land elsewhere) and population growth in the area resulting in new subdivisions and reduced land for grape production. He believed that there are different types of people who adapt in different ways: "some need a tap on the shoulder whereas others need to be run over by a truck". He gave the example of the dairy industry in the region -- why did they not see that it was not viable? Thus, another limit is the ability of people to adapt and to forecast what might happen under different scenarios. Another suggestion was that government funds may be allocated to those who "are beyond help". In this case equity was an issue: was it fair to subsidise those who were unable to adapt but not to subsidise those who were managing and funding their own adaptation activities.

A local government councillor thought that a limit to climate change adaptation was the rejection of scientific advice. He was concerned that politics is always likely to interfere in

adaptation planning and implementation and asked the question "can we rise above politics?" He gave the example of the Murray-Darling Association of local government recognising the need for a "wider college of knowledge". Along similar lines a local council Mayor also thought that politics was a limit to adaptation with lack of trust of governments and political resistance within local communities creating social limits to adaptation. He suggested that if climate change is to be accepted and acted upon, there needs to be more trust between politicians, government and community. Another local council interviewee suggested that local government is itself limited in adaptation planning because it can only promote local initiatives and it depends on state and federal government for initiatives on a broader scale.

Politics and fear of upsetting economic constituencies was an adaptation limit seen by a scientist, who gave the example of the impact of the Hindmarsh Island Marina on local politics and local initiatives in the Region. These types of local limits prevent a holistic view of adaptation being taken in which *all* initiatives are considered for their impact on the environment. Maintaining the status quo becomes the overriding goal and people within the community become cynical because they are consistently "burned out by bad processes". Another conservationist interviewee who had consistently contributed to community engagement initiatives felt that the real limits to adaptation are the capability for understanding large complex systems. She thought that we can deal with small problems, but we do not have the understanding, knowledge or communication powers to deal with large complex problems. In her view these limits had already been reached because there was no general understanding by the community at large about the value of the Region for its landscape function and natural attributes. Another farmer had a similar view suggesting that until people who talk about water being "wasted" in the Lakes realise the value of the area there will always be an adaptation limit of *understanding.* In his view he had already reached an adaptation limit because he felt it was becoming very hard to continue to deal with a situation in which communities were divided over adaptation interventions, and in which he felt that governments had misused information to justify a particular adaptation intervention, such as the Clayton regulator.

Two interviewees, both farmers, were concerned about the long-term impact of "burn-out" from poor consultation in decision-making processes on the mental health of people in the area. One said "my job is to keep my husband alive" describing how he had become reserved and had stopped going to meetings and engaging in farming networks. Another pointed out that women seem to be able to cope better and have stepped up to take on negotiating roles whereas men have become "edgy" and withdrawn. She was concerned about declining health services and facilities in the area and said that to lose the hospital would be a "limit" to social adaptation. All farmer interviewees described how they had been continually adapting to declining water availability, through such measures as changing their stocking practice, purchasing water through pipelines, selling water allocation and moving into beef cattle, buying land in other regions for resilience purposes. However, a major concern and potential limit was whether young people would stay in the area and take over farming and support settlements or whether they would leave for work in regional centres. A doctor in the same rural area suggested that the ability to maintain physical and mental health was a limit to adaptation. If people become depressed they "let their general health go… they drink and smoke… they get ill". This was reinforced by another interviewee who suggested that there are mental limits to adaptation and one of these is depression. Another is being "too tired to keep fighting proposed maladaptations", referring to the campaign against the Clayton regulator. On the other hand, seeing a healthy lake and wildlife gives people an "inner strength… solace and inspiration", which was important in helping people adapt. In the same vein adaptation activities, such as community planting makes people feel better.

In discussions about consultation processes some interviewees raised as a limit to adaptation the fact that community representatives were not given funds for travel expenses for their contribution to community engagement processes. This was not seen to be fair or conducive to continuing engagement. A number of interviewees commented on the extra work entailed in representing community interests, not only the economic expense but also the time taken away from family or earning a living. This was felt to be somewhat inequitable in comparison to government employees who were paid fully for their work. One fisherman explained that being involved on advisory boards and community boards was part of the fishing industry's adaptation strategy, but felt that the lack of government support for that adaptation process was a limiting factor and reinforces the belief in the "tokenism" of politics. Another fisherman suggested that limits to adaptation occurred when governments imposed interventions on communities without adequate reason, information or justification. He used the example of imposing the marine park on the fishery and the building of the Clayton regulator. He thought that people's entrenched positions were also limiting factors where people are not prepared to consider other alternatives or perspectives.

A state government interviewee acknowledged the difficulties in adaptation, both in terms of equity and in terms of making changes to the system that do not result in "catastrophic" change. He thought that practical capacity was a limiting factor and trying to prepare the community in an emotional sense. While he acknowledged that sea-level rise is a natural limit, he suggested that this was not at the top of the action agenda because it was not urgent for the next 20 to 30 years. But he did recognise the major limiting factor of over-allocation of water and the challenge of getting people to "face up to the hard decisions". In this regard the forthcoming Basin Plan was a "major lever" in restoring health to the river system. A local government interviewee also talked about hard decisions and "levers and fear", referring to the notion that is easier to "throw dollars" at a problem, like the acid sulfate soils, than challenge the science and consider alternatives. Thus a limit to adaptation is the perceived inability of governments to facilitate "honest" debate. Similarly, another state government interviewee suggested that a limit to adaptation was the lack of funding for ongoing community engagement.

A recurring theme about limits to adaptation is a perceived lack of "vision", for example, a lack of vision about what we want to do with our resources, specifically and in general. Some were concerned that there is no vision for the entire Murray-Darling Basin: how do we want to use our natural resources; what do we want our ecosystems to look like; what sort of landscape function do we want to maintain and what landscape function are we willing to sacrifice. An ecologist thought that a current limit was the lack of discussion about how natural systems can bounce back (in the context of the acid sulfate problem) and that if we don't invest in knowledge and assess how we engage with the science then we are perpetuating knowledge and scientific limits to adaptation. He suggested that many government managers don't see knowledge and science as valuable because they "tell" rather than "listen". In his view we only start to *value* things when we are losing them because people do not realise the level of risk until it is too late. Not understanding the many different ways in which people value natural assets, such as the Coorong and Lakes, is a limit to adaptation in itself. Another local ecologist talked about limits as being a lack of understanding of what natural ecosystems look like and how they have changed, citing the example of the "massive degradation" along the River Murray since white settlement. She suggested that people don't understand what the impact of the loss of ecosystem services would mean to people or communities, and what would happen if the functioning of the Region was lost due to continuing low water flow.

Interviewees concerned about community talked about the lack of vision for communities: how communities and government could possibly work together in a mutually respectful relationship to devise acceptable solutions. A community leader articulated limits to adaptation in several areas of community-government relations which amount to government

not understanding the capability of community nor treating the community as an equal partner in developing and discussing adaptation options. Another local government employee talked about natural limits to adaptation, such as water levels being important for tourism. In his view it was important to diversify away from livelihoods that depend on water levels, which is why the local council was purchasing a motorsport facility to pursue other sources of income. He thought the land in the area around Lake Albert was not ideally suited for agriculture, so diversification and building resilience were important to enable people to be able to adapt in other ways was an important adaptation strategy. In his view a positive attitude was important "this is our lot, let's work with it and get something out of it".

7.4. Summary: perspectives of adaptation options and the limits to adaptation

This section has summarized some individually and collectively held knowledge and experience about how people value and use the natural resources of the Region, how people work together in the Region and people's differing perspectives and experience of adaptation in the Region.

A key finding is that the people and systems of the Region live in a constant state of adaptation: social and environmental variability and change is ever-present in people's lives. Limits and barriers to adaptation are widespread and occur in every facet of life: material (economic and livelihood), social (family and community), personal (values and beliefs), environmental, institutional and political. In many cases there is a tension between proactive and reactive adaptation: some look ahead in anticipation of change, whereas others try to keep hold of tradition and adapt or change practice with a degree of reluctance. A second key finding is that individuals and communities already have a vast amount of knowledge about the lived experience of adaptation: what has worked, what has not worked, and how to improve the practice of adaptation. This—largely untapped—knowledge could be seen as a source of innovation if a mechanism could be devised to distil and organize it. A recurring community lament was the perceived lack of respect for local knowledge and capability. Two important implications for adaptation emerge from this section. Perhaps *the* most significant limiting factor for human adaptation is the way in which people work together or fail to work together. Working relationships and the capacity of people to work together was a strong and deeply felt theme running throughout the interviews. Conflict, protests and community divisions are the tangible outcomes of this type of barrier or "limit" being reached. In the Region there are concerns about the lack of engagement capacity within both government and community. Infrequent and sporadic community engagement episodes result in disappointment and burnout on both sides with lack of financial assistance for community representatives to participate and lack of people capacity and resources on both sides.

A second and related implication is the lack of a unifying vision for future plans and adaptation around which people can develop options for debate and discussion. Vision is needed on a number of different levels: to show what a healthy ecosystem can be as well as to articulate the bigger picture about long-term use and conservation of connected ecosystems. The next section analyses these findings and implications about adaptation in the Region and presents some adaptation options for the future.

8. ANALYSIS OF ADAPTATION OPTIONS AND THE NOTIONS OF ADAPTATION AND LIMITS TO ADAPTATION

In this section we explore adaptation options and limits from three main vantage points. In the first we examine the many active proposals for new adaptation measures in the region. We catalogue and assess these in the light of the findings described in Sections 6 and 7. We then present our analysis of notions of adaptation and the limits to adaptation as a result of this research project. In the third part we discuss the importance of developing an understanding and appreciation of differing perspectives on adaptation options. We then summarise with an analysis that draws from the past and looks to the future for adaptation in the Region.

8.1. Proposed adaptation measures in the Region

Our analysis shows that adaptation in water management has been underway in the Region since European settlement of the Region and before climate change was recognised. We have documented and drawn lessons from this historical experience (section 6, Table 5) and argue that a more objective assessment of the benefits, costs and limits of these adaptations provides a basis for considering the merits of proposed adaptations.

A number of new or further emergency adaptation measures have been proposed and these are assessed in Table 6 with their locations depicted in Figure 8. Here we discuss the proposed adaptation measures in the context of the Region's two greatest vulnerabilities, water scarcity and resulting loss of quality, as well as sea level rise. These are discussed in terms of the three climate change scenarios adopted for this report.

8.1.1. Water scarcity and resulting changes in quality

Low freshwater inflows are already a major impact on the region, particularly in the context of severe drought. The drastic decline of inflows from 2002-2010 resulted in desiccation, salinity and some acidification, which impacted on wildlife and other ecosystem services. Now and in CSIRO's moderate climate change scenarios for average annual conditions, the major impact lies in excessive diversions of water for consumptive purposes with climate change being a modest, additional impact (CSIRO, 2008, Pittock et al., 2010). Thus the most effective adaptation for the Region would be a substantial reallocation of water from consumptive users to the environment in the Basin, which is affordable, albeit with a small decline in irrigated agricultural production (Pittock et al., 2010, MDBA, 2010, WGCS, 2010, Kingsford et al., 2009, Grafton, 2011). This option depends on adequate action by the Federal Government under the Water Act (MDBA, 2010).

The volumes of water required to improve water quality in the Coorong to revert to more desirable ecological states are modest (Lester and Fairweather, 2009, Lester et al., 2009). In one option, Kingsford et al. (2009) and Geddes (Pers. Comm.) propose using larger River Murray inflows as a "virtual weir" near Wellington to enable "translucent" operation of the Barrages (see also DEH 2007). Kingsford et al. recommend a 630 to 700 GL average annual increase in inflows to achieve this (Kingsford et al., 2009, Kingsford et al., 2011). If such inflows could be maintained it could enable the Barrages to be kept open much of the time, expanding the estuarine habitat and reducing the impact of the Barrages as a barrier, benefitting fish populations. The drought induced substitution of other freshwater sources for people and businesses around the lakes in the past decade now allows the lakes to be operated at more variable levels with great environmental benefits.

South Australia has modest options within its jurisdiction to implement secondary but important water inflow adaptations. The planned extension of the South East Drainage

Scheme to divert more freshwater into the Coorong south lagoon via Salt Creek could significantly lower salinity and improve its ecological state. However it is regrettable that the South Australian Government has not taken more timely action to regulate inflow interception activities in the Eastern Mount Lofty Ranges despite this being required under the 2004 National Water Initiative (Commonwealth of Australia et al., 2004). Belated action is now planned but inflows may have been diminished by recent developments (SA MDB NRM Board, 2011). While the volume of these inflows may be small they can play an important role in maintaining the Currency Creek and Finniss River estuaries as refugia for freshwater biota. An important further adaptation would be the restoration of the historic width of the Narrung Narrows to improve water flows into the terminal Lake Albert. A further beneficial measure would be extension of the program to fence livestock out and systematically restore indigenous vegetation to the shores of the lakes and tributary streams. This will reduce diffuse pollution from agriculture, increase primary productivity, provide habitat and cool water with shade (Davies et al., 2004, Davies, 2010). The salinity levels in the Coorong south lagoon could also be reset by pumping 80-100 GL of hypersaline water over the Younghusband Penninsula and out to sea over 18 months. Physically this intervention has considerable merit but is expensive, requires placement of equipment in Coorong National Park and transport of fuel there. Further land-based salinity control measures may also improve the benefits from freshwater inflows.

The adaptations discussed here are largely soft options that depend on political decision for adequate inflows. Such flows could be sustained with modest climate change. However, with increasing climate change induced warming, evapotranspiration is likely to drastically reduce inflows and risk the reoccurrence of the dire conditions experienced in 2002-2010 (Cai and Cowan, 2008, Schofield, 2011). In the absence of incursion by the sea, with moderate climate change there is the need for both scientific assessment and a value judgement of the risk of more frequent desiccation events. There are a number of hard engineering interventions - also known as “environmental works and measures” or “environmental water demand management” - which could be deployed at this point if society chose to try and maintain a freshwater system.

Water volumes and quality could be more readily manipulated through Lake Albert and into the Coorong with an operable Barrage at Narrung Narrows and the construction of a channel between the Lake and Coorong (on a River Murray paleo-channel). The Currency Creek and Finniss River estuaries could be maintained as refugia for freshwater biota with operable weirs. However, these measures would be expensive and have many of the negative consequences outlined earlier in section 6. The most far reaching of these options would be the construction of the proposed Pomanda Island Weir down river of Wellington. This emergency measure was planned for deployment if the Millennium Drought had worsened in order to maintain the lower River Murray channel as a freshwater weir pool, not least for Adelaide’s water supply (DEH, 2007). The soft, deep channel sediments have raised questions as to the stability of any structures built here, and the emergency weir proposed was non-operable. The state and federal governments had concluded that exposure of acid sulfate soils in the bed of Lake Alexandrina with severe desiccation would be unacceptable, and a threshold water level of – 1.5 m AHD was set to open the Barrages and inundate the lakes with sea water (DEH, 2007). Given that there were three severe droughts in the past century and that the frequently of such droughts is anticipated to increase with climate change, without substantial reallocation of freshwater to the environment a major desiccation event is likely in the coming century. Further, projected sea level rise could inundate many engineering measures by the end of the century raising the question of the long term objectives for management of the Region.

8.1.2. Acid sulfate soils and hypersalinity

Management interventions in the Lakes during the Millennium Drought was driven in large part by the perceived risks from generation of acid from exposed sulfate sediments versus concern that allowing inundation by seawater would result in the system becoming hypersaline if evaporation from the Lakes exceeded fresh and sea water inflows. These same risks will need to be managed if desiccation events become more frequent with climate change. We argue that these risks could be managed with appropriate adaptation measures.

The focus of the governments' work on acid sulfate soils was the identification and mapping of different forms of sulphides in the sediments of the lakes and tributaries (Fitzpatrick et al., 2009). This work demonstrated the presence of acid soils. Whether these soils represented a threat of widespread acidification of lake waters is more problematic (Geddes and Walker, 2009, Kingsford et al., 2009). The "trigger points" for widespread acidification were based on predictions from a purpose-built model which coupled a lake hydrodynamic-biogeochemical model and a newly developed soil hydro-geochemical model (Hippsey et al., 2010). There was limited opportunity for the model to be validated. Some predictions from the model were met but there were areas that were predicted to acidify that were not observed to do so in reality. Further model development and further research into key acid sulfate soil processes were recommended and should now be a priority for government investment. The government managers judged the acid sulfate soils were a high risk in the Millennium Drought and this drove the emergency action that was undertaken. We consider that more sophisticated options than managing the Lakes as entirely fresh or marine systems should be considered for adaptation to future desiccation events, including the "transparent barrages" option.

The concept of "inundating" Lakes Alexandrina and Albert with seawater as a response to the threat posed by acid sulfate soils and the Lakes then becoming hypersaline is simplistic (Geddes and Walker, 2009, Kingsford et al., 2009). Rather there should be a balance between residual freshwater in the lakes, sufficient environmental flows from the River Murray into the lakes, and sea water input via the Barrages. The input of seawater could be used to top up the lakes to target levels when river flows are not sufficient. The input of seawater could be adaptively managed to achieve a balance between target water levels and acceptable salinities (Geddes pers. comm.). With increased environmental flows provided by the proposed Basin Plan it should be possible to allow some seawater into the lakes and still maintain estuarine conditions and freshwater refuges.

8.1.3. Sea level rise

The challenge of maintaining the lakes as a freshwater or estuarine system becomes more challenging with severe climate change as sea levels rise. The Intergovernmental Panel on Climate Change estimated that global average sea levels may rise between 18 and 59 cm by the end of the century however this forecast was qualified and has since been assessed as too conservative (IPCC, 2007, Rahmstorf, 2007, Good et al., 2011). In the case of the Region, the area is subsiding which may exacerbate sea level rise (Matthews, 2005). Sea level rise of around one metre by the end of the century has been the basis of state-wide South Australian Government town planning (Matthews, 2005), but it has not featured in government plans for the Region, such as "Securing the Future" (DEH, 2010).

While there has been speculation that the Sir Richard and Younghusband peninsulas could be breached (Matthews, 2005), a more recent assessment concludes that when a full range of sea level scenarios for +1.5 m sea level rise is modelled to 2109 the coastal recession ranges from a maximum of 250 m (1% probability) to a minimum of 40 m (99% probability) leaving the barriers intact (Coastal Studies, 2009). The implications for the flood tidal delta in the Murray Mouth are uncertain (Matthews, 2005). However the Barrage structures are old,

low and leaky and the islands between them are low-lying. Sea level rise would progressively seep through and overtop the current Barrages in storms, and would drown out parts of the islands at 0.81 AHD, rendering the structures redundant (Matthews, 2005). It may be physically possible to rebuild a higher, continuous 13 km long barrage at great expense. Further, Goolwa Barrage that currently sits on unconsolidated sediments may need to be relocated to more solid foundations at the site of the Hindmarsh Island Bridge. We judge this engineering approach unlikely due to the huge expense and prospect of further sea level rise, and instead consider that living with a rising sea is a more practical strategy.

Sea level rise would inundate some lands. Figure 6 shows the lands that would be inundated with a rise of 1 m AHD (less those areas isolated by higher lands from the lakes). The areas inundated are relatively limited, and few town centres would be affected, but some of the impacts would be severe. The mud flats and islands in the Coorong which are ecologically important for water birds and of cultural significance for the Ngarrindjeri may be drowned out: it is not clear if this habitat would be replaced by extension of the Coorong to the south with inundation of currently ephemeral lakes (Matthews, 2005, Phillips and Muller, 2006, Lester et al., 2009). Large areas of agriculturally rich river- side lands would be inundated along the lower River Murray channel. The key adaptation proposed under these circumstances is the Pomanda Island Weir (Matthews, 2005). The need for a freshwater weir pool in the lower River Murray channel may be diminished with increasing use of desalination for water supplies in South Australia (DEH, 2007, Office of Water Security, 2010).

8.1.4. Adaptation without stationarity

Our discussion of adaptation options highlights how an adaptation for particular, changed conditions may be overly narrow and become redundant with more severe climate change, and how adaptations considered unacceptable now may be considered appropriate with more extreme conditions (Nelson, 2010). In Table 7 the adaptation options discussed above are depicted for each of the three climate change scenarios considered for the Region as either desirable (green), risky (orange) or too costly (red) by our qualitative assessment. Consequently there are difficult societal decisions required as to when to consider such interventions, for instance, whether staged measures are desirable, or whether popular short term measures that would be redundant later (eg. with sea level rise) represent undesirable maladaptation (Hallegatte, 2009, Barnett and O'Neill, 2010).

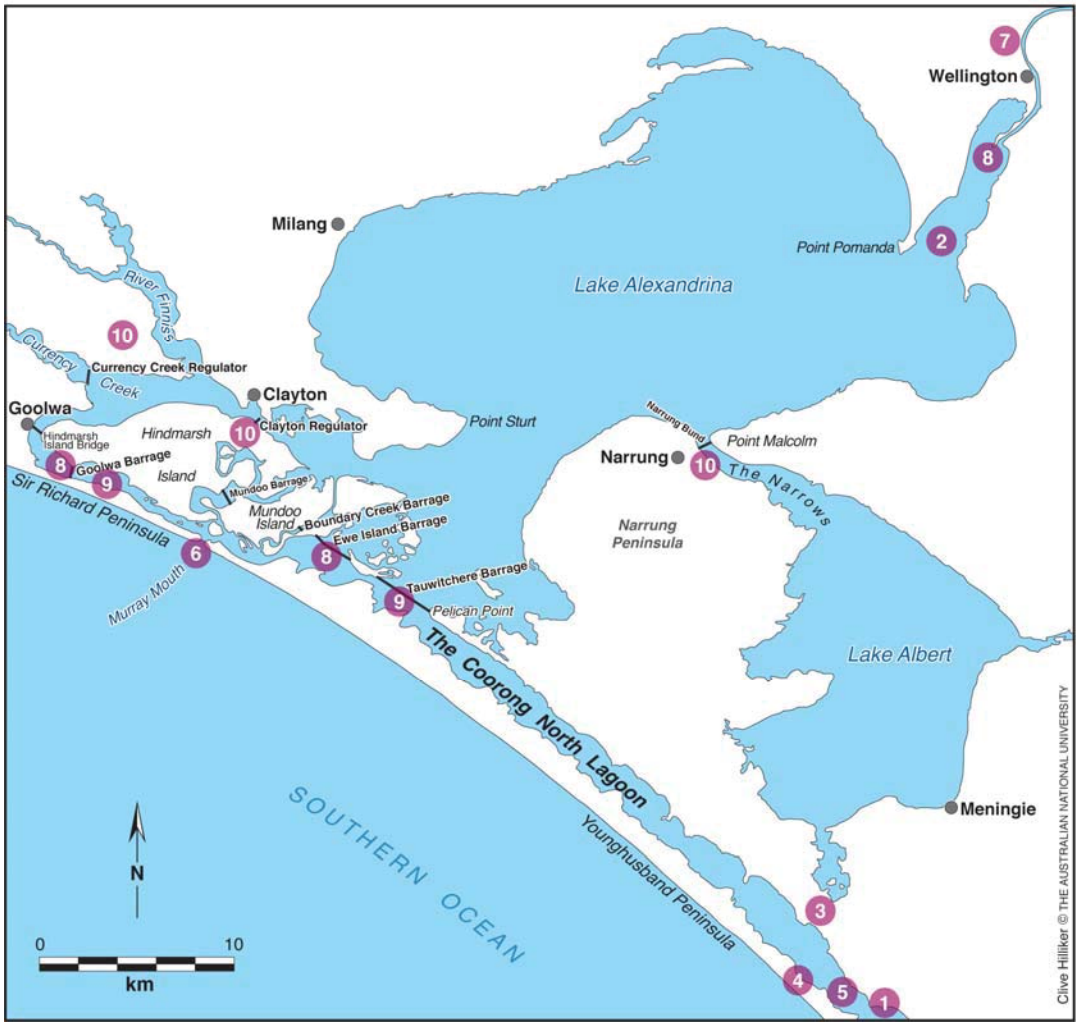

Figure 8: Proposed adaptation measures in the Lower lakes and Coorong. Following desiccation of the Lower lakes and Coorong in 2002-2010 numerous measures to adapt to climatic and hydrological variability and change have been proposed (Table 7).

These include:

1. Coorong South Lagoon Flow Restoration Program (to be delivered to the Coorong South Lagoon via Salt Creek before flowing towards the North Lagoon)
2. Pomanda Island (Wellington) Weir
3. Lake Albert to Coorong channel
4. Pumping hypersaline Coorong south lagoon water to the sea
5. Dredging the constriction between the north and south lagoons of the Coorong
6. Training structures at the Murray Mouth
7. Reallocation of water from agriculture to the environment in the Murray-Darling Basin
8. Managing a “virtual weir” at Wellington and “transparent” operation of the Barrages
9. Opening the Barrages and allowing unrestricted sea water inflows
10. Operable weirs at Clayton, Narrung, River Finniss and Currency Creek
11. Restoring riparian and lakeside vegetation (not shown)
12. Managing inflow interception activities in South Australian catchments (not shown)

Table 6: Key adaptation options suggested for future management of the Region (elaborated based on Kingsford et al., 2009, Kingsford et al., 2010; other sources cited in the table).

#	Adaptation	Benefits	Costs	Risks	Unknowns	Limits
1	Reallocation of water from agriculture to the environment in the Murray-Darling Basin (MDBA, 2010)	This is the primary adaptation option for the Region. Increased flows would enable the Lakes to remain mostly fresh, enhance the Coorong and keep the Murray mouth open longer (Lester et al., 2009, MDBA, 2010). MDBA assessed a reallocation of 27-37% of diverted waters (MDBA 2010). Benefits for biodiversity, fisheries, recreation and water users in the Region.	~$9 billion in water purchases or efficiency 'savings'. Limited impacts through reductions of irrigated agriculture (Pittock et al., 2010, MDBA, 2010)).	Would not necessarily stabilise or reverse the long term decline in the ecological state of the lower lakes due to constant water levels and limited connectivity (due to the Barrages).	Amount of water recovered through water efficiency projects ($6 billion allocated) is uncertain. Unclear whether it could reinstate the 1985 Ramsar ecological character.	In severe conditions as akin to the 2002-2010 drought inflows into the lower lakes would not be sufficient to maintain their health.
2	Coorong South Lagoon Flow Restoration Program (water from far SE region: +80 to 100 GL in a wet year?) (Department of Water, 2011)	Partly dilute hyper-saline southern lagoon of the Coorong with brackish water. Wetlands restored in SE South Australia. Innovative incentives for provided for biodiversity off-sets.	$? Increased brackish inflows into the Coorong's southern lagoon	Potential to reduce water quality of the southern lagoon with agricultural run-off. Further climate change may greatly reduce runoff and increase its salinity.	Works for moderate CC but likely to fail in extreme CC if high evapo-transpiration reduces runoff. Blue gum plantations may reduce inflows.	Volume of available water is limited. Currently averages 6 GL pa and provided up to 16 GL pa in a wet year, compared to the 80-100 GL volume of the south lagoon.
3	Pomanda Island (Wellington) Weir (DEH, 2007)	Maintain lower River Murray as a freshwater system for water supply and allows for the inundation of the Lakes Alexandrina and Albert with seawater to prevent further salination and acidification. May enable greater wetting and drying of wetlands in	$160 M. Likely salination of the Lakes Alexandrina and Albert. Current proposal is for a non-operable weir that would exacerbate loss of connectivity. Roads have already been constructed.	Proposed as a temporary weir. Site on deep, unconsolidated sediment regarded as unstable for large water infrastructure. May be redundant with further	Ecological impact on Lakes Alexandrina and Albert and social and economic impact on communities in those areas	Only a temporary weir. Needed if lakes become estuarine. Creates additional management options. Strong opposition by many people in surrounding communities (River,

		lower channel.		desalination.		Lakes and Coorong Action Group Inc)
4	Lake Albert – Coorong channel	a) May prevent acidification of Lake Albert through inundation with seawater via the Coorong. b) May enable greater freshwater flushing of Lake Albert and the Coorong with inflows from Lake Alexandrina (a prior River Murray channel).	$2-150 M Not required for low CC, useful flexibility for moderate CC, but redundant for severe CC with seawater in the lakes.	Risks from salination of Lake Albert, or of acid transport into the Coorong.	Impacts of transport of different water qualities is poorly understood.	Water movement would be driven by gravity and presence or absence of freshwater inflows.
5	Pumping hypersaline water from the Coorong south lagoon out to sea.	Temporary removal of 'unnaturally' hypersaline water (up to 80-100 GL over 18 months) would enable the south lagoon to be 'reset' with fresh and sea water inflows to restore biota. Has widespread support.	$20 M. Impacts of pumping infrastructure on Younghusband Peninsula and of low quality water on the near shore marine environment	Hard to service infrastructure (eg. fuel). Development in the National Park.	Impacts of low quality water on the near shore marine environment.	Requires careful timing timing to coincide with freshwater inflows or high sea levels to replace hypersaline water.
6	Dredging the constriction between the north and south lagoons of the Coorong.	Promote greater water exchanges to improve water quality in the south lagoon to restore biota.	$? Higher water levels in the south lagoon in Summer would inundate exposure banks with a negative impacts on birds. Has limited or no support. Sea level rise will result in the same outcome.	Impacts on the seasonally variable water levels of the south lagoon may have negative impacts on the aquatic plant Ruppia and on water birds.	Needs further modelling	Geomorphology limits the extent of possible water exchanges.
7	Training structures at the river mouth	A groin may divert sand and prevent blockage of the river mouth at lower cost than recent dredging.	Financial cost unknown. Seasonal pumping of sand likely to be required. These types of structures have a controversial history.	Would stop natural movement of the mouth and coastal sediments. May not work with very low inflows.	Idea has been little developed. Engineering challenge.	High environmental costs, engineering difficulties and expense make this option most unlikely.
8	Managing a "virtual weir" at Wellington and	Proposal to use environmental flows and possibly a V notch weir to	Funds for reallocation of water similar to the MDBA scenario. Similar impacts	Greater risk of the lower lakes becoming more saline should	This option has not been fully modelled	In severe conditions (such as the 2002-2010 drought) inflows

	"transparent" operation of the Barrages (Geddes pers. comm.; DEH, 2007).	restore and maintain a more natural state of the Region in place of engineering interventions. Similar to proposal #1 except that the Barrages would be actively managed to direct flushing flows through different parts of the system and would normally be left open to enhance connectivity, expand estuarine mixing and enable lake levels to vary. Greater restoration of biodiversity is likely.	on irrigated agriculture. Need to adjust infrastructure on the shores of the lower lakes to variable water levels. Arguably meets Ramsar Convention rules for a beneficial and thus permitted change in ecological character	inflows drop for extended periods		into the Lakes Alexandrina and Albert would not be sufficient to maintain their health
9	Opening the Barrages and allowing unrestricted sea water inflows	Semi-permanent change that may limit both acidification and hypersalinity. Maintains water levels for fishing of marine species and recreation. More variable water levels on the lakes may favour some biota, eg. water birds. Once made this change would be resilient to future climate change impacts	Unknown. Low financially but high ecologically. Loss of much freshwater biodiversity. Deliberate shift in ecological state in breach of the Ramsar Convention. Pomanda Island Weir may be considered necessary to keep the lower River Murray channel fresh	No increase in environmental inflows and sea water ingress may see the Murray mouth close up without constant dredging	Impact on acidification is contested. Unlikely that all biological responses could be forecast	Likely to be challenged under the EPBC Act and Ramsar Convention Strong community opposition
10	Operable weirs in the Finniss River and Currency Creek, and/or operable weirs at Clayton and Narrung	May retain these estuaries as a freshwater refuge should the main lakes desiccate or become saline. Presents options for a freshwater refuge in the Goolwa channel (Clayton) or to sacrifice Lake Albert (Narrung)	Unknown. Further fragments the lake system and needs to be operable to enable water and fish passage (unlike the recent regulators). Ngarrindjeri object to fragmenting the wetland system.	Would conserve on limited freshwater habitats. Disconnects either Lake Albert or Lake Alexandrina from river flows	Ecological impact on disconnected area and social and economic impact on communities in those areas	Weirs could work under a range of conditions. Likely to encounter strong community opposition
11	Restoration of riparian and lakeshore	Further fencing livestock out of riparian and lake side areas would enable	Unknown but modest. Requires landholder cooperation. No negative	Sea level rise could inundate low lying vegetation if the	-	Many riparian species may not tolerate extreme dry

	vegetation.	revegetation, increasing primary productivity, increasing wildlife habitat and cooling waters through shading.	impacts expected.	Barrages fail.		conditions.
12	Managing inflow interception activities in South Australian catchments.	Mooted regulations could curtail the expansion of forest plantation, farm dams and other activities that threaten to reduce the ~14% of outflows controlled by South Australia.	Low as a regulatory measure. Some opportunity costs. No negative environmental impacts.	New regulations need to capture emerging as well as current inflow interception activities. These need to be well enforced.	-	Only a limited volume of runoff is from South Australia and it is vulnerable to further reductions due to climate change.

Table 7: Assessment of adaptation options proposed for future management of the Region. The authors' assessment of the desirability and effectiveness of the adaptation options from Table 7 under different degrees of climate change (CC) impact. Green = likely to be effective and beneficial. Amber = less effective or with lower benefits. Red = not effective or redundant, or with negative impacts.

#	Adaptation	Low CC +1.03°C	Medium CC at +1.6 °C	Extreme CC at +4°C
1	Reallocation of water from agriculture to the environment in the Murray-Darling Basin			
2	Coorong South Lagoon Flow Restoration Program (water from far SE region)			
3	Pomanda Island (Wellington) Weir			
4	Lake Albert – Coorong channel			
5	Pumping hypersaline water from the Coorong south lagoon out to sea.			
6	Dredging the constriction between the north and south lagoons of the Coorong.			
7	Training structures at the river mouth			
8	Managing a "virtual weir" at Wellington and "transparent" operation of the Barrages			
9	Opening the Barrages and allowing unrestricted sea water inflows			
10	Operable weirs at Clayton, Narrung, Finniss River and/or Currency Creek.			
11	Restoration of riparian and lakeshore vegetation.			
12	Managing inflow interception activities in South Australian catchments.			

8.2. Notions of adaptation and the "limits" to adaptation

Most adaptation options that have taken place in the Region are based on physical interventions for water management, such as the creation of barriers and building pipelines, etc. There are other adaptation measures that could be further explored in the Region which are more socially and economically oriented, such as the closing or transformation of some industries. The reduction and transformation of the dairy industry in the Meningie area and the establishment of new attractions such as motor sports facilities for visitors are two examples. These types of adaptation to changing environmental and economic circumstances are already taking place, but fall into the "reactive" category initiated by a section of the community as a *response* to changing circumstances, rather than being "proactive" broad-based initiatives that *anticipate* changing circumstances. This brings the discussion back to "limits" to adaptation.

As foreshadowed in Section 2 the research findings described in this report have shown that adaptation should not be considered in simple terms such as limits, or barriers, or as a specific type of adaptation, such as social, economic or environmental adaptation. Rather, notions of adaptation must acknowledge and illustrate the inherent complexity of adaptation in a specific context in which adaptation takes place. Adaptation research must therefore explore a diversity of interconnected, intertwined, tangible and intangible barriers, challenges and obstacles, some of which are physical and measurable, while others are non-measurable perceptions, beliefs and emotions. Thus, any idea or concept of "limits" needs to accept that there are many types of perceived barriers and limits to adaptation. These include the full range of value-based, biophysical, climatic, environmental, institutional, attitudinal, social, economic, lifestyle and demographic barriers. These barriers or limits

combine in a myriad of different ways to form complex interrelated *sets* of limits or barriers to the way people and ecosystems adapt.

The findings show that the notion of adaptation is intrinsically complex within a wide range of considerations, including the national policy context, local institutional constraints, short and long term climate variability, local community development strategies and local environmental conditions. What is being 'adapted to' presents one complex set of factors; who or what is 'doing the adapting' represents another complex set of entities and characteristics, and the environment within which adaptation is taking place presents yet another combination of factors. Therefore, examination of one particular "limit" or barrier to adaptation cannot be done in isolation from the complex environment it inhabits. One can then ask the question: is it useful or legitimate to attempt to study adaptation to climate change in isolation from all other factors to which an individual or system is adapting? This research has shown that the answer to this question is overwhelmingly 'no'. Rather, adaptation to climate change should be considered as one aspect in a complex, ever changing set of environmental, social and economic circumstances.

8.3. Differing perspectives on adaptation options

This report has shown that the Region has seen many different types of adaptation and adaptation interventions since the time of European settlement. The report has shown that adaptation interventions result in environmental, social or economic consequences (intended or unintended) that can be seen as harmful or beneficial. Thus adaptation interventions are seen in different ways by sections of the Region's communities: either as a 'good' adaptation or as a 'bad' maladaptation. The net effect of these interventions in the Region has been to artificially segment what was once an interconnected functional system with differing environmental and social impacts for the localized ecosystem and social community. A benefit to one part of the system (such as maintenance of water level) results in a negative impact to another part of the system, with the emergence of winners and losers being one outcome. Hence a physical division also turns into a social division. From the perspective of social capital this is harmful and destroys rather than builds social cohesion and the capacity to work together. People within communities turn away from each other, and government-community relations are strained and damaged. Trust is eroded and time is lost.

Thus adaptation can be seen as a series of reactions to environmental and social changes, with some being quickly executed emergency responses to crises and others more gradual responses to slowly changing social and economic situations. Some of these responses can be seen as strategic and proactive long-term plans, for example, according to one interviewee, the establishment of water pipelines and removal of pumps from Lakes Alexandrina and Albert were strategic activities that took place during the crisis response of the Millennium Drought. However, responses can be seen in different ways by different sections of the community depending on the availability of information on which decisions are based and the level of transparency and peer review within which decisions are made. Adaptation interventions as a crisis response to the risk of acid sulfate soils fall into this category. The perceived lack of scientific agreement around this issue is one highly emotive example of the failure of governments to proactively anticipate and plan for extreme events such as occurred in the Millennium Drought. It is also an example of the failure of the scientific community and governments to achieve a consensus on the level of risk and the best approach to resolve the issue. A government perspective on this crisis is that it was virtually impossible to plan for this type of extreme event: such an event was entirely unanticipated. In the words of one interviewee "if you planned for the event we had in 2006 some 20 years ago, then people would have believed you were nutty". Another example of a failure to agree on a crisis response was the rescue of turtles from Lake Alexandrina. One—mainly scientific—view is that the community initiative was "ineffective" whereas one

interviewee said if this project had "touched" members of the community then "hallelujah". She suggested it was highly effective as an initiative to encourage action about climate change adaptation and such initiatives should be seen as an antidote to "depression" she had seen in schoolchildren.

The difficulty in achieving transparent and open long-term planning was articulated by several interviewees. One final example in this section illustrates this challenge. One local government interviewee suggested that a sound and viable adaptation option would be to build a permanent and fully operable "barrage" or weir at Clayton to replace the temporary regulator. This would enable the Goolwa channel to be disconnected from the rest of the system in the event of future very dry periods, for the same reasons that the Clayton regulator had been built. Another government interviewee, from the South Australian state government disagreed with this proposal, arguing instead for a permanent fully operable "barrage" or weir at Narrung. He said that a permanent barrage at Clayton would demonstrate that "we would have failed" whereas Lake Albert could be "sacrificed" if dry conditions returned. Both these interviewees commented on the difficulty in having open discussions about these types of proposals, citing political and bureaucratic unacceptability and the need for a "crisis" to get these on the table for discussion.

8.4. Summary: learning from the past and looking to the future

These examples of disparities of thought and action between people in communities and governments show that a different type of institutional arrangement is required. What is needed is an appreciation for the validity of different perspectives and a much greater understanding of these by different parts of society, including communities, governments and scientists. For example, communities must understand government constraints; scientists must understand the different ways in which communities are motivated and can be engaged, and governments must understand the power of community engagement and the different types of innovation that communities can bring. Longer term governance structures are needed to develop greater community consensus on the long term objectives and required interventions, as opposed to the short-term and ostensibly crisis-driven responses led by the state and federal governments during the Millennium Drought. Such governance institutions should draw on local knowledge and aspirations, and develop a more common understanding of the management options available in the Region. It should have a high degree of ownership by the Ngarrindjeri and other local people suggesting a structure more decentralized from the state. Better scientific knowledge would contribute to governance. Critically this governance system should have stable funding, ideally, with a modest part of the funds raised directly in the Region from local use fees and the like, so as to leverage more resources from state and federal governments. There is considerable debate in Australia on the need to enhance capacity and secure long term funding for regional natural resource management institutions that will be important to facilitate proactive climate change adaptation (Robins and Dovers, 2007b, Robins and Dovers, 2007a).
This section has discussed a range of future management and adaptation options that have been identified during the course of this research. Interestingly, this report brings these adaptation options together for the first time. That these adaptation options have *not* been brought together and discussed in this way in a published document is one indication of the failure of current institutional long-term planning. Perhaps this is an indication that governments do not currently have the political capacity or ability for fully transparent long-term planning of this type. This supports our recommendation for a new type of institution which does have the capability to bring together local communities, local government, state government and federal government. What is needed is a new type of institution to: a) plan for the short term and long term; b) develop plans that incorporate adaptation in terms of both regional and national water management as well as climate change; and c) plan for water management that includes upstream river operations as well as water management in the Coorong and Lakes area. This institution needs to assess the options, fully and openly

discuss them, explore anticipated and potentially maladaptive consequences, discuss the risks and determine adaptation pathways forward. We believe that these requirements are best served by the establishment of a new regionally based management institution. The institution should have at its core two guiding principles (Section 7.4): the need for an articulated vision for the community and the Region's resources and an understanding that adaptation depends on the ability of people from different parts of society being able to work together. The institution should work to develop long-term trust and communications between the different sections of the community to develop and implement acceptable options and plans.

8.5. End users' reflections on the research

As described in section 5, two rounds of interviews took place. The purpose of the second round of interviews was to briefly discuss the draft recommendations with "end users", people familiar with and engaged in the institutional and political governance of the Region at the local, state and Basin / federal scales. This feedback was used to refine the conclusions presented in section 9.

Interviewees in general were in strong agreement with many of the recommendations, such as mainstreaming climate change adaptation into water management, developing a genuinely long-term approach to management of the Region and improving institutional capacity and community engagement. Interviewees shared their perspectives about the recommendations in relation to their working knowledge and experience, and discussed challenges and opportunities raised by the recommendations. A summary is presented here.

8.5.1. Establishing a new institution

Several interviewees were against the idea of a new institution. Reasons cited were varied, but focused on current contextual constraints. One interviewee liked the idea of a regional body with a clear purpose but was concerned about the current context of institutional change in South Australia. She suggested "this would go down like a lead balloon" because there has been a lot of institutional change in recent years. Another was against it because it creates another level of bureaucracy and "if there's something wrong with the institutions we've got now then we should fix them". In particular the concern for reinventing the wheel: "people would disregard what's been done in the past because they will want to do it their way". Questions were raised about who the new statutory authority would report to, how it would relate to other institutions and in particular the Murray-Darling Basin Authority. Suggestions were made about the "scientific validation" of water allocation so that it is "beyond reproach" and that the Murray-Darling Basin Authority has the ability to get this type of validation so that decisions can be accepted. How would a regional institution establish this type of "credibility"? In this case the Murray-Darling Basin Authority is well positioned and needs to focus on scientific credibility. A suggestion was made that if a new institution is unlikely to be politically acceptable in the current climate, an alternative would be "staging" of the options and developing a long-term vision with steps to achieve it. This would include better decision-making models, engagement of local communities and recognition of the need for innovation. One interviewee concluded that state and federal governments would not support an independent authority that may be critical of them, thus a high level, multi-stakeholder advisory body would be the next best option. Another interviewee pointed out the current difficulty of finding out exactly what institution is responsible for a recent initiative to return water to the Coorong. Apparently there were about 20 different organisations involved and "we didn't pursue it any further because it was too hard for us". Thus establishing institutional responsibilities and their boundaries is currently a major challenge.

A number of interviewees questioned whether the community would support additional fees or taxes to support an independent authority while one respondent suggested hypothecating the South Australia River Murray levy for the work of such an institution.

8.5.2. Vision and long-term planning

Many interviewees commented on the need for vision in long-term planning, and different aspects of vision, including what is the ideal for the management of the Coorong and Lakes Alexandrina and Albert. For example, what type of outcomes do we hope to achieve in terms of fisheries, vegetation and taking nutrients out of the system. Another commented that "we don't understand how to do long-term thinking or planning" based on a vision that incorporates an understanding of the need to protect our environmental assets and their ecological function. One interviewee argued that it is impossible to be definitive in a long-term plan because it needs to be sufficiently flexible to manage variability "that the system is going to throw at us". This was the situation during the Millennium Drought which was a crisis situation that could not "possibly have been planned for". Another pointed out that the political reality is that long-term plans in government documents tend to "get edited out" and that long-term planning is a real challenge for government. Two interviewees focused on the difficulty of planning with the complexity and number of agencies involved: "there are so many players". The number of people within institutions that need to be consulted, as well as the number of different community sections and groups makes the "job of communicating extraordinary". Getting agreement and aligning policy positions is highly complex, particularly with political influence wielded by many community groups in the region. Another interviewee described the political constraints of long-term planning and the need to "avoid any sort of embarrassment" for politicians thus a conservative and cautious approach dominates and causes a "rampant incrementalism". He advocated an "adaptive management vision" in which system resilience is a goal and system complexity is recognised.

8.5.3. Community engagement, innovation and decision-making processes

One interviewee described her perspective that there is major problem with current decision-making, the lack of innovation and the risk-averse culture in natural resource management institutions and "our institutional culture is holding us back". She proposed that communities and industry can inject innovative thinking into current decision-making processes and we need to understand how to foster innovation in getting to adaptation outcomes. Another interviewee was less optimistic about community engagement in critical situations, such as seen during the Millennium Drought. In critical situations such as these decision-making processes are difficult to manage: the media focuses on controversy and communities focus on outcomes that may not be achievable. However, community engagement processes also need to maintain engagement after a crisis as well as during a crisis: currently there is "public consultation fatigue". Long-term engagement is difficult. Another interviewee suggested that the Coorong, as a Ramsar site, is much more difficult to manage than other wetland areas because of the number of different forces at play, such as the Goolwa boat people and the diverse nature of local communities.

In summary, interviewees raised a wide variety of points about the draft recommendations, drawn from their working knowledge and experience within government agencies and as members of communities. Common to this feedback was the need for more effective management institutions and long term planning, although respondents differed in their views on how to do this. These comments are vital not only in adding to and validating aspects of the report but also in establishing discussion points for application of the following conclusions and recommendations by end users.

9. CONCLUSIONS AND RECOMMENDATIONS

In this project we have taken a multidisciplinary and adaptive approach to investigate a complex set of interrelated ecological and social issues in the region of the Coorong and Lower Lakes (the Region). While the focus has been on exploring the limits to climate change adaptation we acknowledge that climate impacts cannot be considered in isolation from the substantial and on-going non-climate impacts wrought on the Region since European settlement of the Region and the catchment. Consequently, the findings reflect a broad set of interconnected issues which have roots in past social and technological interventions (or adaptations) that must be understood when determining options and pathways for further adaptation to non-climate and climate change impacts. In this final section of the report we respond to the research questions, outline the conclusions and present key recommendations for decision-makers and communities.

9.1. Response to research questions

In response to the questions that this research was directed to address (NCCARF Call for Proposals, 2010:9; http://www.nccarf.edu.au/node/483, as modified in section 1):

1. ***Assuming there will be no planned adaptation, what are the likely impacts of climate change (in association with other known drivers of vulnerability)? For whom will these impacts be a problem?***

In the Region adaptation to upstream water extraction and to climate change are inextricably intertwined. In the medium term without the restoration of substantial environmental flows to the River Murray, nor other climate adaptation measures, the ecosystems of the Region could be expected to degrade. Freshwater inflows into the Region from the Murray-Darling Basin are forecast to decline drastically with higher temperatures and greater evapotranspiration. Reductions of inflows of more than 60% with a 2° C rise in average temperatures are possible (Cai and Cowan, 2008), although CSIRO report the possability of higher inflows under a wet extreme scenario (CSIRO 2008). The bio-physical impacts may include:

- Most importantly, loss of freshwater inflows and increasing salinity of the Lakes and Coorong, progressively rendering areas of the Coorong lagoon from the south and also Lake Albert too salty for most biota;
- Decreasing water quality due to salinity, and also sediment and nutrients in runoff from more frequent storm events in a more arid catchment;
- Increasing instances of desiccation of the Lakes as droughts become more frequent and inflows decline; and
- Loss of key biota including aquatic plants, waterbirds and fish.

Eventually, with sea level rise of 85-100 cm, we would expect the Barrages to be over-topped resulting in inundation of low lying lands, transition of the Lower Lakes to a more saline condition, and constriction of the ecologically significant estuary most of the time to a small and highly mobile area in the River Murray channel between Blanchtown and Lake Alexandrina. It has been suggested that marine incursion into the Lakes would result in a hypersaline state, but we have not found convincing evidence that inflows and outflows would be insufficient to overcome evaporative loses in Lake Alexandrina, although Lake Albert and the Coorong could be hypersaline. While new ecosystems would form, such as mud flats on newly inundated lands, and may have some conservation values, they are likely to be more depauperate than those that they replace.

The socio-economic impacts would be substantial. Valued aspects of the ecosystem would be progressively lost, such as the fisheries. A number of threatened species and ecological communities would be lost, such as *Ruppia* sp. seagrass beds, freshwater refuge areas and fish like the Murray Hardyhead. In particular the cultural and economic base of the Ngarrindjeri people would be severely degraded, for instance, with the loss of culturally important species like Black Swans and fish. The recreational and tourism industries would decline as water levels reduce boat passage and fisheries in the medium term, and the environment becomes less attractive with desiccation. Loss of modest areas of low lying farm lands and infrastructure is likely with sea level rise and salt water intrusion into formerly freshwater areas. Livestock-based producers around the waterways may be particularly vulnerable.

While these impacts would be severe, there is no one limit to adaptation. At different times different thresholds will be crossed which curtail or eliminate a valued aspect of the environment, economy or society. For example, shallow habitat for water birds in the south lagoon of the Coorong would become too deep at a particular point of sea level rise, and this will differ from the timing of drying events in the Lakes that prevent passage for recreational boats.

2. What adaptation strategies are available? Will (can) these strategies address all the climate risks that concern all potential stakeholders?

It is unlikely that any adaptation strategy will be accepted by all stakeholders, nor may these strategies address all the climate risks that concern all potential stakeholders. This highlights the needs for better governance processes that maximize community agreement and ownership over adaptation strategies.

There are five main adaptation options which are not mutually exclusive, but which have different benefits, costs and risks:

a) Increase environmental flows into the Lakes and Coorong. This would be the most effective measure for sustaining the environmental, economic and social values of the Region. Under moderate climate change it would be physically possible to reduce water diversions upstream to sustain a moderately healthy environment in the Lakes and Coorong. This is strongly supported by stakeholders in the Region, but not all interest groups in the broader Murray-Darling Basin. Most of this reallocation would need to come from irrigated agriculture in the Basin. South Australia controls a minor portion of inflows, but could do much better to conserve these, for example, by regulating inflow interception activities in the Eastern Mount Lofty Ranges. This approach may be harder to successfully maintain as climate impacts become more severe but may continue to maximize benefits. The translucent Barrages proposal requires maintenance of higher but modest inflows and may maximize benefits.

b) Engineering interventions. Also known as “environmental works and measures” or “environmental water demand management”, these involve the construction of more weirs, bunds and channels to enable more active management of water, either to channel flows to reduce salinity in particular parts of the Lakes and Coorong, or to compartmentalize the system in dry times into freshwater refuge and sacrifice areas. Some of these measures have widespread acceptance and positive impacts, such as increasing water flows into the Coorong’s south lagoon by extending the Upper South-East Drainage Scheme, or by restoring the natural width of the Narrung Narrows to improve water exchange in Lake Albert. Those that involve sacrificing parts of the system in dry times create winners and losers and are highly contested as shown by the construction of the Clayton regulator. There is a plausible argument for well-built and operable (with gates, boat and fish passage) bunds, but this requires much greater research and engagement with local communities to establish

that the benefits would outweigh the costs. However, there are substantial risks to engineering approaches. One is that it requires organizations capable of wisely operating such infrastructure indefinitely (e.g. operating gates for water flows and fish passage); state governments in the Murray-Darling Basin have not sufficiently demonstrated this level of responsiveness during the Millennium Drought as illustrated by the suspension of water sharing plans in the Basin in New South Wales and Victoria. In many situations it may be less risky to sustain ecological processes rather than substitute human operators to maintain ecological attributes. Further, projected sea level rise is likely to inundate these engineering measures by the end of the century raising the question of the long term objectives for management of the Region.

c) Strengthening the Barrages. Sea level rise of around 18-59 cm by the end of the century is conservatively anticipated by the IPCC, although faster and higher rises are possible. The Sir Richard and Younghusband peninsulas are not expected to be breached, but the marine incursion through the Murray Mouth would progressively leak through and overtop the current Barrages. It may be physically possible to rebuild higher Barrages at great expense. We judge this unlikely due to the huge expense and prospect of further sea level rise, and instead consider that living with a rising sea is a more practical strategy. Nevertheless some lands would be inundated and people displaced as a result.

d) Better catchment management. Without increased environmental flows into the Lakes additional measures to better manage the local catchments in the Region (Eastern Mount Lofty Ranges, South East) are unlikely to make a lot of difference. However, these catchments are extensively degraded through over-clearing of native vegetation and practices that contribute to sediment, salt and nutrient laden run-off. An expansion of the following measures could make modest contributions to adaptation, including:
    - Regulating inflow interception activities like groundwater extraction, plantations and farm dams to sustain stream flows;
    - Further fencing of livestock out of riparian and lakeshore areas to reduce erosion and nutrient inflows;
    - Revegetating riparian and lakeshore areas to reduce erosion and nutrient inflows, shade waters and reduce evaporation, and provide connected habitat for biota;
    - Controlling salinity.

    A modest expansion of these measures may help sustain limited freshwater inflows and refuges for freshwater dependant species – such as South Mount Lofty Ranges Emu Wren and the Murray Hardy Head - in places like the Finniss River and Currency Creek.

e) Better governance. Longer term governance structures are needed to develop greater community consensus on the long term objectives and required interventions, as opposed to the short-term and crisis-driven responses led by the state and federal governments during the Millennium Drought. Such governance institutions should aim to draw on local knowledge and aspirations, and develop a more common understanding of the management options available in the Region. It should have a high degree of ownership by the Ngarrindjeri and other local people suggesting a structure more decentralized from the state. Better scientific knowledge would contribute to governance. Critically this governance system should have stable funding, ideally, with a modest part of the funds raised directly in the Region from local use fees and the like, so as to provide institutional stability and leverage more resources from state and federal governments.

3. ***Assuming climate stabilises at 1.03^{o}C above pre-industrial levels (akin to the CSIRO median scenario and basis of MDBA policy development), what seems to be the likely residual impacts of climate change after adaptation has taken place? For whom will these impacts be a problem?***

We consider that this is an unrealistic scenario given that most global assessments suggest that with current greenhouse gas concentrations in the atmosphere that the planet is committed to greater warming (Rockström et al., 2009, Hansen et al., 2006). At this low level of climate change the effectiveness of adaptation depends on political will to reallocate water to environmental flows. There would be enough water in the Murray-Darling Basin to maintain a moderately healthy ecosystem in the Lakes and Coorong if sufficient water was reallocated to environmental flows. The current debate over the Basin Plan suggests that there may not be the political will in the short term to reallocate the 4,000 GL or more water required to achieve a moderately healthy ecosystem. Reallocation of less water risks repeating the desiccation experienced in the Millennium Drought, increasing salinity and a progressive loss of biodiversity spreading from the Coorong from the south and also from Lake Albert due to the limited exchange of water with Lake Alexandrina.

4. ***Assuming climate stabilises at 1.6^{o}C above pre-industrial levels (similar to NCCARF's +2 °C brief), what seems to be the likely residual impacts of climate change after adaptation has taken place? For whom will these impacts be a problem?***

As discussed in section 2.2 we have assessed this as akin to the CSIRO extreme dry scenario, although an extreme wet outcome is possible. At this level of moderate climate change the effectiveness of adaptation depends on reallocating substantially more water to environmental flows, which will become more difficult as the cheaper options for moving water away from agricultural uses are taken. The Guide to the Basin Plan suggested that 7,600 GL were required for a low risk of degradation of key ecological assets. Reallocation of less water risks more frequent desiccation as experienced in the Millennium Drought, increasing salinity and substantial loss of biodiversity. Desiccation episodes would be most felt through the loss of the Ngarrindjeri's cultural and economic base, as well as reduced fishing, constricted boat movements, loss of tourism and reduced water for livestock. The extent of sea level rise is difficult to forecast with this degree of warming, in particular, whether it would over top the Barrages at around 85 cm.

5. ***Assuming warming exceeds 4^{o}C above pre-industrial levels, what seems to be the likely residual impacts of climate change after adaptation has taken place? For whom will these impacts be a problem?***

At this severe level of climate change the environment of the Region would transition to a different, more marine state due to sea level rise and reduced freshwater inflows. Particular species and ecological communities would be lost due to higher salinity. The Ngarrindjeri would suffer from loss of traditional economic resources and cultural sites, including to inundation. Some agricultural enterprises would be inundated or lack sufficient access to freshwater to continue. Progressive inundation of low lying areas would displace some people however most town centres are well above current lake levels. Some sectors of the community may be maintained by a marine lakes system, including the boating, fishing (change from fresh to salt water species) and tourism sectors. When considering this level of change we need to acknowledge that adaptation is continuous and while people are facing such change they will likely be working to adapt further – adaptation is not a static process.

6. Given anticipated losses, are there substitutes for things that are lost that would be acceptable to affected parties?

The capacity to adapt and substitute varies considerably. It may be possible to maintain small refugia for some biodiversity, for example for some freshwater species in Currency Creek and the Finniss River, but with greatly reduced and more vulnerable populations. Other biota would almost certainly be lost, for example, *Ruppia* sp. aquatic communities and wading bird habitat in the south lagoon of the Coorong with high sea levels and salinity. It is unlikely that the traditional economic base of cultural resources of the Ngarrindjeri people could be replaced to their satisfaction. Displaced people and agricultural businesses could potentially move elsewhere if their finances allowed. Freshwater fishers could potentially switch to catching marine species in a saline lake system, and recreational boating and tourism may be little impacted by a change from a freshwater to a saline lake system. The Region's environment and communities would not end, but they would be substantially different.

9.2. Conclusions

1. Adaptation to climate change in the Region comprises a complex set of ecological, technological and social issues that cannot be resolved using short-term measures. Since the time of European settlement adaptation activities have largely consisted of large-scale water management interventions that began with water diversion for irrigation and continued with technological responses to periods of low rainfall, and now include planning for a range of climate change scenarios.

2. The Region is a complex system comprising a set of connected areas - the River Murray, Lake Alexandrina, Lake Albert, the Goolwa channel, the Murray Mouth, the Finniss River and Currency Creek, the Coorong North Lagoon and the Coorong South Lagoon. For adaptation purposes each area should be considered within its own socio-ecological context as well as those for the local Region and the entire Murray-Darling Basin catchment. The Region has important physical and biodiversity functions that are dependent on and support the biodiversity of the Murray-Darling Basin as a whole. These include the discharge of sediments, salt and other materials to the ocean and the provision of a diversity of unique wetland habitats for wildlife.

3. The Region and its system of interconnected ecosystems and institutions has been the subject of many investigations, land use designations, management strategies and community initiatives. However, to a large extent these have not been interconnected, partly because they have been driven by sectoral interests or seen to be too complicated. This has been to the detriment of the overall aim of achieving greater understanding and agreement on what management actions to take under the different circumstances that drive managerial responses. We envisage this situation as a "plague" of related, well-intentioned, but separate initiatives which "don't land". The result is an ever-extending literature which despite the effort and expenditure of a large sum of money is still incomplete and does not provide the basis for agreement on adaptation options and the usefulness of the underlying science.

4. There is a lack of consistency between institutions, both state and federal, and with the wider scientific community. Partnerships are often temporary, not fully supported, generally not interconnected and at times are incomplete or terminated without explanation.

5. The manner in which science has or has not been included in decision-making preceding, during and after critical events has been uneven and at times ineffectual. This extends to establishing agreement about the "science" itself. A poignant example

is the acidification that occurred in Lakes Albert and Alexandrina; there was little public agreement on the scientific approach needed to establish the degree of risk or the most appropriate adaptation options. The latter may have been the result of a complex and unprecedented situation, but it is without doubt that a learning opportunity was not fully realised in terms of being able to conduct controlled research experiments to ascertain the extent of risk and to develop effective guidance for managers.

6. The level of strategic thinking about adaptation in general and about the more severe impacts of climate change seems to have been somewhat stymied by the prevailing social and ecological conditions and was not sufficiently integrated (see section 8.1.3 about climate change and the Barrages). For example, a crisis management approach as observed in the Region during the Millennium Drought seemed to have had the effect of limiting opportunities for more strategic or even adventuresome thinking. There is no doubt that many people, particularly state government officers, did remarkable work under unexpected and difficult circumstances in response to the Millennium Drought. However such reactive circumstance runs the risk of generating conflict, for instance the Clayton regulator and Narrung bund were perceived by many in the community as reactive responses to crises and are described by some as maladaptations or "overly narrow adaptation".

7. Despite a significant amount of good intent, activity, consultation and discussion, the consultation processes did not result in unified and "owned" outcomes and may have further divided communities. Sporadic and/or time-limited consultation processes that focused on specific plans or adaptation options did not provide a platform for the development of a consistent voice either on behalf of governments or the community. Transparency and participation were key issues – as a consequence government-community relationships become strained and did not develop sufficient levels of trust. Communities became sceptical where they suspected that vested interests had a major influence on decision and outcomes (such as the Clayton regulator). Some adaptation options or interventions were seen to be necessary by some government departments and community groups, but seen to be maladaptations by others. Overall, it seems that consultation frequently failed to deliver a solid foundation (including the scientific facts and the relative merits and risks of management options) for determining acceptable outcomes. Future adaptation measures should be focussed on no and low regrets measures which generate co-benefits such as environmental flows and riparian restoration work.

8. Perceived maladaptations can have significant social impacts. Where communities feel that they have been ignored, have not been given information, or not treated with respect, they become active in opposition to proposed adaptations. One example is the community group which formed in opposition to the proposed Wellington weir in 2007. Social conflict can delay the implementation of interventions and has lasting effects within communities where there is a loss of trust and capacity to conduct a working relationship with government. The lesson for governments is to place the “tough decisions” on the agenda for discussion well before a crisis occurs. (See also point 11 that comments on the SA Government’s “Securing the Future” plan). The challenge for political leaders in South Australia is to establish proactive, adaptive management institutions for the Region that generate community ownership of management strategies which anticipate how to adapt to the impacts of climate change.

9. From a research perspective we make the point that adaptation did not "start" with climate change. Ecosystems, landscapes and communities have evolved and adapted to a myriad of external and internal conditions, stimuli, trigger points, barriers and limits. In other words, climate change is but one variable amongst many to which

individuals and communities in ecosystems and social systems adapt. There is much we can learn from past adaptations, coping mechanisms, interventions and perceived maladaptations to inform the additional adaptation required to cope with climate change. Research that focuses on climate change adaptation should also acknowledge the contribution that past (mal)adaptation can make to our understanding of what we need to do for future adaptation.

10. The term "limits to adaptation" has a number of interpretations, in particular when trying to establish what is meant by a limit. One interpretation is where something that is valued is eliminated, for example a state of predominantly fresh water in Lake Alexandrina and Lake Albert that is highly valued by people living in the locality. We conclude that there are major thresholds (involving a change of state) and major barriers, but in a situation where severe changes are likely the physical and human communities will adapt to new states although with the loss of some cherished attributes. Thus, what is a perceived limit or point of exit to one entity, such as an individual, a community or a plant species, could be an opportunity or point of entry for another entity. We propose that the term "limits to adaptation" is less useful than terms such as "barriers" or "obstacles to adaptation". Certainly finite limits can be reached, for example where individuals leave the community after the loss of livelihood, but these can also be seen as barriers to be overcome or adapted to.

11. Our analysis of the South Australian government plan for the Region “Securing the Future” highlights a number of deficiencies in the adaptation options. Specifically, the document is focused on the short-term, does not go into depth on environmental flow requirements and does not lay out the future options for the Region transparently and explicitly (Section 8).

12. For all its good words, the plan “Securing the Future” does not demonstrate the successful involvement of the Ngarrindjeri people, including their unresolved call for recognition of their land rights. In the “Ngarrindjeri nation yarluwar-ruwe plan”, the traditional owners propose measures for their involvement in the ownership and management of the Region, the types of reforms which have been accepted in other parts of Australia and produced many benefits for society. In our view greater involvement of the Ngarrindjeri Nation in the ownership and management of the Region would not only be just, but would also bring additional traditional ecological knowledge and other resources to the challenge of adaptively managing the Region.

13. A systems understanding for the Region is required, as was developed in the CLLAMMEcology research project for the Coorong with climate change scenarios. As yet there is an inadequate understanding of the ecological processes in the Lakes or in the Coorong other than under the low flow conditions of the last decade. The Recent Goyder Institute report begins to assess a number of ecological parameters in the Region against potential environmental flow allocations proposed in the Guide to the Basin Plan (CSIRO 2011). Further revision is required with a better understanding of the Lakes system and against climate change scenarios to inform management options.

14. The complexity of this Region shows a top-down / one-size-fits-all approach is insufficient to optimise adaptation responses. Therefore, it is necessary to facilitate regionally specific adaptation measures within existing or new local institutions.

15. Australia nominated the Coorong and Lakes Alexandrina and Albert as a Wetland of International Importance under the Ramsar Convention on Wetlands and committed to maintain its ecological character in the state it was listed in 1985. However, poor management, especially through excessive upstream diversion of water and now climate change, mean that the site is undergoing adverse change in terms of its

ecological character. As the Federal Government has the power to ensure the ecological character of all Ramsar wetlands is maintained it should ensure, through the Water Act 2007, that sufficient water is reallocated to the River Murray to sustain moderately healthy wetlands in the Region. The Federal Government could also use the Coorong and Lakes Alexandrina and Albert Wetland of International Importance as a case study for the Ramsar Convention to demonstrate how national governments can develop environmentally-focused and practical goals for maintaining the ecological character of wetlands as part of a process for promoting science-based, transparent and accountable approaches for better adaptation to climate change.

16. The Ramsar Convention was established to conserve wetlands under an assumption of stationarity that is unrealistic in a changing climate. Convention processes require amendment to enable science-based, transparent and accountable adaptive management of Ramsar wetlands to acceptable, new ecological states - where relevant - without allowing national governments to lower conservation standards for mendacious reasons. Such a process should involve independent review of proposed ecological character descriptions by, for instance, the Convention's Scientific and Technical Review Panel. Provision is needed to ensure that listed sites that no longer meet the original Ramsar criteria under which they were listed, but still meet some or new criteria are managed in a condition where such criteria can be met.

9.3. Recommendations

1. Planning for climate change adaptation and water management

1.1 **Climate change adaptation should be mainstreamed into water management**. Adaptation to climate change is important but it should be recognised that climate change is only one of many major environmental and social changes in the Region. In the short-term and under conditions of moderate climate change, water management policies that favour excessive diversions have more direct impacts on the ecological status of the Region than climate change. However, with more severe climate change, further response measures will be required. Adaptation to climate change in river basins is more likely to be successful through integration with other adaptive management measures and institutions.

1.2 The Federal Government's proposed Murray-Darling Basin Plan is an opportunity to **integrate non-climate and climate induced reforms into water management**. However, the proposed reallocation of just 3% of consumptive water to the environment during the 2019 – 2024 Plan implementation period to ameliorate climate change-induced losses is inadequate and appears to be based on the optimistic assumption of a "median" climate change impact by 2030 rather than considering measures need to manage "extreme" conditions, such as those recently experienced in the Region.

1.3 **Develop a genuinely long-term approach to management of the Region with climate change**. Management plans for the Region do not practically consider the very real prospect of ongoing and more severe climate change impacts. Further, there are no dedicated institutions to develop, implement and adaptively manage long-term plans. Now that the immediate crisis of the Millennium Drought has passed there is an opportunity to develop a management plan that considers appropriate measures to manage ongoing climate change impacts in over multiple timeframes. The State Government's "Securing the Future" is tagged as a long term plan, but most of the actions envisaged are short term or temporary measures, without a coherent plan for future management.

1.4 A plan that considers the two major long-term drivers of change in the Region, inflows from the Murray-Darling Basin and ongoing climate change impacts is required. Much depends on the extent to which water is reallocated to river flows through the Basin Plan. The plan for the Region should consider how to manage the most extreme changes, such as loss of the Barrages due to sea-level rise. These are complex questions that require long term research, engagement with the community, and consensus-building if an effective plan is to be adopted.

2. Establish institutions that can better manage the Region with climate change.

The crisis response to the Millennium Drought in the Region exposed the need for more robust institutions to sustainably manage the Region. Current institutions were unable to effectively embrace the social, including land tenures, and ecological complexity that characterises the Region. An enhanced institutional structure is needed to better provide the knowledge, community engagement, vision, and leadership required for planning and implementing social and environmental adaptation measures. We recommend that governments consider the following range of improved adaptive management options:

2.1 **Include the Ngarrindjeri Nation in influential roles in ownership and management structures for the Region**. The Ngarrindjeri Nation bring considerable applied ecological knowledge as well as people and businesses capable of making major contributions to better environmental management.

2.2 **Sustain ongoing relationships with the community on management**. Governments should recognize the importance of long-lasting, consistent, respectful government-community relationships in which multiple knowledge sources provide depth and richness in joint decision-making processes, and invest in building skills and supporting local communities to facilitate long-term consultative processes. In this context the institutional reform recommended in 2.5 (below) should provide a platform or platforms for more robust cross-sectoral education and dialogue between stakeholders on climate change impacts and adaptation options.

2.3 **Consolidate planning in the Region**. The many plans for environmental management in the Region, some with overlapping mandates, should be consolidated and the relationship between them made clear. For instance, the "Securing the Future" plan, Coorong National Park Management Plan, and Ramsar site management initiatives should be clearly linked, if not nested or integrated. These plans need to be iterative so as to prioritise and incorporate new knowledge and adjust to changing circumstances.

2.4 **On-going scientific research program**. Management of the Millennium Drought crisis was more difficult due to the low level of scientific understanding of the Region's environment, especially of the Lakes, despite the establishment of the CLLAMMEcology centre by CSIRO. The low level of government investment in research for management of the Region is in contrast to similar natural icons in Australia such as Kakadu or the Great Barrier Reef. As major changes in the Region are inevitable a substantial and ongoing environmental and socio-economic research program is required that builds on existing institutions. The recent establishment of the Goyder Institute may fulfil this role if it is adequately funded to work on the Region. A number of research priorities are evident, which include: a) climate change impact thresholds in the Region, including b) the efficacy of different environmental flows in sustaining the wetland ecosystems, in particular c) the ecology of the Lakes, which require a research effort similar to the CLLaMMecology work on the Coorong, and d) the rate, impacts and potential responses to sea level rise in the Region.

2.5 **Enhance governance institutions for the Region**. Governance institutions were not prepared for the impacts of the Millennium Drought, as evidenced by the reactive, crisis-driven response and community discord over planned measures. Given the potential for more frequent impacts of this type with climate change, a rethink of governance institutions is recommended. Many interviewees were dissatisfied with the performance of existing institutions but were also wary of creating a new one.

There are a number of options for enhanced management of the Region through the multiple local government regions and land and sea tenures:

i. **State Government agencies**. Enhanced investment in state government agencies could be effective if the risks of perpetuating limited engagement and ownership of management strategies by local peoples, and the likelihood of changes in state government funding priorities, could be minimised. Two further elaborations of this option were suggested by interviewees. One suggestion was to designate the whole of the publicly owned wetlands as part of the Coorong National Park to centralise management, Another potentially complementary option is to designate the Region, including some privately managed lands, as a biosphere reserve under the UNESCO "Man [sic] and the Biosphere Program". A biosphere reserve is where one or more protected areas and surrounding lands that are managed to combine both conservation and sustainable use of natural resources, such as in the existing Riverland Biosphere Reserve in South Australia. (http://www.environment.gov.au/parks/biosphere/index.html).

ii. **Natural resource management board**. The Region is currently divided between the South Australian Murray Darling Basin (Lakes and Coorong north lagoon) and South East Natural (Coorong south lagoon) Resource Management (NRM) Boards. A single NRM Board could be established for the Region. However, NRM Boards are currently being integrated with the operations of the Department of Environment and Natural Resources. A number of interviewees suggested that there was change fatigue in the community and these institutions that would militate against such a change, and that the limited resources available to these Boards would limit effectiveness in managing the region.

iii. **Consensus-based council**. Provide a non-legislative council where all relevant state and local institutions participate in a consensus-based process to agree on management actions with the relevant organizations agreeing to implement these within their own mandates. This approach requires a high degree of political leadership to work effectively; The Fraser Basin Council in Canada provides a working example (http://www.fraserbasin.bc.ca/). A number of interviewees suggested that this would be the best option for engaging the community in more adaptive management if a new decision making institution was not politically feasible.

iv. **Coorong and Lakes statutory authority**. Our preferred model is the establishment of a Coorong and Lakes statutory authority, a model which has precedents elsewhere in Australia and overseas (for example, the Great Barrier Reef Marine Park Authority in Australia, the Norfolk Broads Authority in the United Kingdom, and Chilka Development Authority in India). We consider this is warranted due to the importance and complexity of adapting to both climate and non-climate driven changes in the Region. We also consider that an institution that is not beholden to federal and state government electoral cycles could provide better continuity for promoting adaptive management in the region. Many interviewees rejected this option, either because they felt that their own institution could do an adequate job, or because it was the Murray-Darling Basin Authority's job, or because the state government would not support an institution that may be critical of it. We do not consider that the Murray-Darling Basin Authority can unequivocally speak for the Region since it is actively making water allocation policy decisions that trade off the health of the Region's ecosystems against those in the upper Basin (MDBA, 2010, Pittock and Finlayson, 2011b).

3. Enhance support for adaptation to climate change through effective implementation of the Ramsar Convention on Wetlands.

As the Federal Government has the legislative power to ensure the maintenance of the ecological character of Ramsar-listed wetlands it should ensure sufficient water is reallocated to the River Murray to sustain healthy wetlands in the Region, consistent (in the medium term at least) with the ecological character of the Ramsar sites as at 1985. It could further promote the efforts to maintain these wetlands as a case study for the Ramsar Convention to demonstrate how national governments can develop environmentally-focused and practical ecological character goals as part of a science-based adaptation approach. The Government should also promote reform of the Convention to enable science-based, transparent and accountable adaptive management of Ramsar wetlands to acceptable, new ecological states (where relevant) without allowing national governments to lower conservation standards for mendacious reasons.

4. Implement new adaptation measures and better assess other options for the Region.

While management of the Region is a history of adaptation to environmental variability, many of these measures have proved to be maladaptations. To avoid maladaptation the following are recommended.

4.1 **Adoption of an adaptive management vision.** Management should be guided by an overarching vision of the type of environmental state that is required in the Region. The vision should anticipate the impacts of climate change and consider measures to manage them. One option has been called the estuarine management, or “translucent Barrages”, that would involve provision of sufficient freshwater inflows from the River Murray to keep the Lakes predominantly fresh, but fluctuating in salinity and water levels, which would maximize biodiversity. This vision would need to be periodically reviewed to consider its desirability under more severe climate change impacts. Adaptive management requires a dedicated monitoring programme to detect ecosystem change and evaluate management strategies.

4.2 **Better assess the costs and benefits of climate change impacts and adaptation options.** Climate change impacts in the Region involve a number of thresholds, for instance, cessation of freshwater flows over the Barrages for more that 339 days may tip the Coorong from a healthier state to a degraded hypersaline condition (Brooks et al., 2009). Governments need to work with the regional community to better define these thresholds then cost the impacts of exceeding them versus adaptation measures to better inform decision making. Further, any proposed adaptation measure will have costs and benefits that need to be explicitly identified to inform decision making. Costs may include the financial expense, time and opportunity cost. Many adaptation measures are likely to have co-benefits in generating additional ecosystem services which should be valued to enable identification of more socially beneficial adaptation options.

4.3 **Contested adaptation measures where further assessment and community engagement is required.** A great many other adaptation options are highly contested, divide community opinion, and require more substantial knowledge before better decisions can be taken. In many cases these measures may represent overly-narrow adaptation or maladaptation. These include the temporary or proposed bunds that could segment the lakes. Also in this category are medium term options for responding to potential overtopping of the existing Barrages. These measures should be considered through extensive community engagement and as part of a long term management plan for the Region. Many interviewees perceived

that interventions made to manage desiccation during the Millennium Drought were reactive because they did not think that the full range of management options had been adequately researched and discussed with the community.

4.4 **Implementation of clearly beneficial adaptation measures.** There are a number of adaptive interventions that would be clearly beneficial that should be implemented forthwith. Among these are:

i. Increasing environmental flows from the River Murray;
ii. Enhancing institutions for research, planning, and management, including greater roles for the Ngarrindjeri nation and the Goyder Institute;
iii. Extending the Upper South-East Drainage Scheme to improve inflows into the Coorong's south lagoon;
iv. Restoring the natural width of the Narrung Narrows to increase water exchange between lakes Alexandrina and Albert;
v. Conserving stream and lake side riparian zones through livestock exclusion and revegetation;
vi. Completing water management plans for the Eastern Mount Lofty Ranges catchments to curtail water diversions, including inflow interception activities.

While this research has focussed on the Coorong and Lakes region as a particularly vulnerable region to the impacts of climate change, the lessons derived from adaptation here have much wider relevance. In terms of process, this research has focussed on combining bio-physical science and social knowledge to identify issues and potential solutions. As a result we have identified a number of stakeholder values, concerns and potential responses that bio-physical research alone would not address. This approach should be applied more widely to other adaptation initiatives.

Further, there are hundreds of coastal barrier lagoon and estuary systems of various sizes around the Australian coast (Kench, 1999). While the Coorong and Lakes is among the bigger of these estuaries, the adaptation lessons from the Region have lessons for many other places.

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11. APPENDICES

11.1. Ecological character of the Coorong and Lakes Alexandrina and Albert Ramsar wetland

The Coorong and Lakes Alexandrina and Albert were designated a Wetland of International Importance (a Ramsar site) under the Ramsar Convention on Wetlands on 1 November 1985. As a consequence the Australian and South Australian Governments are required to describe and maintain the ecological character of the wetland, an obligation that is supported federally by the Environment Protection and Biodiversity Act 1999. The Act provides a framework for ensuring that the ecological character of all Australian Ramsar sites is retained, or restored (Pittock et al. 2010). The description of the ecological character forms the baseline or benchmark for management planning and action; including assessment and monitoring to detect negative impacts.

The site was listed as internationally important on the basis of eight of the criteria used by the Convention, namely:

Criterion 1: A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.

Criterion 2: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.

Criterion 3: A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.

Criterion 4: A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.

Criterion 5: A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.

Criterion 6: A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.

Criterion 7: A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.

Criterion 8: A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.

An updated and comprehensive description of the ecological character of the Coorong and Lakes Alexandrina and Albert Ramsar site was published in 2006 by the South Australian Department for Environment and Heritage (Phillips and Muller 2006) with further information provided by Kingsford et al. (2011). Phillips and Muller (2006) point out that the ecological character of this site has been altered and would appear to have been accelerated and exacerbated by water extractions that are too high for the system to be able to sustain itself through the recent drought conditions, as it would have under natural conditions. These sources are used to provide a summary of the ecological character of the Ramsar site. The Convention updated the definition of ecological character in 2005 to include ecosystem services that had previously been seen as being derived from, but not part of the ecological

character. Thus, ecological character is now defined as "*the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time*.

Land tenure and management

The area is mostly Crown Land (water) and National Park and Game Reserves with Lakes Alexandrina and Albert being surrounded largely by private property and the Coorong mainly by National Park and Game Reserve. Land use includes grazing and light farming on adjacent land with some tourist development, although further development seems to be restricted under regulations. Within the site some recreation, camping and boating is allowed alongside conservation management. The Ramsar site is subject to a management plan. It is estimated that the park reserve receives more than 200,000 visitor days per year.

Ecosystem components

The site covers approximately 140 500 ha and encompasses Lake Alexandrina and Albert and the tributaries of the Finniss River and Currency Creek as well as the Coorong, including all land and water within the Coorong National Park. It is situated at the terminus of the Murray-Darling Basin with surface water inflows predominantly from the River Murray into the north of Lake Alexandrina, with other inflows from the tributary streams draining the Eastern Mount Lofty Ranges along the south-western edge of Lake Alexandrina. Lake Albert lies to the south east of Lake Alexandrina and is connected via a narrow channel (Narrung Narrows). Lake Alexandrina is the primary source of inflows to Lake Albert, with supplementation from local rainfall and groundwater discharge. Lake Albert represents a local, inland terminus of the River Murray system. The fresh waters of the Murray and Lake Alexandrina are separated by five barrages from the more saline water of the Murray Mouth Estuary and Coorong lagoons. Inflows from the South East of South Australia into the Coorong's South Lagoon have been re-established in recent years by the Upper South East Drainage Scheme. The mouth of the Murray provides the only connection to the Southern Ocean. The water regime of the site is now highly regulated by the physical structures within the river and lakes.

The site contains a mosaic of 23 wetland types (Tables AX), ranging from the freshwater lakes to the estuarine environments of the Coorong and provides habitat for nationally threatened species such as the Orange Bellied Parrot, the Southern Mount Lofty Ranges Emu Wren, the Murray Hardyhead, the Yarra Pygmy Perch and the Murray Cod. A detailed description of the individual wetland types is provided by Phillips and Muller (2006). The site also contains (in part) the critically threatened *Gahnia* sedgeland ecosystem, the swamps of the Fleurieu Peninsula and a number of nationally listed plant species. As there have been few systematic surveys of plant taxa further surveys are expected to find additional plant species of note, such as the endemic plant communities of musk grass (*Lamprothomium populosum*).

Table A1: Wetland types in the Coorong and Lakes Alexandrina and Albert Ramsar site.

	Marine/Coastal wetlands	Area (ha)
A	**Permanent shallow marine waters** in most cases less than six metres deep at low tide; includes sea bays and straits	50
D	**Rocky marine shores**; includes rocky offshore islands, sea cliffs	788*
E	**Sand, shingle or pebble shores**; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks	1,020#
F	**Estuarine waters**; permanent water of estuaries and estuarine systems of deltas	2,200
G	**Intertidal mud, sand or salt flats**	3,142
H	**Intertidal marshes**; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal brackish and freshwater marshes	536
I	**Intertidal forested wetlands**; includes mangrove swamps, nipah swamps and tidal freshwater swamp forests	4
J	**Coastal brackish/saline lagoons**; brackish to saline lagoons with at least one relatively narrow connection to the sea	10,128
K	**Coastal freshwater lagoons**; includes freshwater delta lagoons	41
	Inland wetlands	
M	**Permanent rivers/streams/creeks**; includes waterfalls	221
N	**Seasonal/intermittent/irregular rivers/streams/creeks**	200
O	**Permanent freshwater lakes** (over 8 ha); includes large oxbow lakes	79,480
P	**Seasonal/intermittent freshwater lakes** (over 8 ha); includes floodplain lakes	120
R	**Seasonal/intermittent saline/brackish/alkaline lakes and flats**	1,729
Ss	**Seasonal/intermittent saline/brackish/alkaline marshes/pools**	1,289
Tp	**Permanent freshwater marshes/pools**; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season	4,474
Ts	**Seasonal / intermittent freshwater marshes/pools** on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes	1,037
W	**Shrub-dominated wetlands**; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils	4,875
Xf	**Freshwater, tree-dominated wetlands**; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils	1,470
Y	**Freshwater springs; oases**	<10
	Human-made wetlands	
4	**Seasonally flooded agricultural land** (including intensively managed or grazed wet meadow or pasture)	1,235
6	**Water storage areas**; reservoirs/barrages/dams/impoundments (generally over 8 ha)	1
9	**Canals and drainage channels, ditches**	44

Shaded rows indicate the dominant wetland types within each broad category; marine/coastal, inland, and human-made.

KEY

* Includes 165 ha from Lake Alexandrina (a freshwater part of the system)

Includes 6 ha from Lake Alexandrina and 1 ha from Lake Albert (freshwater parts of the system)

Ramsar wetland types not found in the Coorong and Lakes system have not been included in the table.

The total area of wetland types is approximately 114,000 hectares. The balance of the land (approx. 26,000 hectares) within the Ramsar site is terrestrial habitat, which is not classified under the Ramsar Convention (see Section 2.2 for a description of the site boundaries).

The native fish of the Ramsar site includes 49, including five species that are listed as vulnerable at either global or national levels, a further 20 species classified as protected or provisionally listed as being of conservation concern within South Australia, 20 species that utilise the site at critical stages of their life cycle, such as, seven diadromous species, twelve estuarine species that spawn or have large populations and any freshwater species that spawn or recruit within the wetland; eight marine species of fish that randomly enter and leave inlets and estuaries.

There are 77 recorded bird species, the majority being waterbirds, including: three species that are listed as endangered or critically endangered at either global or national levels; five further species that are classified as vulnerable within South Australia; 49 species that rely on the wetland at critical life stages, such as migration stop-over, for breeding habitat or as refuge during times of drought 46 species that are listed under Australia's migratory bird agreements with Japan or China, or the Convention on Migratory Species; 16 species that occur at the site in numbers 1% of their estimate population or sub-population numbers. There is a diversity of species with waders and waterfowl predominating. Common species included: Red-necked Stint (*Calidris ruficollis*); Curlew Sandpiper (*C. ferruginea*); Sharp-tailed Sandpiper (*C. acuminate);* Banded Stilt (*Cladorhynchus leucocephalus*); and Red-capped Plover (*Charadrius ruficapillus*). Regular and accurate counts of waterfowl are not available although there are spectacular numbers of Black Swan (*Cygnus atratus*), as well as Cape Barren Geese (*Cereopsis novaehollandiae*), Grey Teal (*Anas gibberifrons*), Pacific Black Duck (*A. superciliosa*) and Australian Shelduck (*Tadorna tadornoides*). The Coorong is an important breeding area for the Pelican, Crested Tern and Fairy Tern, and Lake Alexandrina for egrets, ibises, cormorants and the Rufous Night Heron (Nycticorax caledonicus).

Little is known about carbon and nutrient cycling in the Coorong and Lakes but these cycles are likely to have been greatly influenced by management in the catchment and the wetlands themselves. Recorded change in the extent and distribution of submerged and emergent plants is expected to have led to a decline in detritus and nutrients being transformed within and between the mosaic of wetland types. Further, the amount and type of carbon and nutrients entering the system from the River Murray during flow events will have changed over time and given that very little water has left the Murray in the last decade it is likely to be a sink for nutrients, sediment and salt from the catchment.

Ecosystem services

A listing of ecosystem services derived from the wetlands, and based on the categories used by the Millennium Ecosystem Assessment, is provided below.

Cultural services – science and education; cultural heritage and identity; contemporary cultural significance; aesthetic and sense of place; spiritual, inspirational and religious, including those of the Ngarrindjeri.

Provisioning services – water for drinking, irrigation, tourism activities; food from fishery; wood, reed, fibre and peat, as well as medicinal products used by the Ngarrindjeri.

Regulating services – groundwater replenishment; water purification; coastal shoreline and riverbank stabilisation; carbon storage; local climate regulation.

Supporting services – nutrient cycling; primary production; physical habitat for key biota.

A comprehensive listing and valuation of ecosystem services has not been carried out for the Ramsar site.

Change in ecological character

The ecological character of the site has been altered significantly over the past 20–30 years with many changes already underway at the time of listing as internationally important in 1985. The changes to the ecological character of the site are proceeding faster in some parts of it than others. The Coorong lagoons, once a predominantly estuarine environment with some hyper-saline portions, particularly favoured by wading birds and with great diversity of fish species, are rapidly transforming into more and more turbid and saline systems. This is seeing the rapid loss of the keystone *Ruppia* plant species and with these, declines in much of the biota of the Coorong that justified Ramsar listing. To summarise, the Coorong ecosystem is becoming increasingly simplified as the loss of *Ruppia* continues; this being a consequence of escalating salinities, increasingly turbid waters and inappropriate water levels.

All of this indicates that a comprehensive shift in ecological character has occurred and will require major intervention, although it may prove irreversible. All of these are essentially determined by River Murray flows into and through the system, and historically by flows from the south-east of South Australia. Without significant and urgent intervention it may prove irreversible.

11.2. Interviewee information sheet, consent form and interview questions

11.2.1. Project information sheet

Information sheet on research

The Limits to Adaptation

Understanding adaptation options and limits to adaptation in the Coorong wetlands area

Personal and contact details

Catherine Gross PhD, Visiting Fellow, The Fenner School of Environment and Society, The Australian National University (ANU), Canberra ACT 0200; : E-mail: Catherine.gross@anu.edu.au;
Ph: 02 6125 0348; Mobile: 0438 994 328

Administration

Catherine is principal investigator within a team of four researchers from Charles Sturt University, the University of Adelaide and the ANU. The research focuses on the Coorong and Lower Lakes wetland area. Research findings will be documented in a summary report and published in academic journals. Funding is provided by The National Climate Change Adaptation Research Facility (NCCARF) under its Synthesis and Integrative Research Program. NCCARF is funded by the Australian Government (further information: www.nccarf.edu.au).

The research

The research is one of six projects funded by NCCARF in which vulnerable Australian locations and ecosystems are studied in the context of climate change. The aim of the research program is to add to the body of knowledge concerning adaptation to climate change in circumstances in which the impacts of climate change are unavoidable and adaptation options may be perceived to be limited. This part of the research aims to find out how people living in the Coorong and Lower Lakes area have adapted to climate variability and what they think about adaptation options and potential limits to adaptation. Adaptation options can be those proposed by governments or other groups as well as individual ways of adapting to climate variability.

Participation in the research

I would like to spend between an hour and an hour and a half asking you some questions in a semi-structured format. Questions will be about:

- Your occupation and connection with the general area
- Your awareness of proposals or plans (adaptation options) to alter the nature of the area, such as changes to Barrages or water levels, and your perspectives about these
- Your involvement in discussing such proposals or plans and level of consultation by proponents of these
- How you interact with different stakeholder groups who may have different perspectives about adaptation options
- How you have adapted your lifestyle or business to changing conditions in the past
- Your views and thoughts on whether there might be some tangible limits for your ability to adapt and cope in the future

Participation is entirely voluntary and interviewees can withdraw at any time.

Confidentiality

Confidentiality is very important and we respect the need for confidentiality. For this reason we will not include any names or information which could identify you or your statements in any report or publication. Notes and transcripts will be kept under lock and key in my possession.

Research Contact details

If you have concerns with the way the research was conducted you can also contact The ANU Human Research Ethics Committee:

Human Ethics Officer, Human Research Ethics Committee, ANU, Ph: 02 6125 7945, or human.ethics.officer@anu.edu.au

Thank you for your participation.

Catherine Gross

January 2011.

11.2.2. Interview consent form

CONSENT FORM

I…….……(please print) agree to be interviewed by Catherine Gross regarding my opinions and observations as part of her research project about climate change adaptation options and the limits to adaptation in the Coorong and Lower Lakes wetland area.

I have read the information sheet and understand the following information:-

1. Catherine Gross is a Visiting Fellow at The Australian National University and is Principal Investigator for this project which involves four researchers from Charles Sturt University, the University of Adelaide and ANU. The project is funded by NCCARF, which itself receives funds from the Australian government.

2. The interviews will contribute to research about individual and community perspectives of adaptation options and the limits to adaptation in the Coorong and Lower Lakes wetland area.

3. Participation in the project is entirely voluntary and interviewees can withdraw at any time without any negative consequences.

4. Information obtained during the interviews may be used in a summary report and in related publications.

5. Confidentiality for interviewees will be protected by the absence of any identifying information in all drafts and publications. Catherine will not discuss or disclose the names of people she has interviewed.

6. All raw data from the interviews, including transcripts, will be securely stored and accessible in either hard copy or electronic form by Catherine Gross only, and will not be shown to anyone else, nor discussed with anyone else outside the research team.

Signature Date

THANK YOU FOR YOUR ASSISTANCE

11.2.3. Interview questions guide

Limits to adaptation in the Coorong and Lower Lakes project.

Semi-structured interview guide, November 2010

3 x 5 cards to be placed in front of the interviewee (during the course of the interview) with the words "adaptation", "maladaptation"; "limits to adaptation ", and " impacts" (material, social, personal).

1. Demographics etc

1. Could you tell me your age, occupation, and the length of time you have lived in this area?
2. How would you describe yourself in relation to the community (for example, an active member, not involved, community leader, etc)?
3. Could you describe how you use or interact with the area known as the Coorong and Lower Lakes?
4. Could you describe how you value the area in terms of material use, social use and your own personal values?
5. Are you a member of any group or organisation that is concerned with the Coorong and Lower Lakes area?

2. Adaptation to climate change

1. This research is particularly concerned with perceived limits to adaptation to climate change. Do you have any general thoughts about such limits before we discuss adaptation options for the Coorong and Lower Lakes area in more detail?

3. Existing changes and Potential Adaptation Options for the Area

1. Could you please describe your views of the way in which the Coorong and Lower Lakes area has been modified/adapted/changed and what you think of these. For example, you might see these as positive changes or as maladaptations.
2. Are you aware of any formal or informal proposed plans to change or alter the nature of the Coorong and Lower Lakes area, such as changes to the Barrages or water levels? If so, could you please describe them and how you heard about them.
3. What is your view of these formal or informal proposed plans or changes? How would they impact you?
4. What is your view of past or present government plans or initiatives and the way that governments have consulted with you about such initiatives?
5. Are you aware of other perspectives that people might hold about the Coorong and Lower Lakes area and what are your views on these?

4. Community and Developing Adaptation Options

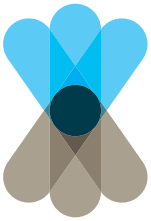
1. Do you interact with other groups who might hold different perspectives? If so, how ? If not, what are the barriers to such types of interactions?
2. Do you feel that viable options have been presented? Please elaborate.
3. In your interactions with groups or government agencies wishing to determine different options for the Coorong and Lower Lakes in terms of how they are managed, do you feel that you have been consulted with?
4. Do you think that these types of consultations (if applicable) can lead to a discussion of viable options being presented for the future of the Coorong and Lower Lakes area?
5. Do you have any particular expectations or requirements from governments or government agencies in relation to adaptation to climate change in this area?

5. Personal/Business Adaptation and Limits to adaptation

1. How have you adapted over the years to the varying ecological conditions in the Coorong and Lower Lakes area? Examples are water extraction for business or personal use; recreational activities, professional or personal use of the area.
2. With the recent extended drought how have you coped with the dry conditions?
3. Do you perceive that there might be limits for your ability to adapt and cope if the degree of variability continues and if dry conditions return and persist?
4. If your livelihood is potentially affected have you as a family/business discussed future options and potential changes?
5. Do you think that there are finite limits in your ability, and your community's ability, to adapt to the changing conditions? What might these be?

These could be in material (such as livelihood), social (such as community well-being) and personal (such as optimism for the future) areas. These could also be in terms of relationships with government and other communities. (Use three cards here)

6. Do you have any comments to make regarding other people's limits to adaptation in the area, or the community in general?
7. Do you have anything else that you would like to add in relation to this research?



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Sunshine Coast

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