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FUTURE RESEARCH NEEDS FOR CLIMATE CHANGE ADAPTATION IN THE MURRAY-DARLING BASIN

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Report to Murray-Darling Basin Authority

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EXECUTIVE SUMMARY

The Murray-Darling Basin Authority (MDBA) commissioned CSIRO to convene a small expert working group, including policy and management practitioners as well as academics and researchers, to discuss adaptation to climate change in the Murray-Darling Basin (MDB). The study was undertaken through literature review, a workshop and some subsequent synthesis.

The literature review highlighted considerable knowledge about potential climate change impacts in the MDB, but noted that there is a growing concern that these impacts may have been underestimated in the past, and that, comparatively, research and knowledge about adaptation was quite limited.

The workshop highlighted the need for adaptation thinking to embrace the possible need for transformative, rather than incremental, adaptation in the region, and noted that this required a major program to help the policy and management community of the Basin to envision different futures. It was seen as likely that institutional change would be required as part of the process of responding to this challenge. Although the challenge is substantial, there is a growing body of theory and practice in Australia and overseas to build on for such an endeavour.

Whilst there are numerous specific topics that can be followed up, three high level activities that would improve the adaptive capacity of the Basin to deal with future change are recommended for development:

1. **Foresighting Basin futures**: this would involve establishing the processes and information content for engaging the Basin community (local and external) in recognising and envisioning a different future for the Basin.
2. **Exploring adaptive institutions**: recognising that a major part of a good adaptive response will include change towards institutions more able to cope adaptively with uncertainty, this will involve establishing the groundwork for such a response.
3. **Assessing adaptive capacity and vulnerability**: this will develop a better understanding of the social, physical, financial, environmental and human assets that will underpin the capacity of individuals and communities to respond to climate change in the context of other changes.

1. INTRODUCTION

Climate change is an increasingly important issue in relation to natural resource management in southern Australia. In addition to climate change, however, other changes such as increases or decreases in regional populations and varying demographic makeup are going to have significant impacts on the way in which natural resources and other policies are managed in the Murray-Darling Basin (MDB). Decision-making bodies, such as the Murray-Darling Basin Authority (MDBA), are increasingly taking into account the implications of climate change and variability in their investment assessment process and in program development.

This report was commissioned by the MDBA as a short review of current knowledge about climate change impacts and potential adaptation response in the MDB. Since 1988, there had been a range of studies which could inform the assessment of adaptation options across the basis. Whilst not providing a fully comprehensive coverage and sometimes being based on superseded climate change scenarios, these studies addressed a considerable number of the core NRM issues for the MDB. The aim of the literature review was to collate and synthesise this literature, while the aim of the workshop was to complement the literature review by assessing climate adaptation options relevant to the MDB, drawing on the knowledge and expertise of the workshop group.

The report opens with a review of key literature of relevance to the remainder of the study. The relative infancy of climate change studies related to NRM in the MDB means that a review of available literature alone would not cover all the issues that need to be addressed. Because of this, the literature review was complemented by an expert workshop which brought together people with a wide range of expertise including coverage of different sectoral activities, sub-regions and disciplines. Expertise at the workshop included knowledge on: climate change adaptation, NRM governance, institutional design, agricultural sectors (including intensive livestock, and horticulture), hydrology and systems analysis. The attendees were also targeted so as to have coverage of the northern, southern intensive and semi-arid parts of the Basin. This approach allowed more contemporary information to be considered in relation to climate change scenarios and contextual factors operating in the Basin. The aim of the workshop was to assess climate adaptation options across all major aspects of NRM relevant to the MDBA, drawing on the knowledge and expertise of the workshop group.

The outcomes of the expert workshop are then synthesised to reflect the participants' views of the current status of adaptation as it relates to NRM in the MDB and future research priorities. Finally, conclusions are drawn by the project team reflecting on the whole process, with recommendations provided to the MDBA on future research to enable successful adaptation to climate change in the Murray-Darling Basin.

2. LITERATURE REVIEW

Since 1988, there have been a range of studies which could inform the assessment of adaptation options across the Basin. Whilst not providing a fully comprehensive coverage and sometimes being based on superseded climate change scenarios, these studies address a considerable number of the core natural resource management (NRM) issues for the MDB. The aim of this literature review is to collate and synthesise this material so as to assess climate adaptation options and strategies across as many major aspects of NRM within the MDB as we can. We have reviewed the literature, provided an overview of relevant climate change research and suggested what new research is required.

This literature review starts by setting the scene with an overview of the Murray-Darling Basin in terms of its importance in Australia in terms of area, population and the fact that it is a key source of food supply within the country. It continues with an overview of climate change projections relevant to Australia and in particular the MDB. It then goes on to summarise the relevant adaptations that may be necessary as a result of these changes that are emphasised by the projection reports. A summary of literature is then presented and organised in the following categories:

- Agriculture
- Biodiversity
- Water
- Economic impacts
- Social impacts

The literature review is not comprehensive, given the short nature of the project, but aims to raise significant aspects of MDB functioning to set the scene for subsequent discussion.

2.1 Overview of the MDB

The Murray-Darling Basin is a large water catchment in Australia covering one seventh of the continent that encompasses areas in the south of Queensland, almost all of New South Wales, the northern half of Victoria and the eastern sector of South Australia (Figure 1). It includes the three largest rivers in Australia; the Murray River, the Darling River and the Murrumbidgee River. The Murray-Darling Basin is also very important for rural communities and Australia's economy. Three million Australians inside and outside the Murray-Darling Basin are directly dependent on its water. About 85 per cent of all irrigation in Australia takes place in the Murray-Darling Basin, which supports an agricultural industry worth more than $9 billion per annum.

It contains over 40% of all Australian farms, which produce wool, cotton, wheat, sheep, cattle, dairy produce, rice, oil-seed, wine, fruit and vegetables for both domestic and overseas markets. It produces one third of Australia's food supply and supports over

Figure 1: The Murray-Darling Basin

a third of Australia's total gross value of agricultural production, and is therefore the most important agricultural region in Australia.

The Basin is not only important in terms of agriculture. It also supports an abundance of native wildlife with significant numbers of endangered plant and animal species and over 30 000 wetlands, some of which are listed for their international importance. It is also important in terms of indigenous cultural values with indigenous people placing great importance on the river systems and the services that are offered in terms of spiritual significance and provision of food. As well, the Basin is a key area in Australia offering recreational and tourism opportunities. All of these issues place great importance on the likely future of the Basin and the consequences of climate change. The impacts of these consequences therefore will be important for future research and trying to assess the possibilities for adapting to climate change.

2.2 Climate change scenarios

A report covering the impacts of climate change in Australia and New Zealand to the Intergovernmental Panel on Climate Change has indicated that climate change in the form of more heatwaves, fewer frosts, altered rainfall patterns and a rise in sea levels has already occurred in the region since 1950, and that these changes have caused impacts on water supply, agriculture, natural ecosystems and landscapes. The main conclusions of the report however were that the climate in both Australia and New Zealand will continue warming, and that extreme events such as heatwaves, fires, floods, landslides, droughts and storm surges are very likely to increase both in frequency and intensity (Hennessy *et al.* 2007).

The report also found that the potential impacts of climate change were substantial, unless further adaptation was to take place. Projected impacts included water security problems, sea level rise and coastal flooding, loss of biodiversity, risks to infrastructure, and declining agricultural and forestry production in certain areas.

The climate impacts on the Murray-Darling Basin are projected to be substantial (Figure 2). The Murray-Darling Basin Sustainable Yields project report (CSIRO 2008) summarised assessments on sustainable yields of surface and groundwater systems, for eighteen regions comprising the Murray-Darling Basin. The project modelled four scenarios, using historical and projected climate data, and current and projected levels of water resource development.

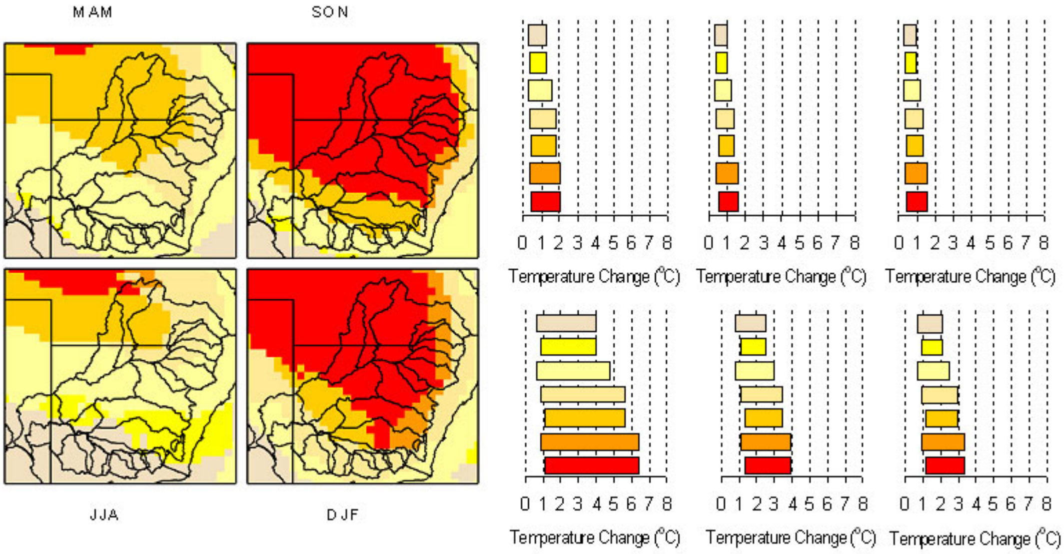
The modelling showed that water resource development has already caused major changes in flooding regimes in the Basin, with resultant impacts on floodplain wetland systems. Severe drought, since 1997 and continuing, has led to greatly reduced catchment runoff, and such droughts are expected to become increasingly common due to climate change. Under the mid-range climate change scenarios, surface water availability was projected to fall by 11% (9% in the north and 13% in the south of the Basin) by 2030. Worst case climate change scenarios were for significantly lower flows. The last 10 years have been worse than the worst case scenario for 2030 in the southern part of the Basin. The reductions in surface water availability, if current water sharing arrangements were continued, were projected to have especially severe impacts on the riverine environment of the Murray River, including the Lower Lakes and the Coorong. Groundwater use was expected to double by 2030, and it was noted that projected future levels of groundwater use would become unsustainable in the Border Rivers, Lower Namoi, parts of the Lower Macquarie, and the Lower and Upper Lachlan River. According to the Bureau of Rural Science's projections (Milne *et al*. 2008), commercial forestry plantations in the Basin could expand by 18% by 2030, leading to significant reductions in annual runoff in certain areas. An increase in farm dam capacity could also result in reduced runoff therefore further exacerbating the problems of lower river flows and water availability.

Another major study projecting the regional impacts and climate change adaptations necessary for Australia (PMSEIC Independent Working Group 2007, p. 28) identified four priority areas that require greater adaptive capacity including:

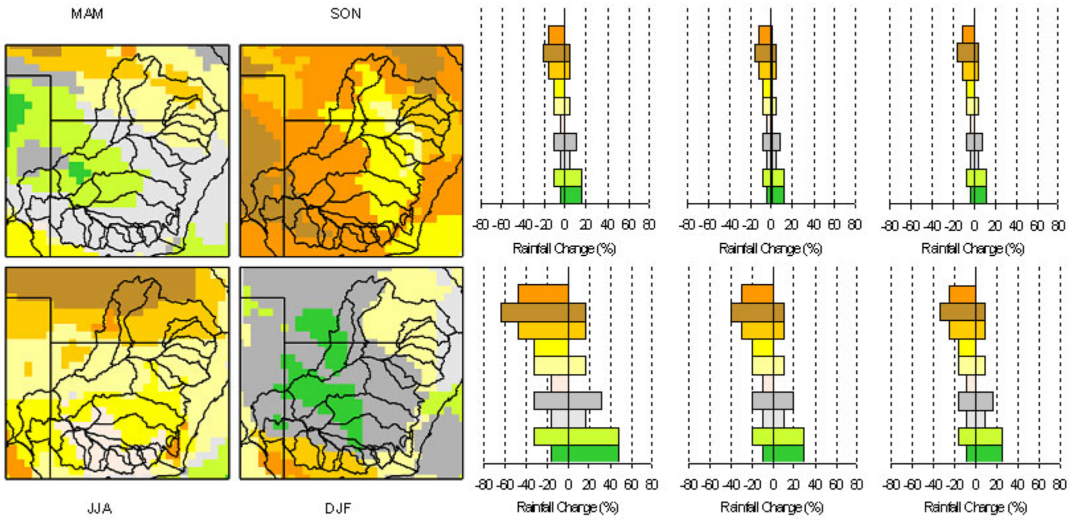
- Australia's major cities and urban complexes – as the majority of Australia's population lives in cities, and these face resource pressures;
- The Murray-Darling Basin – experiencing pressure on its water resources that will exacerbate as the climate changes;
- Australia's iconic biodiversity hotspots – the areas are both vulnerable, and of great economic significance;
- Communities with lower adaptive capacity – remote, indigenous, elderly and economically disadvantaged communities are especially vulnerable to heat waves and extreme weather events.

Figure 2: Projected temperature, rainfall and evaporation changes for the MDB

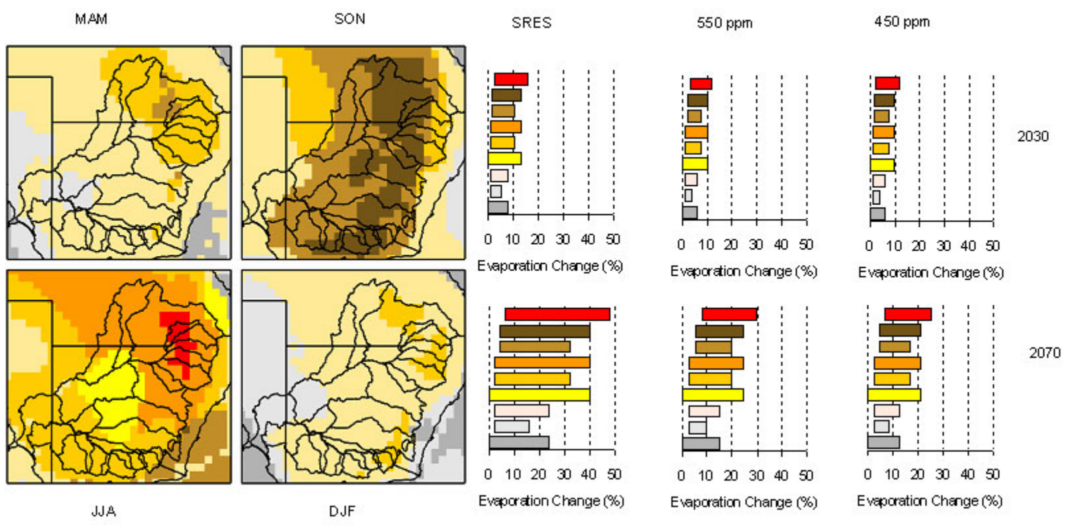
Projected temperature changes for the Murray Darling Basin by 2030 and 2070. Units are in oC.



Projected percentage changes point potential evaporation for the Murray Darling Basin by 2030 and 2070.



Projected percentage changes point potential evaporation for the Murray Darling Basin by 2030 and 2070.

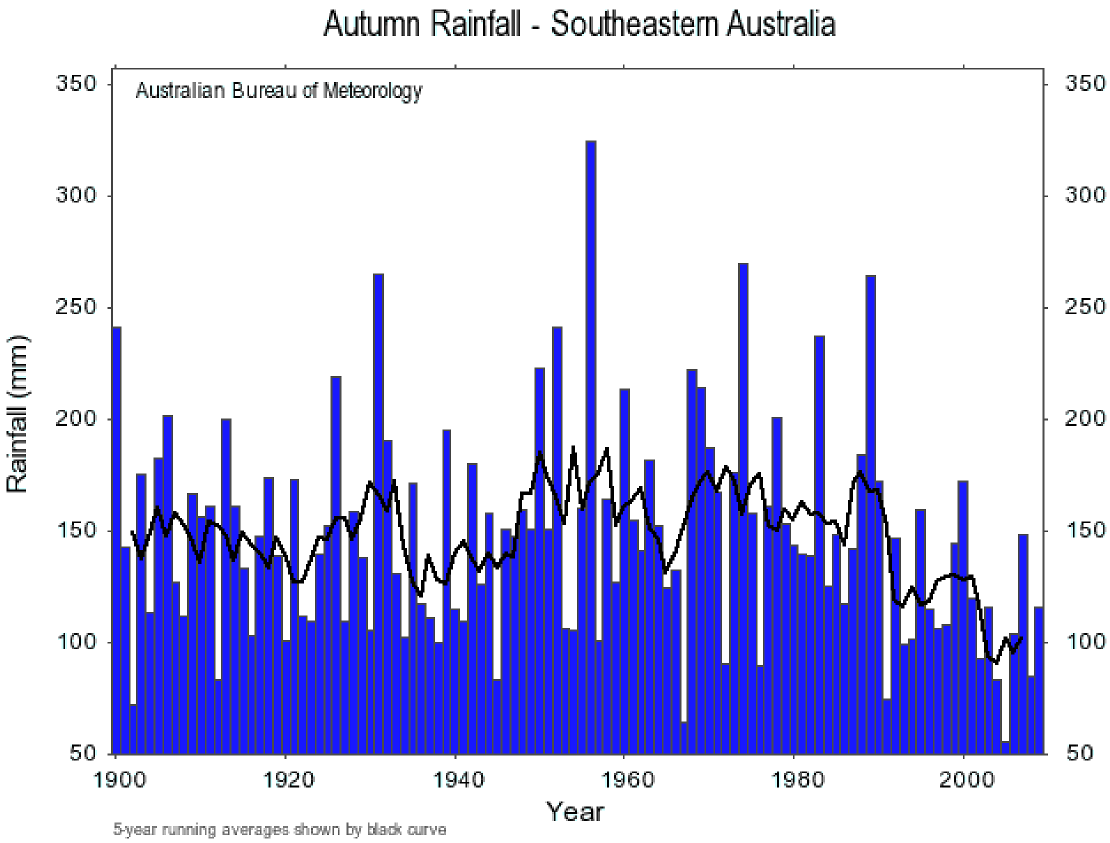


Source: www.csiro.au/news/newsletters/0504_water/story7.htm

The Murray-Darling Basin therefore is seen in many reports as being a prime location for adaptation efforts to be undertaken sooner rather than later, because of the dire consequences that could eventuate due to climate change. The reasons for this are many, but primarily centre on the facts that the Basin is largely dependent on irrigation water for agricultural production and therefore incomes, and that the Basin includes areas that will be greatly affected by lower rainfalls and water runoff as well as the potential impacts on iconic environmental areas and therefore animal and bird species. Given the large population that resides in the Basin, there are likely to be further effects in terms of social impacts if farmers are forced out of production or are faced with lower incomes, and these impacts flow on to the wider community such as local shopping centres, the agricultural transport industry and so on. These social impacts may also include impacts on the indigenous communities if iconic cultural and sacred sites related to the Basin’s rivers and wetlands are destroyed.

Data from the Bureau of Meteorology indicate that the climate changes currently taking place are in line with projections, as shown in Figure 3, below:

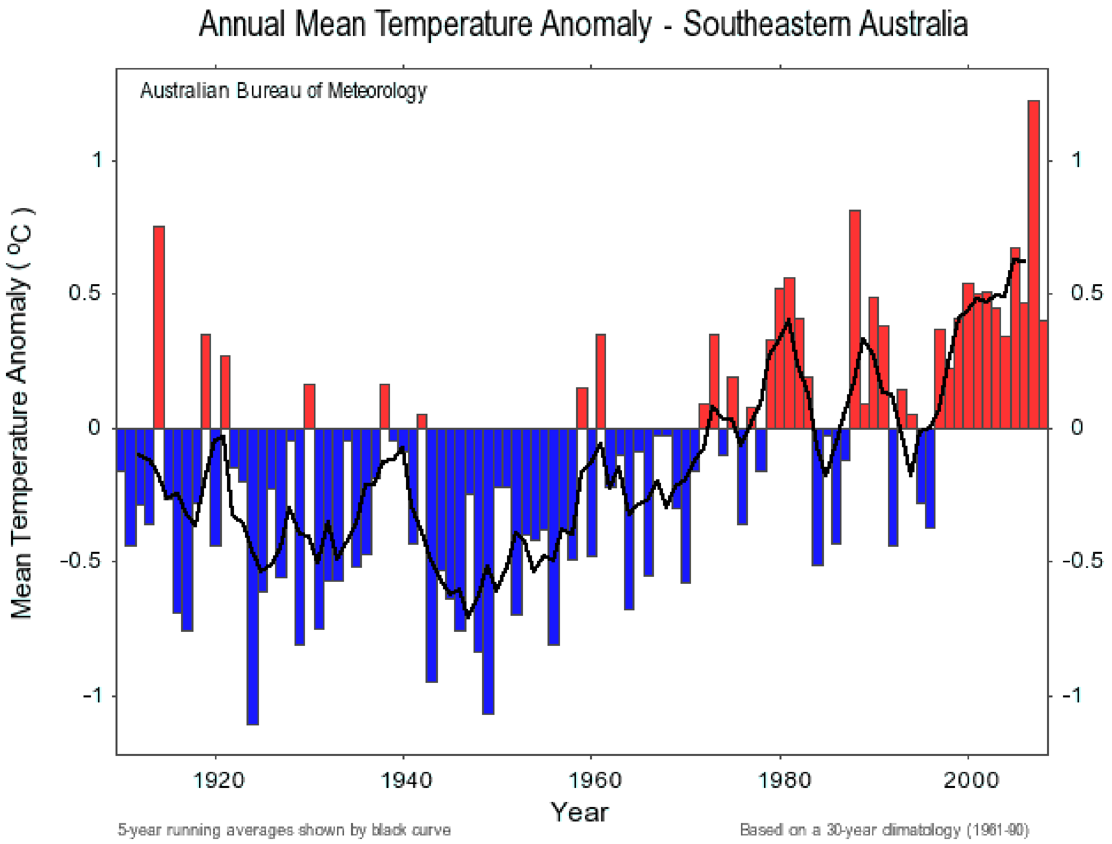
Figure 3: Past and projected autumn rainfall in Southeastern Australia



Source: www.bom.gov.au

Figure 4, below, indicates that there have been significant recent reductions in rainfall in the southern parts of the Basin – almost 30% reduction in autumn rainfall – the worst 5 or 11 years on record. Equivalent winter and spring rainfall figures show this current dry is about the same degree as the 1940's drought. Note however, that the current period is now much hotter than the 40's drought – which is why the impacts are relatively worse.

Figure 4: Annual mean temperature anomaly in Southeastern Australia



Source: www.bom.gov.au

We note that CSIRO's Water for a Healthy Country Flagship is currently preparing a report for the MDBA on the definition of climate scenarios for use in MDBA Basin Plan modelling. This report is expected to be completed in the second half of 2009.

2.3 Agriculture

Given the significance of agriculture in the MDB, a large number of reports have focused on the impacts of climate change on this sector and the likely consequences for agricultural industries as well as the adaptation responses that will be necessary. In their report prepared for the National Climate Change Research Strategy for Primary Industries[1], Stokes *et al.* (2008) provided a table of climate change impacts as well as a list of adaptation issues common across all industries that need to be addressed as

[1] A joint initiative of the Rural Research and Development Corporations, Federal, State and Territory governments, and the CSIRO, managed by Land & Water Australia.

well as those specific to various industries including grains, cotton, rice, sugarcane, viticulture, horticulture, forestry, grazing, intensive livestock and fisheries and aquaculture. Across all industries, the categories that were deemed important to address in terms of climate change adaptation in primary industries were:
Policy, Managing transitions, Accepting Uncertainty, Communication, Climate data and monitoring, R&D and training, Breeding and selection, Model development and application, Seasonal forecasting, Pests, diseases and weeds, Nutrition, Water, Land use/location change and diversification and Salinity.

Specific priorities were also provided in terms of climate change adaptation for individual industries as well as different regions including ten agro-climatic zones across Australia, plus different fisheries and aquaculture regions.

One of the key recommendations was to progress some more adaptation studies which analyse the costs and benefits of implementation of adaptations (including socio-economic aspects as well as potential feedbacks through greenhouse emissions). This R&D needs to be undertaken in a participatory way with industry groups to deal effectively with key concerns. The uncertainties surrounding climate change mean that risk-based approaches need to be taken focusing on a range of plausible impacts that could occur, rather than 'average' projections. Communities could then be given the opportunity to respond to different scenario projections.

Similar conclusions were made in a study by Crimp *et al*. (2008a) which looked at adapting Australian farming systems to climate change. This report, for the Australian Greenhouse Office, explored ways in which broadacre farming systems might become more resilient to climate change, by identifying vulnerabilities and considering adaptation options. The authors looked at three, climatically and agronomically different, Australian regions, and used a participatory approach in the research.

Crop production was modelled across twelve case study farms, in three regions (north-east, south-east and west) using two different climate models and two different global warming scenarios. Data on current conditions at the farms, including crop production, crop and nutrient management, climate risk management, and input and production costs, were also factored into the analyses. The project considered possible climate adaptation options, and evaluated these to tailor them to the individual farming systems. The adaptation options considered included increasing fallowing, reducing planting density, changing crop rotations, selecting shorter season crops, and increasing residue retention.

The conclusions from the project were that the effectiveness of adaptation options depended on a complex range of interacting factors (e.g. soil types, field layout, farm technology in use, likely climate change, and labour availability) and that due to the unique physical, social and economic conditions on each individual farm it is very hard to identify “blanket” adaptation options to suit all farms, or even all farms in a region. The authors found that there was considerable value in combining expert farmer knowledge with biophysical and economic modelling, but that more streamlined approaches need to be developed to effectively evaluate adaptation options.

More specific impacts have been investigated in reports related to climate change impacts on specific crops such as wheat as well as livestock carrying capacity in different areas of Australia.

In assessing the impacts on Australia’s wheat crops (with a large part of Australia’s wheat production coming from the MDB), Crimp *et al*. (2008b) used crop modelling to investigate the impacts of increasing atmospheric CO_2 on Australian wheat cropping yields, across ten existing wheat belt sites. They used a range of scenarios to simulate what might happen at varying CO_2 concentrations, temperature levels and rainfall volumes, finding that while wheat yields were expected to increase if CO_2 concentrations were to increase to 750ppm (and if temperature and rainfall remained the same). However, previous studies (e.g. Howden *et al.* 2003) have suggested that grain protein contents are likely to fall in response to climate and CO_2 changes, resulting in reduced prices unless fertiliser application or pasture rotations were used to reduce the effect. Though these adaptations would themselves potentially increase greenhouse gas emissions.

The report suggested adaptations such as modifying planting windows, varying cultivars, and expanding production areas in response to temperature change. The authors noted that the modelling had not taken into account issues such as potential increases in pest and disease incidence, increasing dryland salinity, soil structural decline and acidification, and that it looked at some but not all of the expected effects of climate change. There is potential for further research to take these issues into account.

Similar uncertainties were associated with the modelling of the impacts of climate change on livestock carrying capacity depending on the assumptions used. McKeon *et al*. (2009) found that climate change has been predicted to impact hard on the world's rangelands and is likely to impact on changes in CO_2, temperature, rainfall, rainfall intensity, solar radiation, humidity, wind and potential evapotranspiration. Measuring Livestock Carrying Capacity (LCC) gives a measure of safe grazing capacity of a pasture to sustainably carry a given amount of livestock or other herbivores. The spatial model called AussieGRASS was used to simulate rangeland forage production. The study found that climate change was likely to affect forage and animal production, and ecosystem function, but with uncertainties involving carbon dioxide effects on forage production, quality, nutrient cycling and competition between vegetation forms and the future role of woody plants including effects of fire, climatic extremes and management of carbon storage. Overall it is likely that climate change will result in large decreases in LCC. Further research is required and the authors suggested these should include field research, remote sensing and modelling. These will be required to address the complex tasks of attribution of current trends and the forecasting of future impacts, because increased CO_2 and increased temperature are likely to have strong but opposing effects on forage production. We need a greater understanding of the risks of enterprise failure with implications for regional communities, potential resource damage and animal welfare as well as human distress including the risk of increased mortalities.

2.4 Biodiversity

Biodiversity conservation is also threatened as the climate changes. Dunlop and Brown (2008), in a report on the implications of climate change for Australia's National Reserve System, found that climate change was likely to have a range of effects on species and ecosystems, including changes in species abundance and distribution, ecosystem processes, and interactions between species. Climate change could also lead to the arrival of new species, native and exotic, in regions, altered fire regimes, altered hydrology and land use change, all of which are challenging to manage and make changes in biodiversity hard to predict. The researchers looked at the possible impacts of climate change in ten agro-climatic zones across Australia, finding that certain zones (“temperate cool-season wet” and “temperate sub-humid”) were likely to experience the most significant changes at the ecosystem level. Both of these climatic zones coincide largely with the Murray-Darling Basin. The authors note that if species are to be conserved it is essential to protect habitat, and that the management of habitat to reduce threats may be particularly important in areas, such as wetlands, where there are especially vulnerable species.

Polglase *et al*. (2008) examined opportunities for different agroforestry systems in Australia, finding that in addition to providing economic benefits and carbon sequestration, there were potential biodiversity benefits in environmental carbon plantings.

2.5 Water

Projections on water availability for the Murray-Darling Basin relate to various sources such as surface water, groundwater and storage water such as farm dams. The overall scenario for the Basin two decades into the future is for droughts to become increasingly common, surface water availability to drop significantly particularly in the south of the Basin, increasing pressures on groundwater use which is expected to approximately double and increases in farm dam storage which would mean a reduction in water runoff into rivers (CSIRO 2008).

A detailed study of New South Wales inland rivers and the impacts of climate change over the next twenty five to fifty years has looked explicitly at the potential adaptation responses to this change in terms of tree planting and agricultural production changes. In a report to the New South Wales Healthy Rivers Commission, Howden (2002) investigated projected impacts of human-induced climate change on NSW inland rivers. It was noted that significant global warming has already occurred over the past fifty years, and as the concentration of greenhouse gases in the atmosphere continues to rise, so will global average and other climatic changes.

Using CSIRO climate change scenarios, the paper provided projections for the NSW inland rivers region: wetter summers and autumns but drier winters and springs, and a temperature rise of 0.5^{o}C to 2.0^{o}C by 2030; and significantly wetter summers, much drier winters and springs, and a temperature rise of 1.3°C to 6.0°C by 2070. The rainfall changes expected by 2030 would reduce river flows, thus impacting on irrigation allocations, water prices, and environmental flows. The higher temperatures and changed flows could also increase algal blooms. These projections have been re-visited in the Murray-Darling Basin Sustainable Yields Project mentioned previously.

In terms of adaptation, land use change may interact with the projected climate changes, and also impact on river flows. For example, widespread tree planting (to meet goals such as carbon sequestration, salinity control and biodiversity conservation) may negatively impact on river flows, particularly in drier climate scenarios. It was suggested in the report that future climate scenarios be taken into account in selecting tree species to plant, so as to use species better suited to warmer situations. The implications of climate change for agriculture in the NSW inland rivers region however are mixed, as some activities may have positive outcomes, whereas others (such as horticulture, and irrigated agriculture) will suffer as temperatures increase and water availability diminishes.

The report noted that, at the time of writing, the potential implications of climate change had not been systematically factored into water resources planning. The use of seasonal forecasting of river flows, in making management decisions, was suggested, as well as the use of Inter-decadal Pacific Oscillation (IPO) data (Howden 2002).

2.6 Economic impacts

The economic impacts of climate change in the MDB will be an important area of research because of the significance of the Basin as an export earner and its contribution to the nation's Gross Domestic Product. Little research has been done so far however on the economic impacts of climate change on the region, and likely flow on effects. Most of the literature in this field has concentrated on the important consequences of climate change on reduced water availability and therefore changes to agricultural production, land use change and also the implications for current water trading policies that operate within the Basin. An early study was conducted looking at economic impacts and potential adaptations due to climate change in the MDB (Beare and Heaney 2002). This study looked at the potential impacts of climate change on the hydrology of the Murray-Darling Basin, and explored some possible adaptation options.

The authors used a simulation model to examine economic and environmental impacts of changes in precipitation and evaporation in the Basin. Using two global warming scenarios (known as SRES A1 and SRES B1) developed by the Intergovernmental Panel on Climate Change (IPCC), they modelled reductions in precipitation and increases in evaporation, and the resultant changes in stream flows, salt concentrations, and economic returns in particular catchments.

The modelling showed declines in river flows and economic returns under the two climate change scenarios. However, there were mixed results for environmental outcomes, with the drier climate projected under the (more extreme) SRES A1 scenario resulting in improved water quality in the Murray River, but more adverse effects on catchment runoff. Two potential adaptation measures – improved water use efficiency, and the existence of an operational water market – were explored through the modelling, and were shown to have the potential to significantly reduce the effects of a drier climate. However, the authors noted that for these adaptations to succeed, well-defined and secure property rights would need to be in place. They also pointed out that water trade can generate both positive and negative downstream benefits to both consumptive users and the environment, and that institutional arrangements need to take these into account.

A more recent study has also looked at similar issues with a related issue of improved irrigation efficiency being addressed. Hafi *et al*. (2009) used a bio-physical economic model to estimate effects of reduced water availability with interactions with salt flows on irrigated agriculture in the Basin. Water trading is also incorporated and can be modified. The results show that a 10 per cent reduction in water availability leads to a 4 per cent decline in aggregate land use and a 9 per cent decline in water use in irrigated agriculture in the MDB. This results in a 4 per cent decrease in GVP for irrigated agriculture and a 2 per cent decrease in aggregate farm income.

The hardest hit regions are in the southern MDB. In the irrigated areas, land moves from lower value dairy, grains, fodder and rice to higher value permanent horticulture, viticulture and vegetable activities. The higher value horticultural, grape and vegetable activities are projected to expand in area, while reducing aggregate water use with the use of deficit irrigation (defined as the application of water below full crop-water requirements (evapotranspiration)). Deficit (or regulated deficit) irrigation is one way of maximizing water use efficiency for higher yields per unit of irrigation water applied: the crop is exposed to a certain level of water stress either during a particular period or throughout the whole growing season. The expectation is that any yield reduction will be insignificant compared with the benefits gained through diverting the saved water to irrigate other crops.

The paper concludes that little is known about the link between irrigation water salinity and crop yield. Also there is little knowledge about the effects of climate change on groundwater recharge and so assumptions had to be made in both cases in the model. Better information would allow better estimates of the potential benefits of institutional adaptation such as removing inter-regional barriers to water trade.

A more general study that reviewed the impacts not only of climate change in terms of less water availability, but also the impact of population growth in Australia over the next two decades, provided a range of options in terms of potential adaptation to such changes. The study by Young *et al*. (2006) looked at the impacts of less water due to climate change and increased populations in Australia and for specific regions using a Computable General Equilibrium model (The Enormous Regional Model, TERM).

This research looked at what would happen in Australia under various assumptions and scenarios of increased population and movements of populations to different regions, decreased water supply, water trading and using new sources of water such as recycling and desalination.

The key messages were as follows:

- If water trading from rural to urban areas is restricted and no major desalination plants, recycling or storm water capture systems are commissioned (and Perth's new desalination plant is not completed), the shadow price of water would rise dramatically – *for the worst affected city, a 10 fold price increase is predicted*;
- but by allowing urban water supply utilities to purchase water from the irrigation industry (as some are already doing) the extent of the increase in the shadow price of water will be much less – *for the worst affected city, a 6 fold price increase is predicted*; and
- by providing access to new sources of water by constructing desalination plants (as Perth and Sydney are doing) or by finding a way to recycle sewage water or

capture and use stormwater at a cost equivalent to desalination changes the story dramatically – *for the worst affected city, only a 3 fold price increase is predicted*.

Their model did provide specific implications for agricultural and other sectors, as well as for specific regions, and could be used to investigate other impacts of reduced water availability on regions in the MDB (Young *et al*. 2006).

Another important recent study has looked beyond the economic issues to suggest that many of the problems that are occurring at present in the MDB and other catchments in Australia could be rectified by concentrating on the institutional arrangements related to water sharing in the regions. Young and McColl (2009) explored the mismatch between current water management regimes in Australia, and "hydrological integrity", or the ways in which water arrives, flows across and flows through land, and can be intercepted. The authors noted that most water allocation regimes were developed when water was not scarce, and that while this is not problematic in times of plenty it leads to mis-entitlement, over-allocation, and environmental problems when water is scarce. This tends to occur when processes that intercept water are omitted from the accounting regime. Many jurisdictions use water sharing plans, developed in consultation with stakeholders, to determine how much water to allocate to users, system maintenance and the environment. The authors state that existing water sharing plans do not deal adequately with over-allocation problems, and that as a result inefficient investment decisions are made and insufficient water is made available to the environment.

The Murray-Darling Basin was used as an example in the paper, and the authors pointed out that activities such as the creation of farm dams and bores, the interception and storage of overland flows, and large-scale plantation forestry all have the potential to intercept large volumes of surface and ground water, and that as such interceptions increase, some other water use must decrease, in order to maintain hydrological integrity.

The authors suggest that new water accounting systems which have hydrological integrity and the ability to adapt to climate changes, be developed. They recommend the development of low cost entitlement and allocation markets, specification of water entitlements as shares, definition of share pools so as to recognise system evaporative losses irrespective of inflows, and the need to allow some water to reach the sea. They also suggest the introduction of practices that require the offset of the adverse impact of un-metered and un-meterable forms of water use, and the management of connected ground and surface water systems as one. They acknowledge, however, that “overcoming the political and institutional difficulties associated with transforming a badly specified water entitlement and allocation system into one that has hydrological integrity remains a significant challenge” (Young and McColl 2009, p. 34).

2.7 Social impacts

To date, little research seems to have been carried out on the potential social and cultural impacts of climate change in the MDB or even the potential adaptation measures that will be necessary to address these impacts. One recent study in this field is the work done by McKeon *et al*. (2009) that suggested climate change impacts on farm production that potentially leads to enterprise failure could have dire consequences on individuals in the form of distress and depression as well as regional communities.

A recent report by Milne *et al*. (2008) presented findings from interviews about the relationship between people’s perceptions of climate change and their preparedness. The respondents were selected from four drought affected communities in the Murray-Darling Basin: two irrigated and two non-irrigated. Three main questions the report emphasizes are how stakeholders perceive drought and climate change, what risk management strategies are agricultural industries implementing to adapt to climate risk, and how governments could assist rural industries and communities in drought and climate change adaptation. Farmers and small businesses expressed a need for clearer, more concise information on climate change and its effects, as they claimed they were receiving conflicting information from multiple sources. Common perceptions about the drought included that it was seen as only one of several significant impacts on rural communities and farming, along with commodity price fluctuations, the strength of the Australian dollar, changes to water access and use, and a skills and labour shortage. There was also uncertainty among those interviewed as to whether the current extended drought was an effect of climate change or whether it was a part of a natural cycle. People’s motivation to respond to climate change was found to come from an immediate sense of danger, a perceived challenge, or a sense of moral responsibility.

The report includes an analysis on the links between personal beliefs on climate change and actions taken, finding that while 59 per cent of those interviewed were open to the idea of climate change, only about half of those were taking any sort of action to adapt. The study suggests that some are not adapting for reasons such as valuing the farming lifestyle, institutional frameworks, incentive structures, limited reserves of capital, and uncertainty about climate change. Several of those interviewed were also concerned that the adaptation strategies for better drought preparedness would not be enough, and that some sort of all-encompassing perspective would be needed for a shift to climate change adaptation. Regarding the role of government, respondents wanted greater support for farmers with small businesses in dealing with the uncertainties of climate change. Some expressed a desire for proactive financial assistance as compared with the current responsive financial assistance. Research suggested included establishing the differences between managing for climate variability and managing for climate change in order to fully understand the implications for developing effective strategies for climate change.

2.8 Concepts in adaptation

The literature on adaptive capacity and adaptation more generally is quite rich, as reviewed in some detail in Preston and Stafford Smith (2009). This literature is increasingly concerned with the nested nature of adaptive capacity – that is, what individuals and businesses can do is greatly dependent on the regional and broader context; but what is possible for policy to create is in turn dependent on the degree to which local communities and individuals are ready to accept the importance of climate change (e.g. Adger *et al*. 2005). Gardner *et al.* (2009) outlined the steps through which most people, businesses and institutions must pass to go from scepticism, to accepting the issue, to accepting it matter for them, to taking responsibility for action (see Figure 1 in Gardner *et al.* 2009). He notes that the specific barriers to progress and related information needs differ as people and organisations move down this path, and that understanding this should greatly affect the combinations of actions that any facilitating body takes.

Many authors emphasise that decisions must be taken in the context of continued (and in some cases, irreducible) uncertainty about the future (e.g. Dessai *et al*. 2008). It is not enough to assume that climate projections will eventually become perfect, both because of limitations to climate science but also, more fundamentally, because the longer term trajectory of greenhouse gases in the atmosphere and consequent climate change depends more on human decision-making than on limits to our scientific understanding. Dessai *et al*. (2008) outline a variety of other decision-making modes which are widely used in society and which manage with risk – such as risk management, robust decision-making, and risk hedging; these need to be increasingly adopted in the face of climate change. These approaches are closely aligned to adaptive decision-making in the face of uncertainty, both in terms of active adaptive management (e.g. reviewed in Chapin *et al*. 2009) and adaptive governance (e.g. reviewed in Nelson *et al*. 2008). Folke *et al*. (2009), for example, emphasise the concept of triple loop learning (see their Figure 5.1), where single loop learning implements efficient incremental change; double loop learning considers whether this learning is occurring within the correct policies or broad management goals; and triple loop learning stops to consider whether even the governance and institutional arrangements within which the policy and management is being implemented are correct. Such thinking is also increasingly linked to ideas about transformative, as opposed to incremental, adaptive change (e.g. Folke *et al*. 2009).

Many of these ideas have been consciously implemented as a 'Strategic Adaptive Management' process in the Kruger National Park region of southern Africa and its related water basins in recent years (e.g. Biggs and Rogers 2003). This includes the explicit design of 'thresholds of potential concern' which essentially embody current conceptual models about how this complex system operates, which are monitored and tested and updated over time in a process designed to rapidly improve the underlying conceptual models and challenge governance where necessary. A brief review of this process is provided in Stafford Smith *et al*. (2009), and could have value for the MDB region. Recent work by Brown *et al*. (in press) may also have relevance for the Basin. The researchers explored NSW land managers' adaptive capacity, and their management of natural resources.

3. EXPERT WORKSHOP

3.1 Introduction

A workshop consisting of experts in the field of climate change and adaptation related to the Murray-Darling Basin was held on 9-10 June 2009. The workshop began with a presentation that summarised the literature review and included future scenarios of climate change impacts on the MDB. This overview then started discussions by two groups on broader areas of work relevant to adaptation with respect to both broader scale issues (catchment level and above) and also local scale issues (sub catchment levels). The second day included an overview of these ideas with further discussions and then finished with groups developing key research areas and questions relevant to climate change adaptation in the Murray-Darling Basin.

The following provides an overview of the workshop and the results; for further detail see Appendix A.

3.2 Participants

Participants at the workshop included: Dr Mark Stafford Smith, CSIRO; Dr Mark Howden, CSIRO; Dr Trevor Booth, CSIRO; Mr Corey Watts, Climate Institute; Mr Neil Ward, MDBA; Mr Jason Alexandra, MDBA; Dr Graham Marshall, UNE; Dr Daniel Connell, ANU; Dr Wendy Proctor, CSIRO; Ms Claire Harris, CSIRO; Ms Karin Hosking, CSIRO; Mr Thomas Carpenter, CSIRO; Dr Mac Kirby, CSIRO; Mrs Dianne Bentley, NSW Natural Resources Commission; Mr Cameron Welsh, SA MDB NRM Board; Ms Jemma Ansell, MDBA and Mr Richard Moxham, MDBA.

3.3 Overview of process

In order to stimulate discussions and to provide some background, a presentation of the literature review presented in Part 1 of this report was provided to the participants. The likely consequences, as collated from the available research on climate change in the MDB, were presented to set the scene and stimulate discussions. Much of the discussion that followed centred on the need to update the information on likely impacts of climate change in the MDB as much of this information was now considered out of date.

In order to come to a final decision on research outcomes, it was agreed that the outcomes that were to be recommended would need to:

- inform good investment by government, without creating barriers;
- inform good investment at multiple scales;
- analyse existing institutional arrangements and transaction costs (including those of intermediaries);
- provide ongoing auditing and a proactive stance in face of uncertainty;
- capitalise on community goodwill with good policy instruments;
- account for the rural/urban schism on acceptance of climate change;
- include institutions that build credibility in government policy, especially in the balance between "self-reliance" and adaptation versus support for change;
- provide relevance to local circumstances in times of change ;
- provide legitimacy;
- encourage leadership in a locally-relevant context; and
- ensure adaptive governance to climate variability.

An overview of issues for consideration in climate research and criteria for measuring success was provided by workshop participants (Table 1).

Table 1: Issues and Criteria for proposed climate research

Issues	***Criteria***
Water quality and quantity Urban water Irrigated agriculture Dryland agriculture Extremes Conservation Social infrastructure	Handling uncertainty Supporting adaptation Barriers Opportunities Transformational incremental change Adoption pathways

Participatory processes that could be used in the research to include stakeholders at different scales were also discussed. Two groups - the first looking at the "basin to global" scale and the second looking at the "below basin or sub catchment" scale - were then formed. The first group considered issues related to governments, international relations, agribusiness and lobby groups, while the second group discussed issues relevant to catchment management bodies, local NGOs, businesses, towns, and individuals. The groups were asked first to consider variations in future scenarios that could include (i) global action, moderate climate change, global institutions, linked markets, etc., or (ii) global inaction, extreme climate change, fragmented institutions, protectionism, etc. They also agreed to consider the issues and criteria listed in Table 1. Issues of significance related to climate change adaptation were then summarised in the two separate groups as follows.

The discussions in the sub-catchment group indicated that climate change would lead to significant changes in crops and other activities; fragmentation of community, conflict; stress, health problems and a sense of "embattlement"; threats to Indigenous values; thresholds at which the water market "fails"; an era of volatility, much of it "indirect"; more flexible and short-term investments; crises, but opportunities to reconstruct; and resource use conflicts – food, carbon, fuel, water, biodiversity, etc.

Detailed discussion on the effects of climate change at the sub-catchment level that will be felt in terms of social, economic and environmental impacts are contained in Table 2.

Table 2: Impacts at the sub-catchment level

Social	
• There is an emotional impact of **losing iconic assets or agricultural land**. People may associate themselves with a given industry or profession, and taking that away from them can be significant.	• We already know that **climate stress is related to suicide levels**. You're under adversity. People can get together under a common cause.
• Under crisis **communities** that were operating harmoniously become **unable to decide what to do**.	• Down in the lower lakes there are a lot of small communities who have been distressed for some time. Within that we have the "us" and "them" as the people who have access to water and those that don't. Those things are alive and well down there.
• Once they come to a realization people may just **go off the land altogether**. It creates a fragmented society.	• This is a lot of **subdividing** as well. In order to survive for another couple of years, they sell a piece of land. City people then come buy the

	land as a sort of vacation spot and don't contribute much to the community or economics in that community.
• With the social too you've got **the impacts of the north are substantially different than the impacts of the south**. Impact in the north will be different for different reasons. (cyclones, etc.).	• For **indigenous** issues and people, there is a risk of wholesale changes to ecosystems.
Economic	
• One thing that's been demonstrated along the river Murray is the **power of the multinational and the investment schemes** and the impacts they have locally	• Economic impacts aren't just high water users. **Low water users** and industries are **affected greatly also.**
• Some ferries won't work anymore because the **water is too shallow**.	• Suffered **huge losses** as far as **tourism** goes in MDB area. The major towns in Australia are tourism towns.
	• Recreation, water quality, and salinity are having **impacts on fishing industries (commercial fishing)**.
Environmental	
• There's the **fire issue** as well. Given climate change and vulnerability to fire, the areas would become unattractive for a number of years	• Water quality and water quantity are connected. Urban water supply, irrigated and dry land agriculture and their future, emergency events management are connected. If big impacts are going to happen, **water quality will be affected greatly also**.
• **Is carbon fixing a win-win?** Timber companies may only target those areas that are nice to grow trees in. This is more on the commercial side of it.	• The problem is if you're thinking of **commercial plantation** you're more **focused on the wet side**.

The discussions from the basin to global group identified the following issues as stemming from climate change: increases in institutional barriers and transaction costs; risks to sunk capital in existing agricultural/social/physical infrastructure; a need to empower and resource CMAs; increasing importance of communication; a need for monitoring and evaluation for flexibility, and transparency in planning; the need to include communities in planning processes; need for better understanding of surface and ground water processes; possible abandonment of prior goals; need for better structural adjustment well; need for independent, regular auditing to build adaptive and enduring institutions; planning for institutional adaptability under different general scenarios; and a need for institutions to facilitate, manage and anticipate volatility, and build flexibility.

Table 3 summarises the social, economic and environmental impacts that were discussed by the other group looking at the basin to global level. They also included a separation in indirect and direct impacts as well as consideration of some of the political impacts.

Table 3: Impacts at the basin to global level

	Indirect Impacts	Direct Impacts
Social	o Socio-demographic change (many young professionals) o Immigration (refugees?) o Some social networks dissolve, other evolve o Loss of confidence o “Siege mentality”? Disorder	o Public health o Animal welfare toll
Economic	o Collapse o Distributed/decentralised o Water/energy supply? o Impacts on world trade o “Opportunistic agriculture” o Food prices rise o Price volatility o Defensive expenditure rises o Carbon boost/biomass boost? Productivity?	o Water quality o New crops and products (e.g. biofuels) o CO_2 fertilisation o “Opportunistic agriculture” o Flexible investing o Conglomeration of businesses o Structural adjustment
Environmental	o Ecological collapse o Abandonment of prior goals (triage) o Loss of ecosystem services (productivity impacts)	o Water quality o More extremes? o Prolonged drought o Sleeper pests, weeds, and diseases
Political	o Governments fall o Scapegoating o Blame o “Survivalism” o Cooperation degenerates o Crisis of federalism o New governance emerges	

General issues relevant at both scales included a need for forecasting, as part of good business practice, and the challenge of developing stable yet adaptable institutions.

The groups noted that the costs of complacency were high (as we have seen in other examples of failed institutional resilience lately, such as the global financial crisis and Victorian bushfires), and that climate change would likely have irreversible effects.

The meeting then discussed emerging research priorities which are integrated in to the next chapter.

4. CONCLUSIONS

Each of the above processes has led to the identification of research priorities. In this section we collate these suggestions, all of which have merit at different levels of detail and priority, and are hence presented for reference. We then synthesise some key early actions that could provide the most value in the near future, given the state of knowledge and activities in the Basin today.

4.1 Suggested research from the literature

A common concern that was noted from the literature review was that there is still much research needed to address successful adaptation strategies in response to climate change in the Murray-Darling Basin. The view emerged that this research should be carried out in a proactive manner, in conjunction with the implementation of associated policies, rather than by taking a reactive approach. From the literature review, the following areas of research were suggested. The following summary by research area is provided based on the recommendations made by papers contained in the literature review.

- Agriculture:
    - More research is needed on climate change impacts on soil behaviour, e.g. dryland salinity, soil structure, acidification; production impacts; economic impacts
    - There should be a ‘horses for courses’ approach – increased farmer/ regional input needed for adaptation assessments
    - New sustainable diversion limits need to be determined for surface and groundwater use
    - More research is needed on the impacts of increased forestry plantations in MDB on runoff as well as increased tree plantings to sequester carbon and salinity
    - More research on livestock carrying capacity because of the uncertainties on production and quality, and
    - More detailed research is required on the irrigation water salinity-crop yield link
- Biodiversity:

    - Greater understanding of the implications of climate change for biodiversity conservation is required, plus
    - An investigation of community attitudes and values about biodiversity linked into the development of pragmatic adaptation options
- Water:
    - The need for potential implication of climate change to be systematically factored into water resources planning with better forecasting of, for example, seasonal river flows
- Economic impacts:
    - Costs and benefits of implementing adaptation and stakeholder input into risks
    - Well defined property rights and institutional arrangements need to be researched and in place
    - Institutional adaptations such as removing inter-regional barriers to water trade
- Social impacts:
    - Impacts on communities - resource damage – animal welfare – human distress
    - More research on public perception and understanding of climate change
    - More public communication to promote adaptation.

4.2 Suggested research from the expert workshop

In summary, the workshop outputs placed a great deal of emphasis on the need for more social and economic research, with particular attention focused on institutional analyses and recommendations for improvements in these. They also emphasised the need for participatory processes to take into account the needs of indigenous people, ethnic groups, different industry groups, and regional issues, as well as various stakeholders and individuals.

There was agreement too on the urgency of the need for decision-linked research, given the potential dire consequences of a lack of adaptation, or adaptation undertaken too late. However, the urgency of this need means that action cannot await endless research, and must be partially fulfilled by adaptive management approaches which can *learn through doing*, in collaboration with research helping to devise the best experiments, and to monitor and analyse the outcomes. Some proposed first steps in this process were agreed upon.

Research needs:

- Socioeconomic analysis of structural adjustment under climate change, etc. (including transformation, multiple scales in MDB, linked outside). What would the benefits of effective incremental adaptation of agriculture, forestry and urban activities in the MDB be? Look at the existing industries, explore adaptations, evaluate these adaptations against a range of sustainability, effectiveness efficiency and equity criteria, look at a first cut at feasibility and assess the costs and benefits.
- Research on institutional design including adaptation/transformation/ resilience
    - potential volatility and need for flexibility
    - identifying the characteristics of self-regenerating institutions, those which have longevity and how they respond to change as well as those which don't and what constrains them
    - comprehensive audit of existing institutional arrangements in the MDB against what is needed to create a strong robust group of institutions able to respond effectively in real time to the challenges we now face in the southern basin. A process could be modelled on the National Competition Policy reform process which undertook a comprehensive review of institutions, law, policy and regulations to improve Australia's level of economic competition.
- Look at the impact of carbon sequestration schemes encouraging forest plantations (e.g. Polglase *et al*. 2008) – opportunities, trade-offs, competition, as well as implications of competition for land use for fuel, food and so on
    - Include understanding of landscape characteristics and function
    - Mapping of these biophysical characteristics
    - Given that there could be substantial policy changes in the MDB, what are the opportunities arising from climate change? Look at different scenarios of change (climate, institutions) and identify key opportunities arising as well as barriers to implementation etc.

- Values analysis – limits to incremental adaptation and the need for adaptive management – are the targets and processes that we are aiming for being realised and if not then these need to be reset
- Research on scenario/foresighting process (including promoting cultural change; other global drivers)
- Analysis to redefining “targets” (water, land use, etc.) and adaptive processes for this under ongoing change
- Adaptive capacity and vulnerability assessments – integrating different dimensions and issues – looking to build on existing processes where possible
- Research on environmental governance including:
  - Exploring adaptive governance bringing together different levels of the governance system (e.g., higher-level arrangements - e.g., federal and state government and the MDBA - and lower-level arrangements - e.g., regional, sub-regional and local)
  - Concepts and principles such as subsidiarity, polycentricity etc could be framed as hypotheses to be tested in answering the question/s.

It was also agreed that the above research should take into account:

- Issues to support legitimacy, etc.
- Analysis of how markets operate including a thorough study on water markets and market behaviour to assess whether they actually achieve the desired outcomes
- Recognition of the complexity and diversity of “communities”, e.g. indigenous and ethnic groups.
- Institutional mapping back “up” from issue
- Trying to work across industry, regional and disciplinary ‘silos’
- Build constituency for topic (e.g. governance).

Potential next steps could include:

1. Coherent overview report
2. Develop a program of activities designed to accelerate the cultural changes needed to live in a drier MDB with a more varied climate. The current reform program is basically focussed on management and technological innovation. Both are needed but they will not go far unless we have a better

educated public and more appropriate expectations and values regarding adaptation.

- Development of conceptual framework and elements of adapting to changing, variable climate
- Develop integrated future scenarios
- A workshop that brought together people with a wide range of expertise to consider the following three questions:-
    - What would the MDB look like if a 50% reduction in flows becomes the new norm?
    - What might be a sensible policy response (taking no notice of state borders)?
    - What sort of institutional arrangements would be most suited to managing these conditions?
- Identify things that can be progressed “no regrets” and do soon

3. Explore alliances
    - With DAFF re: incremental adaptation in agriculture
    - With CSIRO in transformational adaptation
    - Circulate report to NCCARF
        - Water
        - Primary industries, networks
        - Socio-economic
    - Engage with CMAs with caution, e.g. seeking partnership on approach to climate adaptation
        - Draw on those with existing thinking, but engage with others too
4. Other actions
    - Look for multi-agent steering group?
    - Don’t let the program be an excuse for inaction
    - Assembling the body of evidence for need to act.

4.3 Discussion

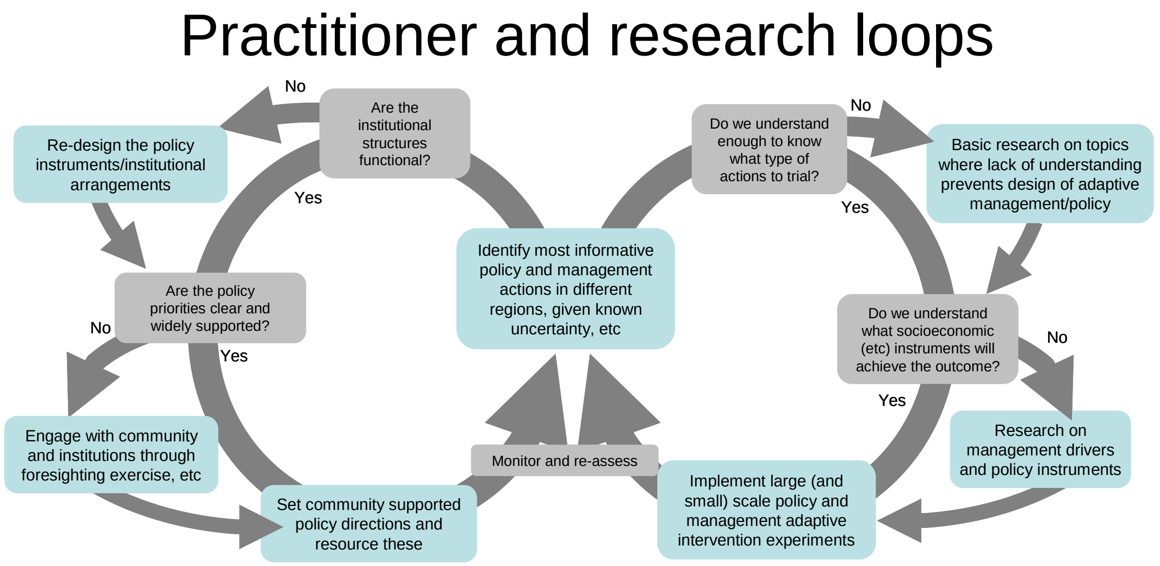
Behind the research suggestions above lie a few key issues:

- The future will involve significant (possibly currently underestimated) change for the MDB, yet action to improve the ability of the Basin and its institutions to deal with these changes cannot wait for perfect knowledge
- Some of the changes needed are likely to involve transformative (rather than incremental) adaptation, and this requires a longer planning lead time and a more profound re-visioning of the future for the region than is currently occurring
- The current institutions and institutional reform process, whilst important, is not progressing fast enough to engage with these challenges, although faster progress cannot be imposed without support from the general Basin community
- Under circumstances of uncertainty and complexity, yet urgency, different styles of decision-making, adaptive learning and community engagement are required compared to historic perceptions of a relatively stable climate and simple development trajectories.

The workshop discussed the nature of the linkages between research and community/policy action in the context of these issues. There is clearly some action-oriented research that is needed to inform policy and management. There is also clearly a major process of community engagement in visioning a different future which needs beginning. In Figure 5 below we attempt to summarise some of the activities that need to occur in each of these domains, as well as the broad links between them

However, it is also worth reflecting on the experience of the Kruger Park area water basin towards managing similar issues at multiple scales (Biggs and Rogers 2003, where they have developed a formal process of 'triple loop learning' aimed at providing day to day practical management approaches within a monitoring and decision-making framework which allows those approaches to be rapidly and formally updated as new information comes to light.

Figure 5: Schematic of how adaptive learning loops in practitioner and research domains ideally intersect for an efficient partnership



Given these points, this report suggests the following three priority actions for the MDBA to consider developing in parallel:

1. **Foresighting Basin futures**: this would involve establishing the processes and information content for engaging the Basin community (local and external) in recognising and envisioning a different future for the Basin. Specific actions would include:
   - developing some integrated scenarios for the future to use in engagement
   - an initial workshop to explore the implications of an extreme scenario (such as a permanent 50% reduction in flows), and then
   - a community-based programme of engagement
2. **Exploring adaptive institutions**: recognising that a major part of a good adaptive response will include change towards institutions more able to cope adaptively with uncertainty, this will involve establishing the groundwork for such a response. Specific actions would include:
   - engagement with the South African Kruger experience using thresholds of potential concern, perhaps by inviting its practitioners to contribute to an MDB workshop

- commissioned thinking about institutional design in the MDB aimed at definite proposals for changing relationships between local, regional and state/national governance processes.

3. **Assessing adaptive capacity and vulnerability**: this will develop a better understanding of the social, physical, financial, environmental and human assets that will underpin the capacity of individuals and communities to respond to climate change in the context of other changes. This would allow targeted policies and programs to cost-effectively build adaptive capacity. Specific actions would include:
   - supporting self-assessment of local adaptive capacity at a spatial resolution that allows understanding of how it varies from place to place along with the climate, environmental and socio-economic stressors that give rise to vulnerability.

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Appendix – Notes from expert workshop

An overview of issues for consideration in climate research and criteria for measuring success was provided by workshop participants (Table A1).

Table A1: Issues and Criteria for proposed climate research

Issues	Criteria
Water quality and quantity	Handling uncertainty
Urban water	Supporting adaptation
Irrigated agriculture	Barriers
Dryland agriculture	Opportunities
Extremes	Transformational incremental change
Conservation	Adoption pathways
Social infrastructure	

Consideration of participatory processes that could be used in the research to include stakeholders at different scales was also discussed. Two groups - the first from the Basin to the Global scale and the second at the below Basin or sub catchment scale - were then defined. The groups consisted of:

Basin to global (setting context/policy):

- Governments
- International
- Agribusiness
- Lobby Groups

Sub-catchment (implementing management/livelihoods):

- CMAs
- Local NGOs
- Businesses
- Towns
- Individuals

Participants were there broken into the two groups to reflect these two different scales and to address issues relevant to these scales. They were asked first to consider variations in future scenarios that could include:

- Global action, moderate climate change, global institutions, linked markets, etc. and
- Global inaction, extreme climate change, fragmented institutions, protectionism, etc.

They also agreed to consider various related issues such as:

- Water quality and quantity
- Urban water
- Irrigated and dryland agriculture
- Conservation
- Social infrastructure

Criteria suggestions were also agreed upon that could be used to measure the success or otherwise of an adaption strategy such as:

- Resilience to uncertainty
- Transformational versus incremental success
- Other opportunities that may result from the changes
- Adoption pathways

Issues of significance related to climate change adaptation were then summarised in the two separate groups as follows.

Overview of discussions from the sub-catchment group:

- Significant changes in crops and other activities
- Fragmentation of community, conflict
- Stress/health/"embattlement"
- Indigenous values
- Thresholds at which water market "fails"
- Era of volatility, much "indirect"
- More flexible/short-term investment
- Crises, but opportunities to reconstruct
- Resource use conflicts – food, carbon, fuel, water, biodiversity, etc.

Detailed discussion on the effects of climate change at the sub catchment level that will be felt in terms of social, economic and environmental impacts are contained in Table A2.

Table A2: Impacts at the sub-catchment level

Social	
• There is an emotional impact of **losing iconic assets or agricultural land**. People may associate themselves with a given industry or profession, and taking that away from them can be significant.	• We already know that **climate stress is related to suicide levels**. You're under adversity. People can get together under a common cause.
• Under crisis **communities** that are going harmonious become **unable to decide what to do**.	• Down in the lower lakes there are a lot of small communities who have been distressed some time. Within that we have the "us" and "them" as the people who have access to water and those that don't. Those things are alive and well down there.
• Once they come to a realization people may just **go off the land altogether**. It creates a fragmented society.	• This is a lot of **subdividing** as well. In order to survive for another couple of years, they sell a piece of land. City people then come buy the land as a sort of vacation spot and don't contribute much to the community or economics in that community.
• With the social too you've got **the impacts of the north are substantially different than the impacts of the south**. Impact in the north will be different for different reasons. (cyclones, etc.).	• For **indigenous**, there is a risk of whole changes to ecosystems.
Economic	
• I think one thing that's been demonstrated along the river Murray is the **power of the multinational and the investment schemes** and the impacts they have locally	• Economic impacts aren't just high water users. **Low water users** and industries are **affected greatly also.**
• Some ferries won't work anymore because the **water is too shallow**.	• Suffered **huge losses** as far as **tourism** goes in MDB area. The major towns in Australia are tourism towns.
	• On recreation, water quality, salinity, are having **impacts on fishing industries (commercial fishing)**.
Environmental	
• There's the **fire issue** as well. Given climate change and vulnerability to fire, the areas would become unattractive for a number of years	• Water quality and water quantity are connected. Urban water supply, irrigated and dry land agriculture and their future, emergency events management are connected. If big impacts are going to happen, **water quality**

	will be affected greatly also.
• **Is carbon fixing a win-win?** Timber companies may only target those areas that are nice to grow trees in. This is more on the commercial side of it.	• The problem is if you're thinking of **commercial plantation** you're more **focused on the wet side**.

Overview of discussions from the Basin to Global group:

- Institutional barriers and transaction costs
- Sunk capital in existing agricultural/social/physical infrastructure
- Empower and resource CMAs
- Importance of communication
- M&E for flexibility, transparency in planning
- Include community in planning processes
- Better surface/ground water understanding
- "Triage"? Abandonment of prior goals
- Discussion around how to do structural adjustment well
- Independent regular auditing for adaptive/enduring institutions
- Trust in institutions for times of change
- Foresighting institutional adaptability under different general scenarios
- How far will incremental adaptation from now take you?
- Understand (or plan) more/less reliable areas
- Institutions to facilitate, manage, anticipate volatility, flexibility

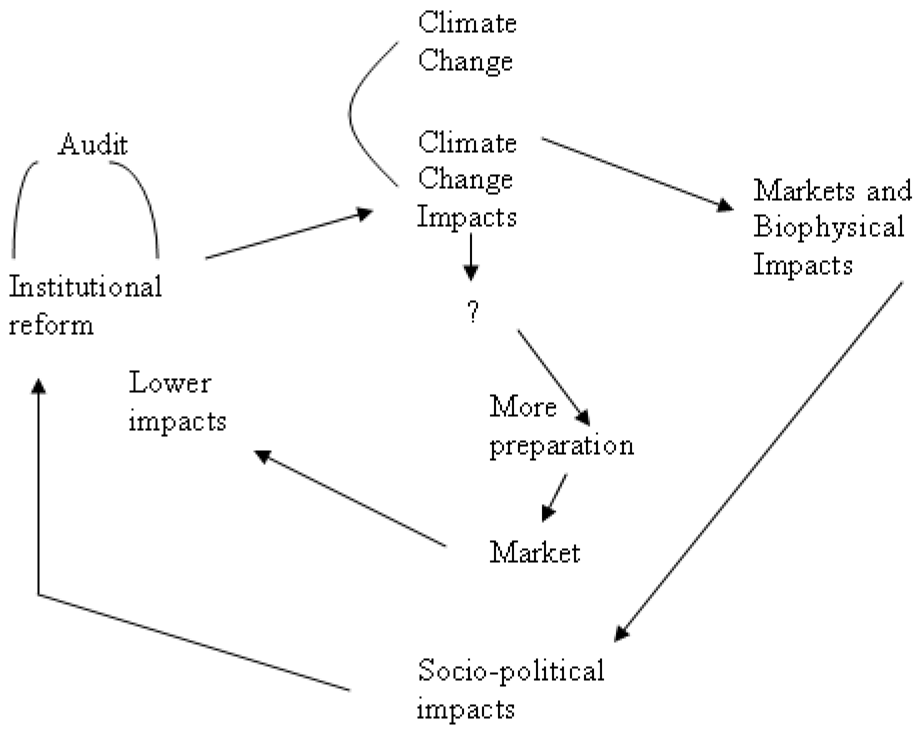
Table A3 gives a summary of the social, economic and environmental impacts that were discussed by the other group looking at the basin to global level. They also included a separation in indirect and direct impacts as well as consideration of some of the political impacts.

Table A3: Impacts at the basin to global level

	Indirect Impacts	Direct Impacts
Social	o Socio-demographic change (lot more young professionals) o Immigration (refugees?) o Some social networks dissolve, other evolve o Loss of confidence o "Siege mentality"? Disorder	o Public health o Animal welfare toll
Economic	o Collapse o Distributed/decentralised o Water/energy supply? o Impacts on world trade	o Water quality o New crops and products (e.g. biofuels) o CO_2 fertilisation

	o “Opportunistic agriculture” o Food prices rise o Price volatility o Defensive expenditure rises o Carbon boost/biomass boost? Productivity?	o “Opportunistic agriculture” o Flexible investing o Conglomeration of businesses o Structural adjustment
Environmental	o Ecological collapse o Abandonment of prior goals (triage) o Loss of ecosystem services (productivity impacts)	o Water quality o More extremes? o Prolonged drought o Sleeper pests, weeds, and diseases
Political	o Governments fall o Scapegoating o Blame o “Survivalism” o Cooperation degenerates o Crisis of federalism o New governance emerges	

Figure A1: Scenarios of change – a diagrammatic representation of what might be happening:



General issues relevant at both scales included:

- Forecasting as part of good business practice
- Stable yet adaptable institutions – challenge
- Culpable to ignore:
  - Consequences of irreversible changes
  - Demonstrated benefit cost values

  - Capturing opportunities
  - Avoiding conflict with mitigation
- Need for some demonstrations of value – e.g. centralised and forward planning of risk in water allocations
- Costs of complacency – cf. global financial crisis and failed institutional resilience; bushfires.

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