MURRAY**FUTURES**

Lower Lakes & Coorong Recovery

Securing the Future

A Long-Term Plan for the Coorong, Lower Lakes and Murray Mouth

Draft for public comment

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Government of South Australia

WATER FOR GOOD

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FOREWORD

The crisis that has developed around the Coorong, Lower Lakes and Murray Mouth is unprecedented. Yet, it had been predicted for many years by reputable scientists and had also been predicted by Ngarrindjeri leaders. Everyone should be distressed by the state of the Murray-Darling Basin, and the Coorong and Lower Lakes in particular, but no one should be surprised.

In the 1860s in South Australia, the Surveyor-General, George Goyder, formulated what became known as Goyder's Line, the delineation between those parts of the state to the south of the line that were suitable for agricultural pursuits and those to the north that were not. However, there was a strong belief by many within the expanding settler communities that rain would follow the plough and Goyder's views were ridiculed and dismissed. If land was opened up for agricultural development, then the climatic conditions to ensure the success of those developments would surely follow.

So it was that agricultural development expanded through the Willochra Plains and west of the Flinders Ranges. And for a few years it did rain. Then the rains stopped. The place names and the ruins are still there. Only 50 kilometres south of Marree, which is at one end of the Birdsville Track, are the ruins of a small settlement called Farina. Yes, people really did grow crops at Farina for a few years before the desert reclaimed its own. This failed agricultural expansion was not really the result of greed or unbounded optimism. It was essentially caused by settler communities not understanding the true nature of Australia. Similar stories abound in all of the Australian states.

The over development of the Murray-Darling Basin has also been an example of the triumph of hope over experience. The extreme variability of climate and rainfall across much of Australia was well known. The history of drought across the Murray-Darling Basin was well known. The catastrophic conditions in the Coorong and Lower Lakes may be recent, but the ecological character had been in decline for decades.

As a nation we have again failed to understand the true nature of Australia, or if we did understand it, we chose to ignore it. Now we are paying the price.

This plan is about what is achievable to secure a future for the Coorong, Lower Lakes and Murray Mouth in the light of the current circumstances and predicted future climate change. We must ensure that, this time, Australians really do come to terms with the land and waters on which they live and depend.

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EXECUTIVE SUMMARY

The current crisis in the Coorong Lower Lakes and Murray Mouth threatens the key values of the site.

Substantially lower flows in the last four years than have been historically the case have led to the water level in both lakes falling below sea level for the first time and the wetlands fringing the lakes are dry and no longer connected to the main water bodies. Vast areas of the lakebed have been exposed to air and have acidified. Inflows are now so low that there has not been a flushing of salt through the barrages to the sea for some years, or a freshening of the Coorong waters. The last four years of salt carried down by the River Murray from all states in the Murray-Darling Basin are currently sitting in Lake Alexandrina and cannot be discharged from the Basin. The failure to discharge the salt is a problem which is owned by all of the states in the Murray-Darling Basin.

Science has guided our understanding of these problems and the possible solutions. In the development of the plan, a major acid sulfate soil research project was undertaken, involving the key universities and research bodies from around Australia with expertise in this area. We undertook bioremediation trials involving over 50 square kilometres of seeding of exposed soils, experimented with acid sulfate mitigation and limestone dosing of over 3000 tonnes in the Goolwa Channel, drew from the extensive science already undertaken on the site and developed numerous models of ecosystem processes.

Emerging from this work, the key strategy for this site for the future is to return adequate supplies of freshwater. No other strategy provides a long-term future which preserves to any extent the values of the site. The Murray-Darling Basin planning process currently being undertaken by the Murray Darling Basin Authority is the key mechanism in delivering on that strategy in the long-term. Its target is to ensure that the amount of water diverted from the Basin should not compromise its key environmental assets, key ecosystem functions, the productive base or key environmental outcomes of the water resource.

There are other ways of bringing freshwater flows to the site which will be pursued: through the Commonwealth Environmental Water Holder, the River Murray Environmental Manager and its environmental watering plan, the Living Murray initiative, and through the South Australian Government's development of an environmental water reserve. All of these, however, only supplement rather than replace the need for the Murray-Darling Basin plan to ensure that diversions of water are set at sustainable limits.

Essentially, the Coorong Lower Lakes and Murray Mouth represent a basin-wide problem. A basin-wide solution is required.

Freshwater inflows may take some time to return and will at times depend upon unpredictable climatic conditions. The management challenge is thus how to use the freshwater which is available in the interim to best effect, while mitigating the worst effects of the crisis on the site and preparing the site to adapt to a more uncertain future under changing climatic conditions.

An adaptive approach to management is proposed. This will continue to use the best available science in developing management actions, and monitoring closely the effect of those actions through the crisis period and a future of climatic uncertainty.

The actions proposed to be undertaken at any one time will vary depending on the climatic circumstances and the lessons learnt from previous actions. The end goal of this approach to management is to build ecological resilience into the site so that it can maintain its values no matter what climatic conditions are faced in future.

Our goal is to secure a future for the Coorong, Lower Lakes and Murray Mouth as a healthy, productive and resilient wetland system that maintains its international importance. Achieving this will directly support the economic, cultural and social wellbeing of the regional communities. This will be based on a return of adequate freshwater end-of-system flows, which the best available information indicates is realistic, and can be achieved through the Basin Plan process. This is essential for any improvement in the health of the site: there is no substitute for freshwater. *(See Section 7 for more detail. For details on the actions to be undertaken see Sections 8, 9 and 10.*

Envisaged in the goal are:

- freshwater Lakes Alexandrina and Albert operated at variable lake levels
- the Murray Mouth generally kept open by end-of-system flows
- a return of salinity gradients to the Coorong that are close to historic gradients
- a dynamic estuarine zone
- the return of amenity for local residents and their communities
- adequate flows of suitable quality water to promote a living Ngarrindjeri cultural life
- a prosperous tourism industry supporting the many businesses associated with it
- the continuation of productive and profitable agricultural industries.

This goal will be met through a combination of mitigation actions - which reduce the rate of degradation, remediate damaged areas, prevent permanent collapse and maintain the ecosystem until conditions improve - and adaptation actions which aim to build a resilient ecology that can adapt and respond to a drier future climate. (*See sections 7 and 10 of this document for more detail*).

Priority mitigation actions identified for the next five years include:

- maintaining an open Murray Mouth
- pumping hypersaline water from the South Lagoon of the Coorong to lower its salinity
- limestone dosing for acid sulfate soil management
- installation of sub-surface barriers to increase soil moisture levels in areas of high acid sulfate soil risk
- the management of water levels in Lake Albert.

Priority mitigation and adaptation actions include:

- vegetation plantings
- the construction of an artificial wetland at Meningie
- protecting critical environmental assets
- improving connectivity between the two Lagoons of the Coorong
- the translocation of the key aquatic plant species *Ruppia tuberosa* and *Ruppia megacarpa*, once salinity within the Coorong is appropriate.

Priority adaptation actions that have been identified include:

- the diversion of water from the South-East of South Australia to the South Lagoon of the Coorong and
- the construction and installation of fishways and the management of the lakes at variable levels.

A range of mitigation actions has already been implemented, including dredging the Murray Mouth, limestone application for acid sulfate soil management, vegetation and bioremediation activities, ex-situ conservation of fish species, and delivery of environmental water. The construction of a bund between Lakes Alexandrina and Albert, and the Goolwa Channel Water Level Management Project both manage water levels to prevent major acidification risks.

Adaptation actions already implemented include the installation of pipelines to provide an alternative source of freshwater other than the Lakes, research activities, investigating end-of-system flows, and the re-establishment of some freshwater flows to the South Lagoon of the Coorong from the South East (*see section 8 of this document for more detail).*

Research is also currently underway to inform an Environmental Impact Statement into the potential introduction of a minimum amount of seawater to avert acidification. Pending the final conclusions of this research project, the introduction of seawater is seen as a last resort short-term response. The proposed adaptive approach to management will use the best available science to determine whether this response may be appropriate within a longer term context.

Governance for the site will ensure that there is clear and transparent accountability for the delivery of the project, will build on the relationships already established with the Ngarrindjeri – its Traditional Owners – the community, and with all three levels of Government which have a responsibility for its future.

While this plan is a long-term plan to secure the future of the site, the document also looks specifically at the next five years. This period is crucial to mitigate the worst of the crisis and to achieve a freshwater outlook for the site.

Introduction

The Coorong, Lower Lakes and Murray Mouth (CLLMM) have been recognised internationally as one of Australia's most significant wetlands. They are of central significance to the life and culture of the Ngarrindjeri people, who continue to live on their traditional country. They are also the basis for a local economy that has supported healthy communities. Australia has a special responsibility to care for this area through its international commitments.

Located at the terminus of Australia's largest river system, the CLLMM is acutely sensitive to both climate and water management throughout the entire Murray-Darling Basin. The health of the CLLMM provides a touchstone for Australia's commitment to environmental protection and the equitable distribution of water resources.

Years of over-allocation of the water resources of the Murray-Darling Basin combined with the recent severe drought across most of the catchment have led to severe impacts upon the CLLMM. Water levels in the Lower Lakes are now well below sea level, as the amount of water entering the lakes in recent years has not matched evaporative losses.

There is no desirable future for the Lower Lakes if water levels continue to be below sea level for an extended period of time. Nothing can compensate for a lack of adequate freshwater flows through the Murray Mouth. As the water levels have fallen, serious land and water management issues have progressively emerged. Wetlands have dried out, previously submerged sulfidic soils have been exposed, and different elements of the system have become disconnected (see Appendix 3). With water not having flowed through the barrages for several years, salts and pollutants are not being flushed from the system and water quality is continuing to decline. Lake Alexandrina has become a sink, collecting salt, sediment and dissolved materials from all states across the entire Murray-Darling Basin.

The Coorong as we have known it has lost much of its productivity. Conditions within this Ramsar listed Wetland of International Importance are now unsuitable for much of the wildlife it has previously supported. It no longer supports the full range of economic activities that sustained the surrounding communities, nor the cultural life of the Ngarrindjeri people who have always been able to rely on its health and productivity.

Water levels have not fallen to this extremely low level since sea levels rose some 7,000 years ago. There is therefore no precedent for dealing with environmental impacts on this scale.

Predicted changing climatic conditions are expected to result in changes in freshwater availability and sea level rise, but the precise timing and impacts of these changes are uncertain.

The ecosystem services that underpin the regional economic, cultural and social values derived from the site depend on a healthy and functioning wetland environment.

Our approach to management, while founded in science and interpreted with local knowledge, will also be responsive to cultural and community guidance and oversight. This includes looking at new forms of governance, such as the developing relationship with the new Ngarrindjeri Regional Authority.

Purpose and context

The purpose of this Plan is to provide a clear direction for the future management of the CLLMM.

Over the next 20 years, this Long-Term Plan for the region will work towards keeping freshwater in the CLLMM system, which will also support a desirable salinity gradient in the Coorong, and when necessary implementing complementary management actions.

While this is a long-term plan, it also proposes a number of short-term actions and interventions, because without these our longer term goals for the CLLMM will not be achieved.

This document outlines the priority actions for funding in the next five years, through partnership arrangements between the Australian Government's *Water for the Future* program and the South Australian Government's Murray Futures program. However, given the significant uncertainties we face because of the continuing extremely low end of system flows, all proposed actions are being taken with a view to maximising potential future options.

The current crisis has damaged the ecosystem, social fabric and economy of the region. For some values this damage may be irreparable. However not all is lost. In fact most of the environmental, social and economic values of this wetland of international importance can be nurtured back to health, with enough commitment.

The Australian Government has implemented a number of measures that are associated with the current actions of this program. As part of the Australian Government's *Water for the Future* strategy, the Australian Government has invested substantially in buying back water for the Murray-Darling Basin, implemented a program for Sustainable Rural Water Use and Infrastructure, as well as many other measures to protect and restore environmental assets including funding of $200 million to secure a long-term future for this site.

This plan does not exist in isolation. A wide range of legislation, international agreements and policies influence the CLLMM area and its management. These are listed and explained in Appendix 1. Two particularly important pieces of legislation are the Australian Government's *Environment Protection and Biodiversity Conservation Act 1999*, which provides legal protection for wetlands of international importance, and the *Water Act 2007*, which both implements the process for developing a Basin Plan and sets out the arrangements for sharing water between New South Wales, South Australia and Victoria.

The only way that the health of the CLLMM can be recovered to any degree is by adequate inflows of freshwater from the River Murray. All other management interventions aim simply to minimise further damage and to facilitate recovery when adequate flows return. The scope of this Plan does not cover all of the necessary changes to water management throughout the Murray-Darling Basin that would enable adequate River Murray flows to be restored to the CLLMM. That issue is to be addressed elsewhere. This Plan primarily details actions and strategies that will be undertaken at the site. The intensity of management intervention required will depend upon River Murray inflows over the next few years and beyond, as addressed in the adaptive management section of this document. For this reason, this Plan proposes a different suite of management interventions that will be undertaken to varying degrees under different inflow scenarios.

The development of this Plan has been supported financially by the Australian Government. It has called on the expertise of scientists, academics and research establishments. A considerable amount of research has been carried out in the preparation of this Plan to further our understanding of the CLLMM site and the factors affecting it, and is listed in the References section of this document.

Furthermore, feasibility assessments have been undertaken on the range of management actions proposed in this Plan. These are referred to in Section 10 of this document.

An essential component of the development of this Plan has been consultation with the community. This has been progressed through a Long-Term Plan Reference Group, extensive discussions with the Ngarrindjeri Regional Authority, and through many meetings with interested people, especially within the communities surrounding the Lower Lakes. Many individuals and organisation have provided helpful comments and suggestions through the feedback processes employed in the development of this Plan.

If you want to know more than is in this document

Just as this Long-Term Plan exists within a broader legal and policy framework, it also exists among a wide range of supporting and complementary documents. It is not feasible to repeat in this Plan all the detail that can be found in these documents, which are often of a specialist or technical nature. However, some people may wish to further their knowledge or interest beyond what is in this Plan.

If you want to know more about a specific matter, the reference list at the end of this Plan has an extensive collection of source reports and articles that you may wish to consult. There is also a wide range of material available online, and the Department for Environment and Heritage has provided links to informative reading at www.environment.sa.gov.au/cllmm/reference-publications.html.

List of acronyms and symbols

AHD	Australian Height Datum
CEWH	Commonwealth Environmental Water Holder
CLLAMMecology	Coorong, Lower Lakes and Murray Mouth ecology
CLLMM	Coorong, Lower Lakes and Murray Mouth
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEH	Department for Environment and Heritage
DEWHA	Department of the Environment, Water, Heritage and the Arts
DWLBC	Department of Water, Land and Biodiversity Conservation
EC	Electrical Conductivity
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
g/L	Grams per litre
GL	Gigalitre (1 billion litres)
GRP	Gross regional product
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
IUCN	International Union for Conservation of Nature
km	Kilometres
NPWA	National Parks and Wildlife Act 1972
NRM	Natural Resource Management
ppt	Parts per thousand
µS/cm	Micro Siemens per centimetre
USED	Upper South-East Drainage Scheme

PART 1

1 Introduction to the site

1.1 Site description

The Coorong, Lower Lakes and Murray Mouth (CLLMM) Wetland of International Importance lies where the Murray-Darling Basin, draining approximately one-seventh of the Australian landmass, meets the ocean. Surface water inflows are predominantly from the River Murray into the north of Lake Alexandrina, near Wellington. Other inflows are provided by tributary streams draining the Eastern Mount Lofty Ranges and from the Upper South East Drainage Scheme (USED) (**Figure 1**). Rainfall is also a significant input, although variable and relatively minor compared to the River Murray, while groundwater discharge is a less significant contributor.

Lake Albert lies to the south-east of Lake Alexandrina, connected via a narrow channel (Narrung Narrows) near Point McLeay. Lake Alexandrina is the primary source of inflows to Lake Albert, driven by wind seiche, supplemented by local rainfall and groundwater discharges. Lake Albert has no through-flow connection to the Coorong or Murray Mouth.

The fresh waters of the River Murray and Lake Alexandrina are separated by a series of five barrages from the more saline waters of the Murray Mouth estuary and Coorong lagoons (**Figure 1**). These barrages - Goolwa, Mundoo, Boundary Creek, Ewe Island and Tauwitchere - were completed in 1940 between the mainland and Hindmarsh, Mundoo, Ewe and Tauwitchere Islands, which are situated between the Lower Lakes and the Coorong. Calcareous limestone, a feature of the region's geology, protrudes from the bed of the lake between Hindmarsh, Mundoo, Ewe and Tauwitchere islands, forming a natural sill, and was used as the foundation to parts of the barrages.

Historically, surface flows of freshwater from the South-East of South Australia are believed to have been significant in preventing an escalation of salinity in the Coorong. However, the various drainage schemes implemented over several decades redirected this water to the ocean. In recent years, inflows from the south-east of South Australia into the Coorong's South Lagoon have been reconnected through Morella Basin and Salt Creek. To date, only small volumes of water have been released under regulated conditions via the USED Scheme.

The Murray Mouth is the only site where water contaminants such as silt, salt and nutrients can be discharged from the Murray-Darling Basin. Through-flow is dependent upon co-ordinated barrage releases and dredging in times of low flow to maintain an open Murray Mouth to the Southern Ocean.

To assist in describing the ecological character of the site the following six geographic components are recognised [1]:

Freshwater system units

- Lake Alexandrina
- Lake Albert
- Tributary wetlands ((lower reaches of Finniss River, Currency Creek and Tookayerta Creek).

Estuarine-saline system units

- Murray Mouth and Estuary
- Coorong North Lagoon
- Coorong South Lagoon.

The same approach has been adopted for this Plan to describe the range of actions required to address the key threats to the site.

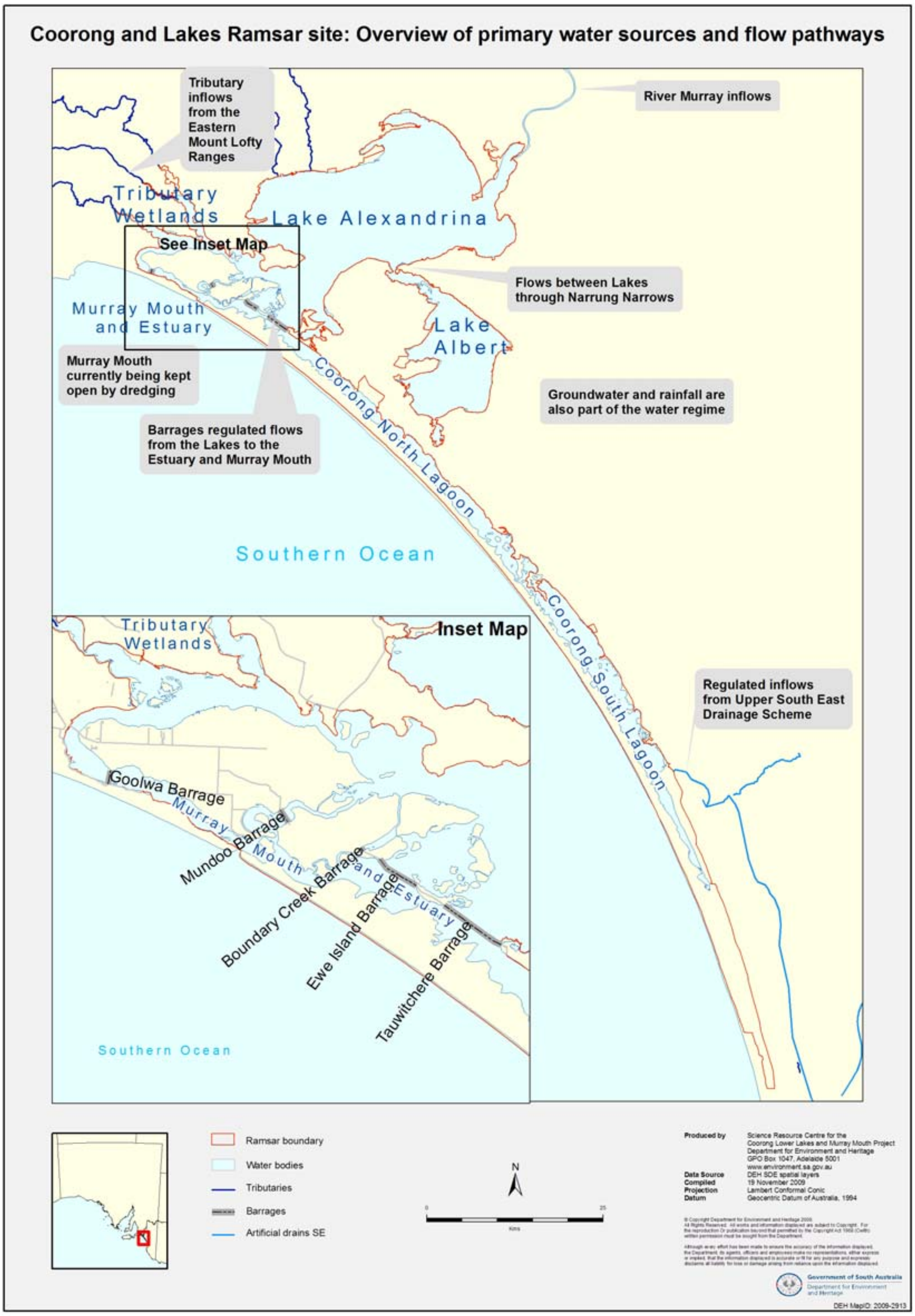

Figure 1. Coorong and Lower Lakes Ramsar Site: overview of primary water sources and flow pathways.

How the ecosystem functions

A detailed description of the functioning of the CLLMM ecosystem is provided in the *Ecological Character of the Coorong, Lakes Alexandrina and Albert Wetland of International Importance*[1] and a brief summary is provided here.

At the broadest scale, the CLLMM ecosystem is influenced by natural factors beyond human control including:

- rainfall and runoff in the Murray-Darling Basin and, to a lesser degree, in the South East of SA, which affect:
    - the amount of freshwater flowing into the system.
- local weather conditions, which influence:
    - the rate of evaporation from the surface of the waterbodies
    - water levels via wind-induced seiching
    - the extent and timing of local direct rainfall.
- sea level, which varies:
    - daily (tides)
    - seasonally (sea level in Encounter Bay is higher in winter than in summer)
    - according to the weather (e.g. storm events can increase sea level).

> **Wind seiching**
>
> Wind seiching is the movement of water by wind energy. Wind is a major driver of water movement in the Coorong, River Murray and Lower Lakes.
>
> Water levels between Lock 1 near Blanchetown and Wellington vary on a daily basis by up to 50 centimetres due to wind seiching. It is important for keeping the Coorong, Lower Lakes and Murray Mouth healthy by increasing oxygen levels in the water and distributing nutrients used by plants and animals for food.
>
> It also has the potential to transport pollutants in the Lower Lakes into the River Murray. Wind could transport poor quality water upstream, posing a threat to the quality of South Australia's public water supply.

A number of factors under human control also influence the ecosystem. These include:

- Flow regulation and consumptive water use (including groundwater extraction) in the Murray-Darling Basin, which influence:
    - the volume
    - seasonality
    - water quality of inflows to the CLLMM.
- Regulated inflows to the Coorong from the USED scheme (*see Technical Feasibility Assessment: South East Flows Restoration* [2]).
- Operation of the barrages and their associated fishways, which influence:
    - water levels in the Lower Lakes (see *Technical Feasibility Assessment Managing Variable Lake Levels* [3])
    - the 'openness' of the Murray Mouth
    - the degree of connectivity between the estuarine-saline system units and the freshwater system units.
- The openness of the Murray Mouth, maintained by dredging during periods of low flow (see *Technical Feasibility Assessment Maintenance of an Open Murray Mouth* [4]).

While all ecosystem components and processes are important to the overall healthy functioning of the system, some stand out as being central to maintaining ecological character, or could be considered primary determinants. For the Coorong and Lakes

Ramsar wetland, the following have been identified as the primary determinants of ecological character, and they are most directly influenced by end-of-system flows [1]:

- salinity
- turbidity and sedimentation patterns
- keystone aquatic plant species and assemblages
- water levels
- habitat availability, particularly temporal and spatial
- connectivity
- water regime, particularly flow patterns.

If these primary determinants are maintained within certain limits, then the expectation, based on scientific and local knowledge, is that the system as a whole will operate or function as expected and ecological character will be maintained. These limits are referred to as the 'limits of acceptable change'. The limits of acceptable change for each of the primary determinants differ within each of the geographic units of the site. For example, the Coorong South Lagoon is naturally much more saline than Lake Alexandrina.

1.2 The historic extent of marine incursions

It is estimated that the historic end-of-system flows - that is, the amount of water that flowed through the Murray Mouth - averaged 12,200 GL per annum prior to the development of the Murray-Darling Basin for irrigation and urban use [5]. Geomorphological studies show that the current mouth formed some 7,000 years ago. In post-European times it had never closed completely until 1981 [1]. Before the barrages were constructed there were occasions during severe droughts when there was reverse flow at the Murray Mouth, with seawater entering the Lower Lakes, but these events were infrequent and the quantities of seawater were generally not large [1].

This is supported by the record of diatoms, microscopic single-celled algae with a hard outer shell, which are deposited in the sediments of the Lower Lakes. Different species of diatoms are adapted to different salinities. The diatom record in lakebed sediments provides strong evidence that the Lower Lakes have been predominantly freshwater for the last 7,000 years and that seawater ingressions, when they did occur, did not extend northwards of Point Sturt [6]. **Figure 2** shows the typical salinity prior to large scale consumptive use of water and the construction of the barrages, based on the evidence of diatoms.

There are many anecdotal accounts of marine creatures, such as sharks, occurring as far upstream as Morgan and these are not inconsistent with the diatom record. Some marine shark species are known to migrate up rivers for considerable distances to hunt and purge themselves of parasites. Therefore their movement up-river does not necessarily indicate that the river was saline. Importantly, historical accounts of salty water in the river channel upstream of the Lower Lakes are most prevalent from the period between the Federation Drought and the construction of the barrages, a period when river flows were substantially lower than would have naturally occurred. Therefore these accounts suggest that European water resource development altered the state of the lower sections of the river very rapidly (i.e. within 50 years [7]) rather than being indicative of its natural state. It is also likely that these observations were rare and thus were considered noteworthy. Furthermore, naturally occurring groundwater discharges may have been the source of some of the salty water recorded upstream.

Diatom studies have also been undertaken in the Coorong [8]. These studies suggest that prior to European colonisation, salinity levels in both lagoons were generally at, or below, those of seawater (35 g/L). Periodic estuarine episodes (between 5 and 35 g/L) were evident in the North Lagoon, but the freshwater prism generated by the River Murray rarely penetrated further than about halfway down the North Lagoon. While there is evidence for occasional elevated salinities in the South Lagoon, freshwater inputs from the South East, rather than those from the River Murray, were responsible for periodic estuarine conditions, and for maintaining marine salinities in that lagoon [8]. Without fresh water inputs, the lagoons of the Coorong would have become hypersaline (i.e. saltier than the sea) due to evaporative concentrations of salt.

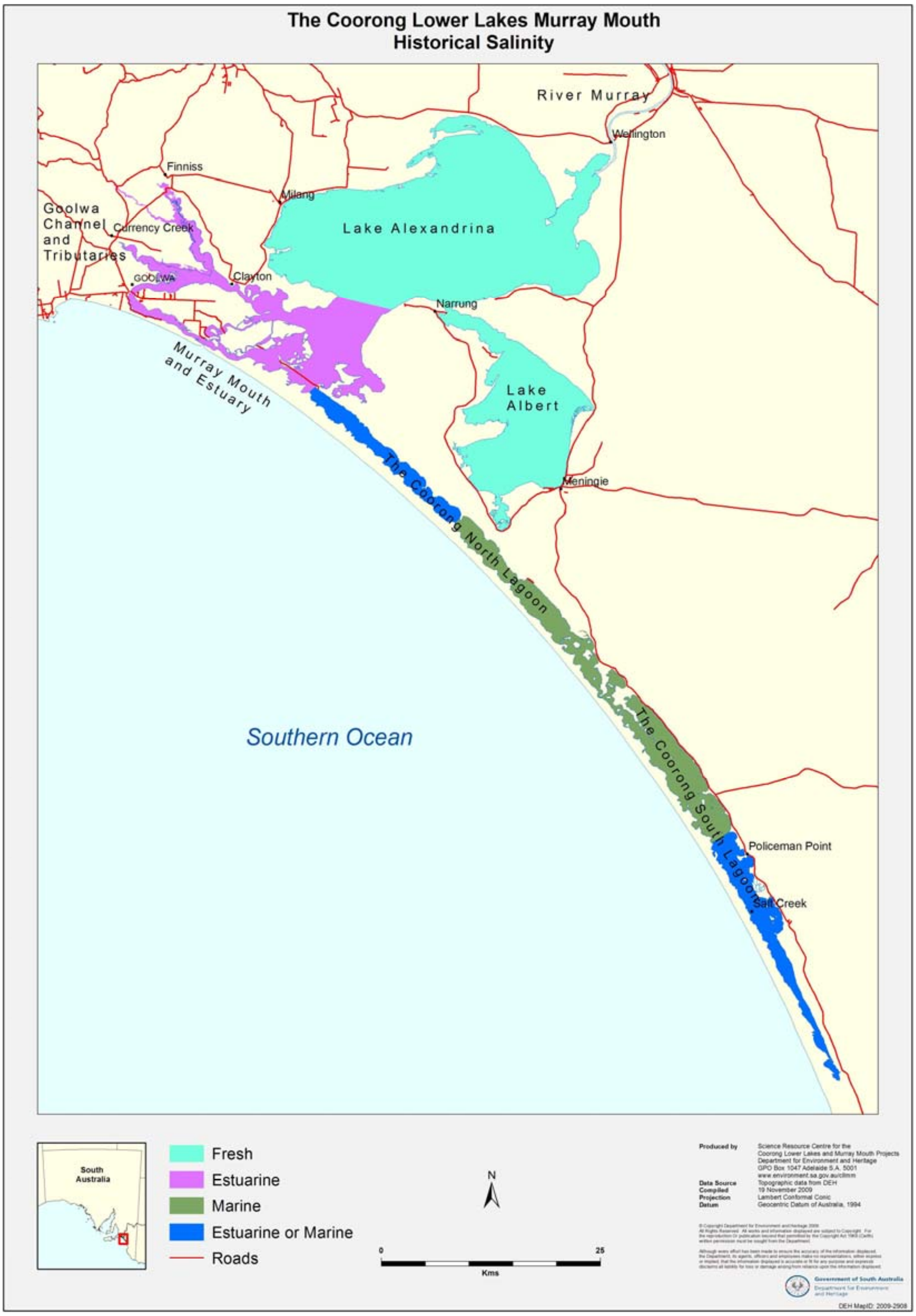

Figure 2. Summary diagram showing the typical salinity of the CLLMM before large scale consumptive water use in the Murray-Darling Basin and barrage construction, as inferred from diatom-based evidence [6,8,9].

2 A history of human use of the site

2.1 The Ngarrindjeri story

The Lower Lakes and Coorong region represents most of the homelands of the traditional owners, the Ngarrindjeri people, and thus is central to Ngarrindjeri culture and spiritual beliefs. This association is expressed through Creation stories (cultural and spiritual histories) about Yarluwar-Ruwe (Sea Country) which reveal the significance of the relationship between the country and the people, both practically and spiritually:

> *The land and waters is a living body. We the Ngarrindjeri people are a part of its existence. The land and waters must be healthy for the Ngarrindjeri people to be healthy.* [10]
>
> *The waters flowing down the Murray-Darling system bring life to the River, the Lakes and the Coorong. The waters bring life to the Ngarrindjeri too. This is both a practical and a spiritual statement.* [10]

Freshwater flows down the Murray-Darling system are seen by the Ngarrindjeri as the life blood of the living body of the River Murray, Lower Lakes and Coorong. The *Ngarrindjeri Yarluwar-Ruwe Plan*, which was prepared by Ngarrindjeri people in 2006 [10], articulates a vision for caring for this country, emphasising that 'the river, lakes, wetlands/nurseries, Coorong estuary and sea have sustained us culturally and economically for tens of thousands of years'.

The Ngarrindjeri Creation stories record dramatic changes in sea level in the area. They also document a richness of natural resources – especially a wealth of marine life such as fish, shellfish, eels, waterbirds and water plants – and sustainable use and management of them. In fact, Ngarrindjeri Yarluwar-Ruwe supported amongst the highest density of Aboriginal people anywhere in Australia prior to European arrival (estimated to be 6,000 at the time of European settlement) [11].

Since the arrival of European settlers the Ngarrindjeri have witnessed the draining of wetlands along the rivers and in the South East of South Australia and the dissection of the living body of the River Murray, Lower Lakes and Coorong through the installation of locks, levee banks and barrages. They have watched their totems (ngartji) decline or disappear, the clearing of the land and the rapid degradation of their Ruwe (country).

2.2 The European story

The early history

Sealers and whalers from Kangaroo Island were the first Europeans known to be aware of the Lower Lakes in the early 1800s and Captain Charles Sturt officially confirmed their existence to the colonial authorities in 1830, describing Lake Alexandrina as: '*a beautiful lake, which appeared to be a fitting reservoir for the noble stream that has led us to it…*' [7]

Shortly after the Proclamation of South Australia in 1836 the region was considered for settlement because of its ready supply of freshwater. By the 1840s settlers were grazing cattle and sheep along the lake shores, with stock drinking fresh lake water [7].

By the late 1840s the lake-shore land was being surveyed and it became highly valued. Towns such as Clayton, Goolwa, Meningie and Milang were settled on the shores from the early 1850s. The Murray, including the Lower Lakes, became a major means of transport, with paddle steamers carrying wool, wheat and other goods up and down the river and out to the sea near Goolwa [7]. The paddle steamer from Milang to Meningie was a stage on the way from Adelaide to Melbourne.

A brief history of Murray-Darling Basin management

The waters of the Murray-Darling Basin are shared between New South Wales, Victoria, Queensland, the Australian Capital Territory and South Australia. Since pre-Federation days, achieving agreement on the management of the River has been difficult. The fact that the Murray forms the boundary between New South Wales and Victoria, for much of its length, adds to this complexity.

One of the first discussions on managing the Basin took place in 1863 [7] and many other conferences were held in the following 40 years to discuss how best to use the River to meet the needs of farmers, boat operators and traders. However, little progress was made because of the prevailing parochialism of the various colonies.

Rural development through irrigation along the River Murray became an increasingly common practice from the 1880s. Shortly after irrigation pioneers, such as the Chaffey Brothers, established irrigation in the semi-arid mid-reaches of the river, the Federation Drought commenced, lasting from 1895 to 1902. This led to the building of catchment storage and distribution facilities so that farmers might enhance the productivity of the land and protect their interests from drought. As early as 1887 there were great fears that reduced flows would cause the lower River Murray to be impregnated with salt. Saline incursions became more common after 1900 when reduced river flows, due to drought and large-scale extractions for irrigation upstream, depleted the head of freshwater, such that it could not hold back the sea.

An informal working agreement between the states emerged from a non-government conference in 1902. The 1915 River Murray Waters Agreement shared the available resources of the River Murray system (the River Murray, the Darling River downstream of Menindee and the tributaries such as the Murrumbidgee, Goulburn and Ovens Rivers) between the states and provided for the construction of key assets to assist in regulating the rivers to provide for navigation and irrigation.

The River Murray Waters Agreement confirmed the rights of Victoria and New South Wales to the water in their respective states but required the two upstream states equally to provide South Australia with a minimum amount of water from their resources. This Entitlement Flow to South Australia was designed to provide for dilution and loss requirements from the South Australian border downstream to Wellington, in addition to a volume available for consumptive uses within South Australia. No provision was made under the agreement for losses (e.g. evaporation) from the Lower Lakes or to ensure discharge of water, and dissolved salt, through the Murray Mouth.

As early as 1903 the *Southern Argus* reported the following observation:

> '*Through the joint influences of long continued drought and an increasing diversion of its waters in its upper course, the River Murray has steadily lowered its levels so that its lower reaches and the lakes which for centuries it had supplied with a constant flow of fresh water, have fallen to sea level, with the result that instead of the river "rushing out to sea" the tides of the ocean have flowed in, changing the fresh water lakes to salt ones.*'

This history indicates that while drought has been an intermittent problem over the years, the current environmental crisis is one that is caused by historical over-allocation of water resources. Water was allocated to developments designed for economic benefit, to the detriment of sustainable, wise use of water resources and which did not take into account the high variability of river flows in Australia.

Government interventions to manage these problems have a long history. There have been numerous plans and schemes proposed to regulate the Murray Mouth, dating from the 1840s. In fact in 1842, Charles Sturt had suggested harnessing the flow down the Murray by directing all of it through the Goolwa Channel to make it safer for boats to pass through.

River regulation

Later, when the river flow lessened, plans were devised to retain freshwater in the Lakes, rather than letting it flow out to the sea to 'waste'. Later again, as reduced end of system flows resulting from extractions impacted on the Murray Mouth, attention shifted to excluding the seawater that was invading the system, resulting in the building of the five barrages at Goolwa, Mundoo, Boundary Creek, Ewe Island and Tauwitchere, which were completed in 1940 and are still in place today [7]. Other infrastructure developed to regulate the Murray-Darling Basin system includes a system of four shared storages, sixteen weirs and numerous other smaller structures.

The first ten weirs, with their accompanying locks to facilitate navigation, were constructed between 1922 and 1935. Their purpose was primarily to allow permanent navigation between the Murray Mouth and Wentworth, and to provide a relatively constant pool level to facilitate pumping for irrigation and water supply. The storage capacity of these weirs is relatively small. Construction of the Hume Dam, above Albury, and with a capacity of 3,000 GL, was begun in 1919 and completed in 1936. Work commenced on the large 4,000 GL storage at Dartmouth in 1973. The series of locks and weirs has dramatically changed the flow of the natural river, affecting the aquatic ecosystems, wetlands, river bank vegetation and waterfowl.

In addition, the temporal pattern of flows to the Lower Lakes has been altered with peak flows now being received in December to February each year compared with the pre-regulation peak flows which were usually in spring.

More recent Murray-Darling Basin management arrangements

However, there is now an increased awareness of the environmental qualities of the river and the flow requirements of the river ecosystem to ensure that its health is sustained. The relationship between a healthy environment and healthy and prosperous communities has been acknowledged as the detrimental impacts on people of this environmental crisis have become more evident. There is more willingness to use water for environmental purposes and to appreciate Ngarrindjeri knowledge and management regimes that encourage whole-of-system solutions.

In 1987 the River Murray Waters Agreement was replaced by the Murray-Darling Basin Agreement with the stated purpose 'to promote and co-ordinate effective planning and management for the equitable efficient and sustainable use of the water, land and other environmental resources of the Murray-Darling Basin.' During the time of the Murray-Darling Basin Commission, Indigenous interests, knowledge and culture were recognised. The Living Murray initiative introduced Indigenous policies and programs based on the requirement of 'informed consent'.

The Murray-Darling Basin Authority replaced the Murray-Darling Basin Commission in 2008 and has the major task of preparing The Basin Plan in consultation with Basin states, Indigenous groups and local communities. The Authority is working to a timetable that will produce a proposal by mid 2010 and the first Basin Plan in 2011. The Basin Plan will specify limits on the amount of water that can be taken from Basin waters on an environmentally sustainable basis. It will include an environmental watering plan that will specify the environmental objectives for the water dependent ecosystems of the Basin, and the principles for determining priorities for environmental water. It will also include a management plan for water quality and salinity, and rules about the trading of water rights. The effective implementation of the Basin Plan will take place once existing state water resource plans expire, which will occur progressively from 2012.

Recent water allocation history within South Australia

In recognition of the stressed condition of the River Murray, South Australia imposed a freeze on further irrigation entitlements following the drought of 1967-68. However, other states did not follow the lead set by South Australia and continued to increase irrigation entitlements for another thirty years, resulting in over-allocation of Basin water resources.

There is a fundamental issue with the current Murray-Darling Basin Agreement provisions for meeting system dilution and loss requirements which differ upstream and downstream of the South Australian border. Upstream they are met on a real-time basis from the shared resource. Downstream of the border, a set dilution and loss volume (696 GL) is included in the flow allocated to South Australia. This volume is not adjusted for, and does not meet, real time dilution and loss requirements to the river mouth (between about 950 GL and 1 350 GL per year).

Because of the freeze imposed by South Australia in the 1960s the State does not use all its non-dilution and loss (consumptive) allocation from its 1850 GL Entitlement Flow. Part of South Australia's non-dilution and loss allocation is therefore used to meet part, or all, of the shortfall. Unregulated flows through the system have also assisted to maintain flows into the Lower Lakes. However, in dry periods when South Australia's Entitlement Flow is less than the minimum entitlement under the Agreement, and/or losses are high, this shortfall can not be met.

For the last three years, South Australia has received barely enough water to meet its critical human water needs and support critical allocations to irrigators necessary to prevent the collapse of the industry. Where possible, in line with the State's drought allocation framework, it has provided water for environmental outcomes, through allocations to environmental entitlement holders (at the same level as irrigators), use of the 696 GL dilution and loss water, or water savings achieved within SA and though water allocation purchase. During 2008-09 an additional 50 GL was secured from the market for the Lower Lakes. This water was carried over for delivery during 2009-10. Some of this water will be used to offset pumping into the Goolwa Channel to mitigate the risks of acidification and ecological collapse in the Finniss River and Currency Creek.

In November 2009 the South Australian Government agreed to allocate, subject to inflows during 2009-10, a minimum of 120 GL towards a Lower Lakes Environmental Reserve (in addition to 50 GL purchased during 2008-09). Delivery of this water will commence as soon as possible according to an optimised delivery pattern. This water would have historically been allocated to irrigators.

This environmental reserve lessens the risk of acidification in the Lower Lakes and saline wedges entering the main channel above Wellington, thereby reducing the impact of potential back-flow events on potable water supply extraction points. Maintaining higher water levels below Lock 1 also mitigates adverse impacts on river banks, levee banks and floodplains, and lowers salinity in the Lower Lakes.

How River Murray water is shared between consumptive users and the environment from the water that enters South Australia is a state responsibility. This responsibility is discharged through the *Natural Resources Management Act 2004*. The objective of the allocation is to optimise the allocation of water that becomes available to South Australia, in excess of critical human needs, to support the long-term sustainability and viability of the South Australian community for the greatest net benefit of the whole community. This involves complex and, at times, conflicting decisions between environmental, irrigation, urban and other users. Allocations are based on an adaptive decision making framework that is reviewed on a monthly basis following the assessment of water available for sharing between New South Wales, Victoria and South Australia. Irrigators have a legal entitlement to water, are a key industry supporting regional communities and must be considered in the provision of critical water needs.

3 Values of the site

3.1 Ecological values

The Coorong, Lakes Alexandrina and Albert site was nominated and accepted in 1985 as a Wetland of International Importance, commonly known as a 'Ramsar Site'. This listing recognises the site's diverse range of wetland ecosystems, habitats and bird, fish and plant species, a number of which are threatened with extinction [1]. It is regarded as an important site for biodiversity in southern Australia.

There are nine criteria used to identify Wetlands of International Importance under the Ramsar Convention (**Table 1**). To be listed, a wetland needs to meet at least one. The strength of the argument that the CLLMM is indeed internationally important is illustrated by the fact that it meets eight out of the nine criteria. It may, in fact, meet all nine criteria; however the site has not yet been assessed against criterion 9. The Ecological Character Description [1] documents in detail how the site qualifies against each of the eight criteria. These 'Ramsar-significant biological components' are summarised below.

Criterion 1:	Contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate bioregion.
Criterion 2:	Supports vulnerable, endangered or critically endangered species or threatened ecological communities.
Criterion 3:	Supports populations of plant and/or animal species important for maintaining the biological diversity of the region.
Criterion 4:	Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
Criterion 5:	Regularly supports 20,000 or more waterbirds.
Criterion 6:	Regularly supports 1 per cent of the individuals in a population of one species or subspecies of waterbird.
Criterion 7:	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:	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.
Criterion 9:	Regularly supports 1 per cent of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.

Table 1. Ramsar's criteria used to qualify Wetlands of International Importance. The Coorong and Lakes site qualifies against criteria 1-8 (shaded).

Criterion 1

The Coorong and Lakes Ramsar site incorporates the freshwater bodies of Lakes Alexandrina and Albert, and the more saline Murray Mouth estuary and lagoons of the Coorong and Southern Ephemeral Lakes. Using the wetland classification system of the Ramsar Convention there are 23 different wetland types at the site, existing as an interconnected mosaic of fresh to hypersaline and permanent to ephemeral aquatic habitats [1].

Criterion 2

Threatened flora

Six plant species listed as threatened at the state or national level occur at the site. However, several of these occur in terrestrial vegetation adjacent to the waterbodies. Two species are strictly wetland-dependent; George's Groundsel and Metallic Sun-orchid [1]. Further surveys are expected to reveal more plants of note in this context.

Threatened fish

The site is known to support five species that are listed as vulnerable at either global or national levels. These are the Murray Cod, Murray Hardyhead, Yarra Pygmy Perch, Silver Perch and Big-bellied Seahorse [1].

Mount Lofty Ranges Southern Emu Wren

As noted below, the Swamps of the Fleurieu Peninsula, which are listed as a critically endangered ecological community under the *Environment Protection and Biodiversity Conservation (EPBC) Act*, provide habitat required by the Mount Lofty Ranges Southern Emu-wren, which is also listed as critically endangered. Given the dependence of vegetation health in the Fleurieu Peninsula Swamps upon water levels in the Lower Lakes, it is highly likely that the Mount Lofty Ranges Southern Emu-wren populations are also dependent upon Lower Lakes water levels.

Orange-bellied Parrot

The Orange-bellied Parrot is listed as critically endangered under the *EPBC Act*, and critically endangered by the International Union for Conservation of Nature (IUCN) through the 'Red List' process. Approximately 150 individuals remain in the wild [12]. The species breeds in south-west Tasmania and migrates to the mainland in winter, utilizing over-wintering feeding habitat within the Ramsar-listed area. Of particular importance to this iconic parrot are the saltmarsh habitats that occur around the margins of brackish to hypersaline waterbodies throughout the CLLMM. Vegetation dominated by species including Beaded Glasswort, Sea Heath, Austral Seablite and Shrubby Glasswort is favoured feeding habitat. In the CLLMM this vegetation is most abundant around the margins of the southern Coorong although its predicted distribution includes almost the entire Ramsar site, except areas of open water [1].

Southern Bell Frog

The Southern Bell Frog was once widespread throughout south-eastern Australia but its range has contracted and it is now listed as vulnerable under the *EPBC Act*. In South Australia it has been recorded along the River Murray from the Victorian border to the sea and also in the South East [13]. There are several records from around the margins of the Lower Lakes. The impact of the current water level crisis upon the Lower Lakes populations of the Southern Bell Frog was the subject of field surveys undertaken in spring 2009.

Swamps of the Fleurieu Peninsula

The listing of Swamps of the Fleurieu Peninsula as a critically endangered ecological community under the *EPBC Act* is relevant, as this area and the Ramsar site partially overlap. These areas of overlap are also important habitat for the endangered Mount Lofty Ranges Southern Emu-Wren (see above). Areas defined as Fleurieu Peninsula Swamp occur at the confluence of Lake Alexandrina and the Tookayerta and Currency Creeks and the Finniss River. The health of these swamps is strongly influenced by water levels in the Lower Lakes, and also by inflows from these tributary streams.

Criterion 3

Wetland-dependent or related ecological communities and species that qualify the site under Criterion 2 (above) also automatically qualify the site under this criterion. Additionally, the criterion includes:

- wetland-dependent/related plant species that are:
  - o listed as vulnerable or endangered (but not rare) under South Australian legislation, and/or
  - o listed as threatened, vulnerable or endangered regionally for the Southern Lofty botanical region or Murray botanical region of South Australia.
- native fish species that are listed at the State level as:
  - o P – protected under the *Fisheries Act 1982*, or
  - o C – provisional State conservation concern under the *draft Threatened Species Schedule National Parks and Wildlife Act 1972*.

Using the above decision rules there are one vegetation association, one plant species, 20 fish species and five bird species that contribute to the site qualifying against this criterion [1].

Criterion 4

Species that qualify the site under this criterion include:

- 20 species of fish in addition to the 20 listed under Criterion 3, including a number of migratory or diadromous species
- 49 species of birds including 25 migratory waterbird birds listed under the Japan-Australia and China-Australia Migratory Bird Agreements plus many resident species that breed within the site or rely on it for refuge during times of drought.

Criterion 5

The site supports well in excess of 20,000 waterbirds, at times reaching populations estimated at between 10 and 20 times greater than this. In some years the site has supported over a quarter of a million waterbirds. The significant species that comprise this large waterbird community include the 51 species listed under Criterion 4 and 16 listed under Criterion 6, a total of 77 species [1]. These include:

- three species that are listed as endangered or critically endangered at either global or national levels, namely, Mount Lofty Ranges Southern Emu-wren (see above), Orange-bellied Parrot (see above) and the Australasian bittern
- five further species that are classified as vulnerable within South Australia, namely, Lewin's Rail, Latham's Snipe, Eastern Curlew, Hooded Plover and Little Tern
- 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, China, the Republic of Korea, or the Convention on Migratory Species.

Criterion 6

A compelling example of the area's ecological significance is that it typically supports more than 30 per cent of the migratory shorebirds summering in Australia. These birds migrate from as far away as Siberia to take advantage of the highly productive mudflats of the CLLMM during the southern summer. It is among the top three sites in Australia for seven species of waders and in the top six sites for a further three species.

Some 16 species of birds have been regularly recorded in numbers exceeding the 1 per cent level. Among these are two species of grebe, Cape Barren Goose, Sharp-tailed and Curlew Sandpipers, three species of plover, Banded Stilt, Red-necked Avocet and Fairy Tern.

Criterion 7

The CLLMM are considered significant for 49 fish species [1]. Taken collectively they qualify the site under this criterion because of their biodiversity. The transitional environment from fresh to marine waters makes this site a unique habitat for fish species.

Criterion 8

As indicated above the site is important for 49 marine, freshwater and diadromous fish species. Of these, all but six are considered reliant on the ecosystem in the ways specified under this criterion [1]. The native fish community includes:

- five species that are listed as vulnerable at either global or national levels (see Criterion 2) (see *Technical Feasibility Assessment Protecting Critical Environmental Assets Program – Critical Fish Habitat and Refuge* [14])
- 20 further species that are classified as protected or have been provisionally listed as of conservation concern within South Australia
- 20 species that utilise the site at critical stages of their life cycle, such as, seven diadromous species, 12 estuarine species that spawn or have large populations and any freshwater species that spawn or recruit within the wetland
- eight so-called 'marine stragglers' - marine species of fish that randomly enter and leave inlets and estuaries.

3.2 Ecosystem services

Ecosystem services are the benefits provided by ecosystems to its users. Ecosystem services can be categorised into [15]:

- provisioning services such as food, water, timber, fibre, and genetic resources
- regulating services such as the regulation of climate, floods, disease, and water quality as well as waste treatment
- cultural services such as recreation, aesthetic enjoyment, and spiritual fulfilment
- supporting services such as soil formation, pollination, and nutrient cycling.

Wetland ecosystems are among the world's most productive and for this reason they are recognised for the range of ecosystem services they offer. The preceding section highlighted those attributes of the site which are of greatest interest from the perspective of biodiversity conservation; however, the CLLMM are also important for the range of other services they provide, these being a product of a 'healthy' wetland ecosystem.

The description of ecological character for the CLLMM [1] included a comprehensive list of the ecosystem services of this site.

Table 2. Ecosystem services provided by the Coorong and Lakes Ramsar site [1].

Ecosystem service	Details
Provisioning services	
Wetland products	Water source for irrigators (horticulture, viticulture)
	Drinking water supply (augmentation of Adelaide's water supply)
	Commercial fisheries
	Commercial cockle industry
	Grazing
	Reeds and grasses for traditional crafts
	Traditional food sources such as swan eggs

Ecosystem service	Details
Regulating services	
Maintenance of hydrological stability	Flood mitigation
	Groundwater interactions
Water purification	Removal and dilution of wastewaters from irrigation areas, urban areas and septic tanks
Coastal shoreline and river bank stabilisation	Reduce impacts of wind and wave action and currents
	Prevent erosion by holding sediments with plant roots
Sediment and nutrient retention	Flood retardation and sediment and nutrient deposition
Local climate regulation	Local climate stabilisation, particularly in relation to rainfall and temperature
Climate change mitigation	Sequestering of carbon
Biological control of pests and diseases	Support of predators of agricultural pests (for example ibis feeding on grasshoppers)
Cultural services	
Recreation and tourism	Boating and water-skiing
	Bird watching and sightseeing
	Swimming, picnicking and camping
	Recreational fishing
Cultural values	Aesthetics, amenity
	Cultural and spiritual significance for the Ngarrindjeri people
	Educational and research site
Supporting services	
Food web support	Nutrient cycling
	Primary ecosystem production
Ecological values	Representative of a unique ecosystem (globally, nationally and regionally)
	Supports a large variety of ecological communities
	Supports a number of globally and nationally threatened species and communities
	Supports a high diversity of species and assemblages important for conserving biodiversity at the bioregional scale
	Supports animal taxa at critical stages of their lifecycle and during drought
	Supports significant numbers and diversity of wetland-dependent birds, including migratory species listed under the Japan-Australia Migratory Bird Agreements, China-Australia Migratory Bird Agreements and Republic of Korea-Australia Migratory Bird Agreement.
	Supports significant numbers and diversity of native fish, including migratory species.

The above is based on the definition of ecosystem services as promoted by the Millennium Ecosystem Assessment, and as now endorsed for use under the Ramsar Convention through Resolution IX.1 of the 9th Conference of the Contracting Parties in November 2005.

Biosequestration and greenhouse gas emissions

Carbon biosequestration is an important function of ecosystems. Many of the proposed actions identified in this Plan seek to improve ecological function. This will provide long-term biosequestration benefits. These will be in the form of improved carbon storage and capacity as ecosystem health is restored.

3.3 Social values

The CLLMM are a national treasure that occupies a unique place in the Australian psyche. The 1976 film *Storm Boy* (based on Colin Thiele's cherished Australian classic book) was set and filmed around the Coorong. The ecology of the area is one of several themes explored in the film, which achieved box office success both nationally and internationally.

Today the CLLMM is one of the most popular tourism and recreational locations in South Australia. It is a popular area for recreational activities such as sightseeing, bird-watching, camping, walking, picnicking, fishing, swimming, boating, canoeing, water skiing and 4-wheel driving. In 2008 the South Australian Tourism Commission estimated the visitation rates to the Coorong National Park to be around 138,000.

There are a number of caravan parks, camping areas, motels, and numerous shacks and permanent dwellings in the area, many by the river and also some near the Lakes and on the Coorong. People are attracted to the area's significant mature vegetation and diversity of scenery and topography. The Coorong and Lower Lakes are highly valued by birdwatchers, with their wetlands attracting at least 85 species of birds.

There are also less tangible values associated with the area's natural beauty. People speak of its spiritual value and the sense of freedom and renewal they experience when spending time there.

> *People living in the area have a strong affinity with the site's aesthetics while, perhaps most importantly in the case of its Ramsar listing, others derive 'existence value' from the Icon Site – that is, they gain satisfaction purely from the continued existence of the site [16].*

3.4 Indigenous cultural values

The wellbeing of the Ngarrindjeri people is centrally linked to the health of the CLLMM. They have explained its significance through the story of Ngurunderi the Creator.

> A long, long time ago Ngurunderi our Spiritual Ancestor chased Pondi, the giant Murray Cod, from the junction where the Darling and Murrundi (River Murray) meet. Back then, the River Murray was just a small stream and Pondi had nowhere to go. As Ngurunderi chased him in his bark canoe he went ploughing and crashing through the land and his huge body and tail created the mighty River Murray. When Ngurunderi and his brother-in-law Nepele caught Pondi at the place where the fresh and salt water meet they cut him up into many pieces, which became the fresh and salt water fish for the Ngarrindjeri people. To the last piece Ngurunderi said 'You keep being a Pondi (Murray cod)'.
>
> As Ngurunderi travelled throughout our Country, he created landforms, waterways and life. He gave to his people the stories, meanings and laws associated with our lands and waters of his creation. He gave each Lakalinyeri (clan) our identity to our Yarluwar-Ruwe (country) and our Ngartjis (animals, birds, fish and plants) – who are our friends. Ngurunderi taught us how to hunt and gather our foods from the lands and waters. He taught us, don't be greedy, don't take any more than you need, and share with one another. Ngurunderi also warned us that if we don't share we will be punished.
>
> Ngarrindjeri respect the gifts of creation that Ngurunderi passed down to our Spiritual Ancestors, our Elders and to us. Ngarrindjeri must follow the Traditional Laws; we must respect and honour the lands, waters and all living things. Ngurunderi taught us our Miwi, which is our inner spiritual connection to our lands, waters, each other and all living things, and which is passed down through our mothers since Creation.

Ngurunderi taught us how to sustain our lives and our culture from what were healthy lands and waters. Our lands and waters must be managed according to our laws to make them healthy once again. As the Ngarrindjeri Nation we must maintain our inherent sovereign right to our Yarluwar-Ruwe. Ngarrindjeri people have a sovereign right to make our living from the lands and waters in a respectful and sustainable way.

We are asking non-Indigenous people to respect our traditions, our rights and our responsibilities according to Ngarrindjeri laws. [10]

The land and waters must be healthy for the Ngarrindjeri people to be healthy. We say that if Yarluwar-Ruwe (our country) dies, the waters die, our Ngartjis die, then the Ngarrindjeri will surely die. [10]

The crisis that has engulfed the region constitutes a new threat to the very foundations of Ngarrindjeri culture. Through its Caring for Country programs the Ngarrindjeri Regional Authority is working with government and local communities to develop new forms of governance that incorporate Ngarrindjeri expertise and capacity. Further research is required to understand the effects of declining water availability and quality on Ngarrindjeri culture in the region.

The Coorong National Park is acknowledged as culturally vital to the Ngarrindjeri people, with nationally important middens, burial sites and other sacred places throughout the park giving evidence of Ngarrindjeri ways of life over many thousands of years.

3.5 Economic values

The CLLMM has a mix of primary industry which is predominantly irrigated and dryland agriculture, manufacturing industries centred on wine, machinery and equipment, boat building and maintenance, and recreation and tourism activity. Sheep, beef and dairy cattle farming, grain, vegetable, fruit and nut growing, viticulture and fishing are the main primary industries in the area (see Appendix 2). There is also a significant urban population, with associated housing and service sectors.

The major towns associated with the CLLMM region include Goolwa, Clayton Bay, Milang, Langhorne Creek, Wellington, Meningie, Narrung, Raukkan and Salt Creek.

Many regional communities upstream are affected by the current conditions and decisions regarding the future management of the CLLMM. The River Murray and Lower Lakes, from Lock 1 at Blanchetown downstream to the barrages, comprise one weir pool. When lake levels recede it follows that levels in the River Murray channel recede. It also follows that the quality of water in the Lower Lakes has the potential to affect the quality of water in the upstream channel. Problems that have arisen upstream of the Lower Lakes include the drying of wetlands, the slumping of riverbanks and irrigation levee banks, disruption to the operation of ferries across the river, and stranding of irrigation infrastructure. These issues are being addressed by the South Australian Government's drought contingency planning which is currently underway.

The gross regional product (GRP) of the Lower Murray/Lakes and Coorong regional economy was estimated to be around $700 million in 2006-07 [17]. Primary industries directly contributed about $145 million to this and directly employed around 2,000 people. Irrigated agriculture employed 1,000 people, contributing over $70 million to the GRP. Anecdotal evidence suggests that drought conditions over the last few years have substantially reduced these numbers.

The restructuring of regional industries which has occurred in recent years can be expected to continue, with changes impacting on all industries in the region. There has been a reduction in the number of dairying farms and a reduction in livestock numbers. Wine production and the irrigation industry have been affected by drought and water availability. Impacts are being detected in other agricultural industries as well as the fishing, tourism, and boating industries. Further research is being undertaken to quantify the effects of declining water availability and quality on industry in the region.

4 Threats

4.1 Over-allocation

The long-term productivity and sustainability of the Murray-Darling Basin is under threat from over-allocated water resources, salinity and climate change. Water use in the Basin has increased five-fold in less than a century [18]. The problems caused by over-allocation have been exacerbated by severe drought and the early impacts of climate change [18]. There is insufficient water to maintain the Basin's natural balance and ecosystems, resulting in a marked decline in its ecological health.

The CSIRO Murray-Darling Basin Sustainable Yields Project [5] found that in the absence of flow regulation and consumptive water use in the Murray-Darling Basin, 12,200 GL/year would reach the Murray Mouth on average, based on the historical climate. Current surface water use in the Murray-Darling Basin is 48 per cent of the available surface water resource and is a very high relative level of use [5]. This level of use has reduced average annual outflows through the Murray Mouth by 61 per cent to 4,700 GL [5].

If 4,700 GL flowed over the barrages every year, the CLLMM ecosystem would probably be in good condition. However, average flows do not occur every year, and it is the changes to below average flows that are cause for concern. The incidence of cease-to-flow conditions at the Murray Mouth, when no water passes over the barrages, has increased from 1 per cent of the time to 40 per cent of the time due to consumptive water use in the Murray-Darling Basin [5]. This has necessitated sand pumping to maintain an open Murray Mouth and acid sulfate soils management activities such as the construction of bunds, pumping, seeding of exposed soils and limestone dosing of acid waterbodies. Additionally, severe drought inflows to the Lower Lakes (which CSIRO [5] define as annual inflow less than 1500 GL) prevail in 9 per cent of years under the current level of water resource development and current water allocation policies [5]. In the absence of water resource development and under the historical climate severe drought inflows to the Lower Lakes never occurred. The minimum annual pre-development inflow to the Lower Lakes was 2,250 GL [5]. These hydrologic changes are linked to the significant levels of environmental degradation observed at numerous floodplains and wetlands across the Murray-Darling Basin including the Coorong and Lower Lakes [5].

Climate change is predicted to exacerbate the ecological degradation of the CLLMM under the current water sharing arrangements in the Murray-Darling Basin. For example, in the three highest water use regions of the Murray-Darling Basin (the Murray, Murrumbidgee and Goulburn-Broken), current water sharing arrangements would protect water users from much of the climate change impact and thus transfer a disproportionate share of the climate change impact to the environment [5]. For the Murrumbidgee and Goulburn-Broken regions this means that much of the impact of climate change would effectively be transferred downstream to the Murray region, which includes the Lower Lakes and Coorong. In the south of the Murray-Darling Basin, current water sharing arrangements offer floodplain wetlands little protection from the expected impacts of climate change. Without changes to water sharing arrangements in these regions, climate change would be likely to lead to irreversible ecological degradation [5].

In summary, over-allocation of the water resources of the Murray-Daring Basin has been implicated in the ecological degradation of the CLLMM under the historical climate. Current water sharing arrangements do not ensure the environmental water requirements of the site are met, particularly during times of drought. Climate change may exacerbate this situation. The need for reform of water sharing arrangements in the Murray-Darling Basin so that the occurrence of severe drought inflows to the Lower Lakes can be reduced, or preferably avoided, is obvious.

Management challenges and approaches

The over-allocation of water resources across the entire Murray-Darling Basin will take considerable time and cost to resolve. The exceptionally dry conditions we are experiencing across most of the Murray-Darling Basin currently mean that, even if large volumes of freshwater were to be secured immediately, remedial works would also be required at the Coorong and Lower Lakes over an extended period to minimise ecological damage. The longer-term management strategy is to secure adequate freshwater for the site and ensure monitoring is in place to demonstrate that the flow is sufficient to support the desired ecological character.

4.2 South East drainage

Prior to European settlement the South East of South Australia featured extensive wetlands. In 1866 George Goyder, Surveyor-General for South Australia, stated to a Parliamentary Select Committee:

> *'My opinion is that from Salt Creek southward the area of the South East is equal to 7,600 square miles, and in every wet season half of that is under water. The depth of the water varies from one to six feet, and some of it is never dry.'* [19]

There is evidence that much of the water in the South East historically flowed along natural flowpaths in a north-westerly direction, to ultimately enter the Coorong South Lagoon. This evidence takes the form of:

- former flow paths still observable today [19]
- Ngarrindjeri oral history and culture [10]
- historical accounts [19]
- the living memory of both indigenous and non-indigenous people of the region
- palaeoecological studies, which reveal the historical salinity and likely water sources of the southern Coorong [8].

From the 1860s onwards, an extensive network of drains was constructed throughout the South East to alleviate flooding and make land more suitable for agriculture [20]. Major drains were constructed to divert water directly to the sea near Kingston, Robe and Beachport (the Blackford Drain, Drain L and Drain M respectively). The effect of this engineered solution to flooding was to deny the Coorong freshwater inflows from the South East. It is argued by some that the commencement of salinity increase and ecological degradation of the Coorong South Lagoon corresponds with the completion of key components of the South East drainage network [19]. The record of diatoms preserved in Coorong sediments appears to support this view [8] and it is highly likely that the loss of inflows from the South East has exacerbated the effects of very low inflows from the River Murray.

The combined average annual discharge to the sea from the Blackford Drain, Drain L and Drain M is 136.4 GL [21]. Discharge is quite variable and in high rainfall years very large volumes flow to the sea through these drains. For example, in 2000 the combined total discharge was 449.9 GL [21]. Without the drainage network in place, a considerable proportion of this water would have flowed into the Coorong South Lagoon. To put these volumes in context, the total volume of the Coorong South Lagoon varies from approximately 140 GL when full in winter to 90 GL in late summer [1].

4.3 Drought

Drought is a natural phenomenon in the Murray-Darling Basin, a region of high climate variability. The Basin is presently experiencing the worst drought since records began in 1891, with the past three years being particularly severe [22]. More than 12 years of below average rainfall and increased evaporation resulting from record high temperatures across much of Australia, including the Murray-Darling Basin, have resulted in the longest period of low flows since river regulation. Rainfall deficits and temperature averages between 1996 and 2007 are shown below.

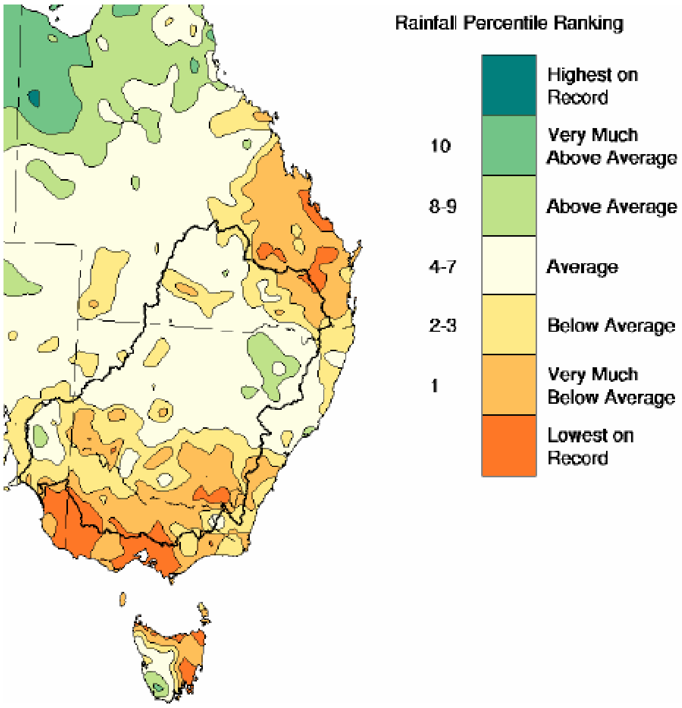

Figure 3. Rainfall deciles in the Murray-Darling Basin between November 1996 and October 2007 [23].

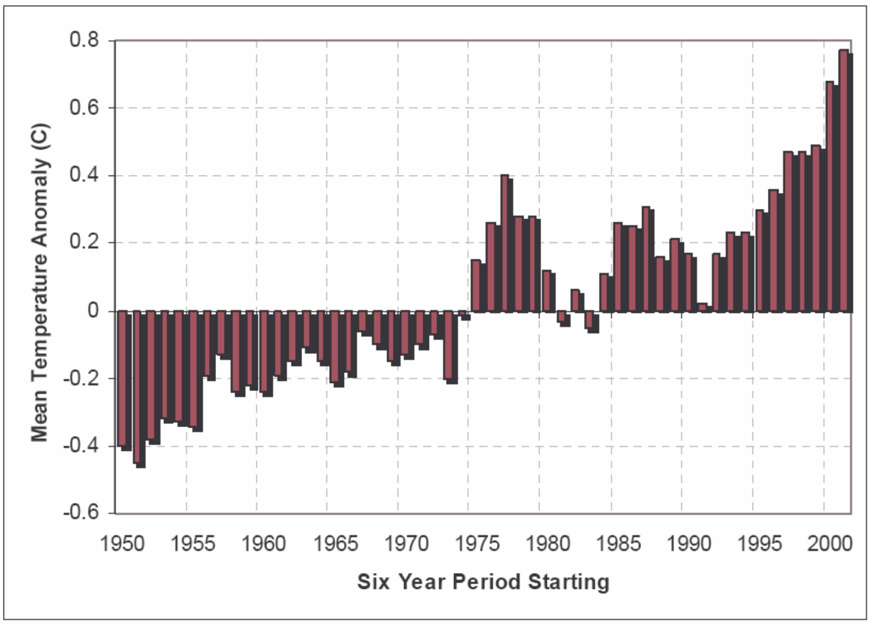

Figure 4 Murray-Darling Basin mean temperature difference from long-term average [23].

The consequences of the prolonged drought are evidenced by the reduced inflows to the Murray-Darling system, shown in Figure 5.

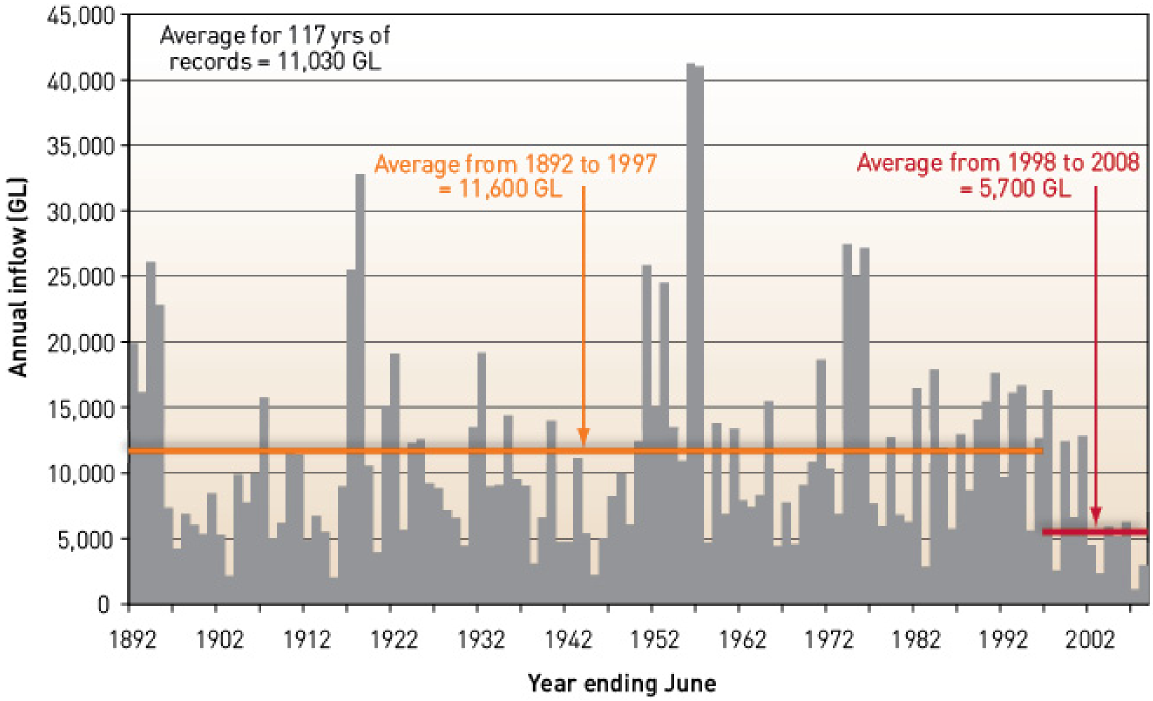

Figure 5 Murray-Darling Basin inflows [1].

It is estimated that some 200 cubic kilometres of water has been lost from the Murray-Darling Basin during this drought, when groundwater losses are included [24]. Despite above average rainfalls in 2009 in parts of southern Australia, the water resources within the Murray-Darling Basin remain well below long-term averages due to the dry catchments and the need to replenish shallow groundwater systems before normal base river flows return.

Much of South Australia is not currently in drought, but because the CLLMM rely almost exclusively on flows from upstream in the Murray-Darling system, they are directly affected by the quality and quantity of water that is delivered. The longevity of the drought has compounded the effects of over-allocation to severe detrimental impacts on the CLLMM.

The impacts of drought upon inflows to the Lower Lakes and Coorong are greatly exacerbated by the current water sharing arrangements in the Murray-Darling Basin.

4.4 Climate change

Climate science predicts that south eastern Australia, which includes the southern Murray-Darling Basin, will become drier and hotter in the future due to anthropogenic climate change. Climate change will have profound implications for stream-flow in the Murray-Darling Basin, particularly at the end of the system. The experience of the last decade is consistent with, although more severe than, the predictions of climate science. The current drought in south eastern Australia is now the worst on record and 'now more closely resembles the picture provided by climate model simulations of future changes due to enhanced greenhouse gases' [22]. Thus, the intensity of the current drought may lie outside the limits of natural variability and may possibly be explained by reference to climate change.

[1] Murray-Darling Basin Commission, A*nnual Report 2007 – 2008.*

The CSIRO Murray-Darling Basin Sustainable Yields Project [5] examined rainfall and runoff in the Murray-Darling Basin under five climate scenarios; historical (1885 - 2006), recent (1997 – 2006), median future climate, extreme dry future climate and extreme wet future climate. The three future climate scenarios were based on global warming scenarios from the Intergovernmental Panel on Climate Change Fourth Assessment Report [25] and are all potentially representative of the year 2030.

Despite this, the CSIRO Murray-Darling Basin Sustainable Yields Project forecast average flows in the Basin at much higher levels than recently experienced – even in the extreme dry 2030 climate scenario there is a predicted average end of system flow of 1,417 GL per annum in comparison with the current non-existent end of system flows [5]. Recent inflows appear to be unusually low, even taking extreme climate change into account, and higher inflows are anticipated to return in the future. However, an overall trend of declining availability of surface water across the Murray-Darling Basin is anticipated, especially in the southern Basin, where the median decline is predicted to be some 13 per cent from historical availability [5].

The median 2030 climate would lead to conditions in the Lower Lakes that, in the absence of action to decrease extractions, would be worse than under the historic climate, but better than under the current crisis conditions. Flow at the Murray Mouth is predicted to cease 47 per cent of the time and severe drought inflows to the Lower Lakes of less than 1500 GL per annum could occur in 13 per cent of years. The situation is predicted to be considerably worse under the extreme dry future climate: flow at the Murray Mouth ceasing 70 per cent of the time and severe drought inflows to the Lower Lakes occurring in 33 per cent of years, based on modelling.

There are some indications that the current drought may be influenced by climate change [26]. However, it is difficult to be certain to what extent the current conditions are a consequence of natural but severe drought, climate change, or a combination of both. Planning for the CLLMM area must therefore consider a range of possible futures.

4.5 Sea level rise

Current predictions, based on Intergovernmental Panel for Climate Change projections, are for a sea level rise of at least 0.3 metres by 2050 and 1.0 metres by 2100. Sea level rise is not seen as an immediate threat due to the geomorphology of the region, but it is acknowledged that it may lead to a transition of the Lower Lakes to an estuarine environment in the longer-term.

Furthermore, 'localised temporary events such as extreme tide (plus surge) as well as storm and wave effects, could raise water levels locally and temporarily but nevertheless quite significantly'[27]. In extreme circumstances such as these, islands which are important nesting grounds for birds are likely to be submerged, and mudflat habitats which support many species of water birds, including migratory waders, could be permanently lost.

Sea level rise could also threaten the barrages in the medium to long-term, especially during storm events. While not a threat in the medium-term, in the longer-term there may also be sea level rise implications for the security of the water supply for Adelaide and many country towns. Increasingly salty water in Lake Alexandrina could be forced upstream and compromise potable water at South Australian pumping locations in the River Murray below Lock 1.

However, research strongly indicates that the Younghusband and Sir Richard Peninsulas are not threatened by sea level rise within the next hundred years and neither, therefore, is the Coorong [28].

Management challenges and approaches

At present, it is predicted that if the barrages were to be permanently opened during periods of low freshwater flow down the system, this would lead to hypersaline conditions in Lake Alexandrina and the loss of its ecological character. In the very long-term, however, the impact of sea level rise will probably lead to a move to a more estuarine environment. Planning for the site will aim to maintain a healthy environment which adapts successfully to changing conditions.

A component of the management response will be the use of best practice adaptive management to strengthen the resilience of the system to the predicted impacts of climate change.

4.6 Maintenance of stable water levels

Prior to the current water level crisis in the Lower Lakes, the primary objective of water level management there was human utility, although some ecological factors have been given consideration. Barrage operation is the management 'lever' used to control water levels in the Lower Lakes. Since their construction in the 1930s the barrages have been operated to [29]:

- maintain low salinity levels in the Lower Lakes and the River Murray downstream of Lock 1 by preventing the ingress of seawater during periods of low flow
- stabilise the river level, and normally maintain it above the level of reclaimed river flats between Wellington and Mannum, so as to provide irrigation by gravitation rather than pumping
- reduce the potential for wind and wave induced erosion of the lake shore, which is promoted if levels of 0.55 metres AHD persist due to the geomorphology of the soils [1]
- reduce the potential for saline groundwater discharge into the lakes
- maintain pool water that can be pumped to supply Adelaide and the South East of South Australia from pumping stations at Mannum, Murray Bridge and Tailem Bend on the River Murray downstream of Lock 1
- facilitate the supply of freshwater, by direct extraction from the Lower Lakes, to towns and agricultural enterprises located around the lake margins
- prevent flooding of surrounding land
- minimise the need for dredging to maintain an open Murray Mouth
- permit fish passage between the Lower Lakes and the sea.

To achieve the above objectives the key water levels in the Lower Lakes are [29]:

- 0.40 to 0.60 metres AHD: preferred minimum level
- 0.75 metres AHD: full supply level
- 0.85 metres AHD: surcharge level (note: water begins to spill over the spillways associated with the barrages as surcharge level is achieved)
- 0.87 metres AHD: inundation of surrounding land commences.

Under typical conditions (i.e. those prior to the current water level crisis), Lakes Alexandrina and Albert fill during winter/spring from a low of approximately 0.60 metres AHD, typically attained in April/May, to a high of 0.75 metres AHD (full supply level). If inflows are adequate, the Lower Lakes are surcharged to 0.85 metres AHD by the end of spring. The aim of surcharging the Lakes was to prevent levels falling below 0.60 metres AHD in the following autumn.

It is recognised that the post-barrage approach to water level management and barrage releases has prioritised human utility of the Lower Lakes over ecological objectives. Although ecological objectives such as the maintenance of an open Murray Mouth, the flushing of salt from the system and the provision of fish passage have been given consideration, water level management has been restricted by the need to facilitate water extraction and the ecosystem of the Lower Lakes has been compromised as a consequence [1,16]. For example, excessively static water levels have resulted in [30]:

- a simplification of the aquatic and fringing plant communities making them less suitable habitat and restricting growth to a narrow band approximately 0.45 metres AHD (submerged) to 0.7 metres AHD (emergent reeds)
- a lack of floods not allowing for flushing through of silt which accumulates in lakes resulting in very high turbidity due to wind and wave action; this in turn simplifying the system by favouring algal growth over plant life
- accumulation of salt to levels approaching or exceeding the tolerances of some species
- increased lake shore erosion when lake levels are held at 0.6 metres AHD and above
- reduced exchanges between Lakes Alexandrina and Albert
- loss of spawning triggers for flood dependent fish species.

Additionally, episodic rapid falls in water level, which have been a feature of water level management, are not ecologically ideal, resulting in [30]:

- 'lost' reproductive effort and therefore reduced resilience and vigour of ecosystem components
- rapid desiccation of aquatic plants and consequent loss of habitat and macroinvertebrate communities
- disconnection of freshwater and estuarine-saline components of the aquatic habitat at critical times in fish life histories.

Management challenges and approaches

A Lakes Operating and Water Release Strategy with ecological objectives as its highest priority is desirable but requires the decoupling of Lower Lakes water levels from water supply. Water supply pipelines recently completed and under construction around the Lower Lakes have largely achieved this decoupling [3], providing an opportunity for a new approach to water level management.

5 Impacts and consequences

5.1 Reduced freshwater inflows

Although inflows to the Lower Lakes have continued at reduced volumes, end of system flows have ceased because inflows are less than evaporative losses from the surface of the Lower Lakes. The salts, sediment or pollutants that enter the Lower Lakes are accumulating instead of being discharged into the ocean.

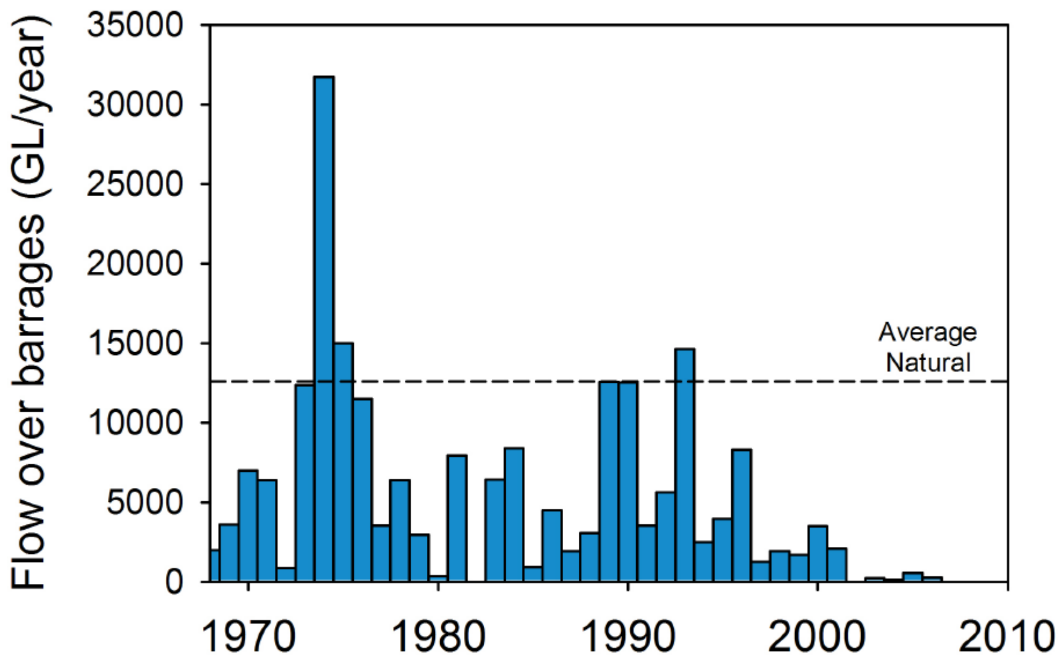

Figure 6. River Murray discharge at the barrages from 1968 to 2009 [31].

In 2006/07 there was a minor barrage discharge of 63 GL, but there has been no discharge since then. Between 1975/76 and 1996/97 average annual barrage discharges were 6023 GL. However, since then, the average annual barrage discharge has been only 890 GL, clearly demonstrating the impact of over-allocation and drought.

In an average year about 40-50 per cent of the public water supplies for Metropolitan Adelaide and associated country areas including the Fleurieu Peninsula, Yorke Peninsula, Upper South East and the Mid-North, is extracted from the Murray. However, in the past two years the River Murray has provided a much greater proportion than this, due to reduced inflows to the Mount Lofty Ranges reservoirs - although they have filled during the spring of 2009.

5.2 Low water levels

As the amount of water entering the Lower Lakes is now much less than the evaporative losses, water levels are falling and reached -1.0 metre AHD, in early 2009, which has never previously occurred. Salinity levels for both Lake Alexandrina and Lake Albert are climbing rapidly, and the lake water is now unusable for most human and agricultural purposes. Lake Albert is likely to experience a major fish kill by early 2010 due to increased salinity and both lakes are at risk of future acidification unless end of system flows improve.

Water levels in the Coorong have not fallen to the same extent because the Murray Mouth has been kept open by dredging. However, as water evaporates from the Coorong, it is replaced by seawater, but not freshened by water flowing through the barrages as was historically the case. The substantial volumes of water from the south east of South Australia that once flowed to the South Lagoon have been intercepted by various drainage schemes and redirected to the sea. The consequence of these two factors has been an escalation of salinity levels in the waters of the Coorong. Summer salinity levels in the South Lagoon are now as much as six to seven times that of seawater.

Due to the barrages holding back seawater, freshwater levels in Lakes Alexandrina and Albert have fallen to lows that are unprecedented, disconnecting the two lakes. Over the 2009 year, the water level in Lake Alexandrina has dropped to as low as -1.0 metre AHD, and in Lake Albert -0.5 metres AHD. This has resulted in the exposure of acid sulfate soils.

Acid sulfate soils

Low water levels in the Lower Lakes and tributaries have uncovered large areas of previously saturated sulfidic sediments that are acidifying on drying. These acid sulfate soils can have a number of undesirable impacts. These include:

- *Environmental*: poor water quality (acidic), release of heavy metals and metalloids, aquatic ecosystem toxicity, polluted soils and vegetation toxicity, metal mobilisation and unpleasant odours
- *Health*: contribute to skin and eye inflammation through direct contact
- *Economic*: impacts on local infrastructure and agricultural productivity
- *Cultural*: impacts on Ngarrindjeri culture, cultural sites and landscapes.

There is particular concern over the mobilisation of acid and heavy metals, both during the 'drying' of acid sulfate soils when water levels are falling, and in the 're-wetting' phase, as water returns (e.g. through rain events). If Lake Alexandrina were to acidify, this would pose the risk that water of increasing acidity could accumulate and contaminate potable water at South Australian pumping locations in the River Murray below Lock 1.

Recent research on areas adjacent to Lake Alexandrina, identified that large areas of extremely acidic soils existed. Acid level readings in soil, as expressed in pH units, have been as low as pH 1 in some of the sites being investigated [32]. In some parts of the site, it was noted that there was the potential for acid sulfate soils to develop if the water levels continue to drop, although the risk of this occurring is thought to be low to moderate provided that the materials are kept under anaerobic conditions (i.e. oxygen is excluded by saturation of soils with water). This study also concluded that monitoring will be particularly important during rewetting phases from winter rainfall events when acidity and metal mobilisation may occur. A significant new finding in May 2009 is the identification of acidic (pH 3.8 to 3.3) ponded and flowing water bodies in localised areas previously identified as containing widespread sulfuric cracking clay soils [32].

Acid sulfate soils

Acid sulfate soils naturally occur in coastal and fresh water areas where there are large amounts of sulfate and organic material in the water. They are a natural part of the ecosystem.

As long as the soils are covered by water they are harmless to the environment, but if water levels drop and the soils are exposed to the air they react with oxygen to form sulfuric acid and can release heavy metals from the soil. The acid can also cause toxic metals such as manganese, aluminium and arsenic to be released. When the soils get wet again, through rainfall or increased river flow, the acid and metals can spread and affect large areas.

Based on water levels at March 2009, over 20,000 hectares of acid sulfate soils were exposed in Lake Alexandrina and Lake Albert resulting in acidic salts forming over much of the dried out lakebeds.

To our knowledge, there is nowhere else in the world that has such a diversity or concentration of acid sulfate soil sub-types or has experienced their exposure on this scale of magnitude.

Management challenges and approaches

The best management approach is to prevent acidification by saturating soils with freshwater. Bioremediation, limestone dosing, the Goolwa Channel infrastructure works and Narrung Narrows regulator are currently being employed to manage acidification which has already occurred and to prevent further acidification. Ngarrindjeri cultural sites require conservation and management as part of bioremediation and associated strategies. The introduction of limited amounts of seawater to the site to prevent acidification is a last resort, but will be explored.

Elevated salinity

The 23 different wetland types in the CLLMM now have salinity levels well above their historical ranges.

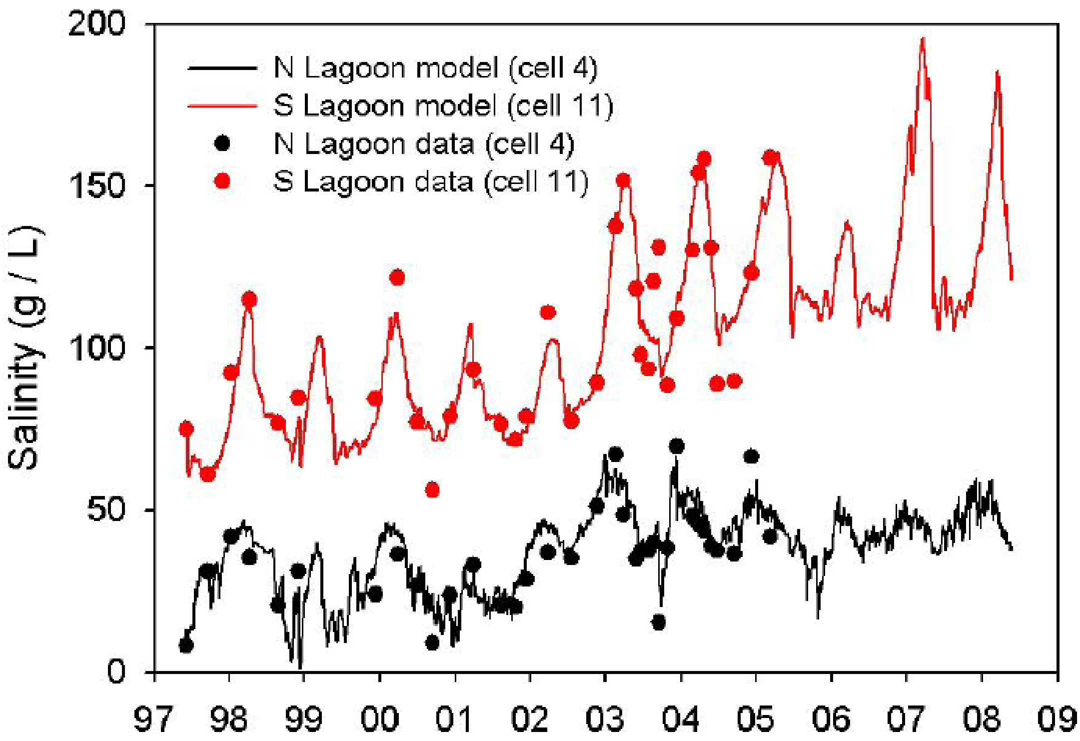

Figure 7. Salinity (modelled and actual) in the South Lagoon (red line, points) and North Lagoon (black line, points) of the Coorong from mid 1997 to mid 2008 [33]. Note "cell 4" refers to the area of the North Lagoon in the vicinity of Mark Point and "cell 11" to the area of the South Lagoon in the vicinity of Woods Well.

Whereas salinity levels in Lake Alexandrina generally used to be less than 1,000 EC units (which was suitable for stock, domestic supplies and irrigation), current readings are more than five times that amount. In Lake Albert, salinity levels are over 10,000 EC units, and likely to increase substantially as the lake dries down in 2010. In the Coorong, salinity continues to fluctuate seasonally as it has historically. However both the seasonal maximum and seasonal minimum salinities have been increasing for the last decade and particularly so since barrage flows declined after 2002 (**Figure 7**). Parts of the Coorong now experience salinities six to seven times the salinity of seawater, far higher than at any other time in the 7,000 years that it has existed.

The salinity level is beyond the limits for most freshwater ecosystem functions. This situation is severely affecting the entire landscape which supports the biodiversity and the agricultural productivity of the region.

Management challenges and approaches
The only effective management approach is to discharge the salt and other dissolved or colloidal load through the Murray Mouth. This is not possible under current circumstances of extreme low water levels in the Lower Lakes. Maintaining an open Murray Mouth at all times, which is currently being achieved through dredging, is crucial to ensure that the Coorong is flushed as far as possible with cool, well oxygenated and relatively low salinity water to maintain its health.

5.3 Ecosystem degradation

The current crisis has had, and is continuing to have, a profound impact upon the ecosystem of the CLLMM. The key drivers of ecosystem degradation are:

- low water levels in the Lower Lakes
- elevated salinity in the Lower Lakes, Murray Estuary and Coorong
- a lack of connectivity between the Lower Lakes and the sea
- localised acidification of surface waters in some areas of the Lower Lakes.

Appendix 3 lists an indicative ecological response to declining water levels and quality.

Low water levels in the Lower Lakes

Before the current crisis much of the biodiversity of the Lower Lakes was dependent, either directly or indirectly, upon the band of aquatic vegetation around the lakes margins. This vegetation included tall reeds, rushes and submerged aquatic plants such as Ribbon Weed, Water Ribbons, pondweeds and milfoils. Inundated areas of aquatic vegetation provided shelter, feeding, roosting, nesting and nursery habitat for a high proportion of the Lower Lakes fish, bird, amphibian, reptile and invertebrate species [1].

This band of vegetation is located between 0.85 metres and 0.30 metres AHD. Water levels in the Lower Lakes have dropped below sea level for the first time since barrage construction. They have remained below this level since and continued to decline. Consequently, the fringing band of aquatic vegetation is no longer connected to the waterbody of the Lower Lakes and can no longer act as shelter, feeding, nesting and nursery habitat. This has had a profound effect upon the Lower Lakes ecosystem. It appears to have caused the local extinction of the threatened Yarra Pygmy Perch and dramatic declines in other threatened, small-bodied fish species such as the Murray Hardyhead and Southern Pygmy Perch[34,35]. Declines in a range of waterbirds including ducks, darters, shorebirds, terns, coots, cormorants and ibis have been documented [36]. Submerged aquatic plants are now largely absent from the Lower Lakes and the fringing beds of reeds and rushes, stranded high above the current water level, are in poor condition. In some locations, such as near Milang, the exposed lakeshore has been subject to natural colonisation by terrestrial plants. This is beneficial in regards to managing acid sulfate soils and wind erosion, but does not support species threatened by the current conditions.

The critically endangered Orange-bellied Parrot favours habitat in close proximity to surface water [37]. The receding waterline of the Lower Lakes has greatly increased the distance between surface water and formerly favourable habitat for this species, rendering such habitat unsuitable for Orange-bellied Parrots.

In the absence of adequate inflows from the River Murray, water levels in the Lower Lakes are predicted to continue their decline. As a consequence water quality is anticipated to decline also, with salinity anticipated to increase and dissolved oxygen concentration anticipated to decrease. A major fish kill, as dissolved oxygen falls below a critical threshold, will mark another stage in the ecological collapse of the Lower Lakes. Given current trends a fish kill is anticipated for Lake Albert in early 2010 unless it can be prevented by management intervention. For Lake Alexandrina the timing of a fish kill is more difficult to predict but it is likely to occur at some time in the next few years unless River Murray inflows increase or some other management intervention prevents it.

Elevated salinity in the Lower Lakes

Salt enters the Lower Lakes from the River Murray and other tributaries from groundwater, through leaks in the barrages (which has been reduced) and from the air. Without flushing flows through the barrages salt accumulates in the Lower Lakes. Coupled with evaporation (which removes water but leaves the salt), this has caused salinity in the Lower Lakes to rise. Before the current crisis, salinities in Lakes Alexandrina and Albert typically fluctuated between 400 and 2,300 EC (seawater = 58,333 EC) [1]. In autumn 2009 (prior to winter rains) salinity in central Lake Alexandrina had reached 6,430 EC and was 35,100 EC near Goolwa [38]. In Lake Albert salinity near Meningie was 12,200 EC.

Salinity has a strong influence upon aquatic ecosystems including the Lower Lakes [1]. All aquatic organisms can tolerate a range of salinity but will not persist at salinities outside that range. Therefore, the salinity of a waterbody will determine the organisms that are able to inhabit it. The salinities now present are outside the ideal range for many resident species and are promoting the overabundance of other species.

The abundance of salinity tolerant tubeworms has increased dramatically. Tubeworms have encrusted the carapaces of tortoises and other hard surfaces with a hard, coral-like calcareous mass. This weighs down the tortoises and covers the shell openings, preventing the animals from breathing, moving properly and restricting their ability to feed, eventually leading to their death.

Large-bodied native freshwater fish species are believed to be less directly dependent upon fringing aquatic vegetation than small-bodied species. They are also longer-lived and can therefore, theoretically, persist for longer without successfully breeding. For these reasons large-bodied species are likely to have been less dramatically affected by falling water levels in the Lower Lakes than small-bodied species. However, rising salinity may also take its toll upon vulnerable life-stages of large-bodied species.

The large-bodied native freshwater fish species that were present in the Lower Lakes prior to the current crisis and the respective salinity tolerances of their most salinity sensitive life stage (typically larvae) are:

- Silver Perch (12,670 EC)
- Golden Perch (20,000 EC)
- Murray Cod (15,680 EC)
- Bony Herring (58,333 EC)
- Eel-tailed Catfish (19,000 EC)
- River Blackfish (10,000 EC) [39].

As noted above, parts of the Lower Lakes have already exceeded some of these tolerances and, if low inflows persist, more will be exceeded in the future. Rising salinity poses a threat to what remains of the large-bodied native fish community in the Lower Lakes, except where this impact is moderated within the ‘Goolwa Pool’ - the recently created waterbody between the new Clayton levee and the Goolwa barrage.

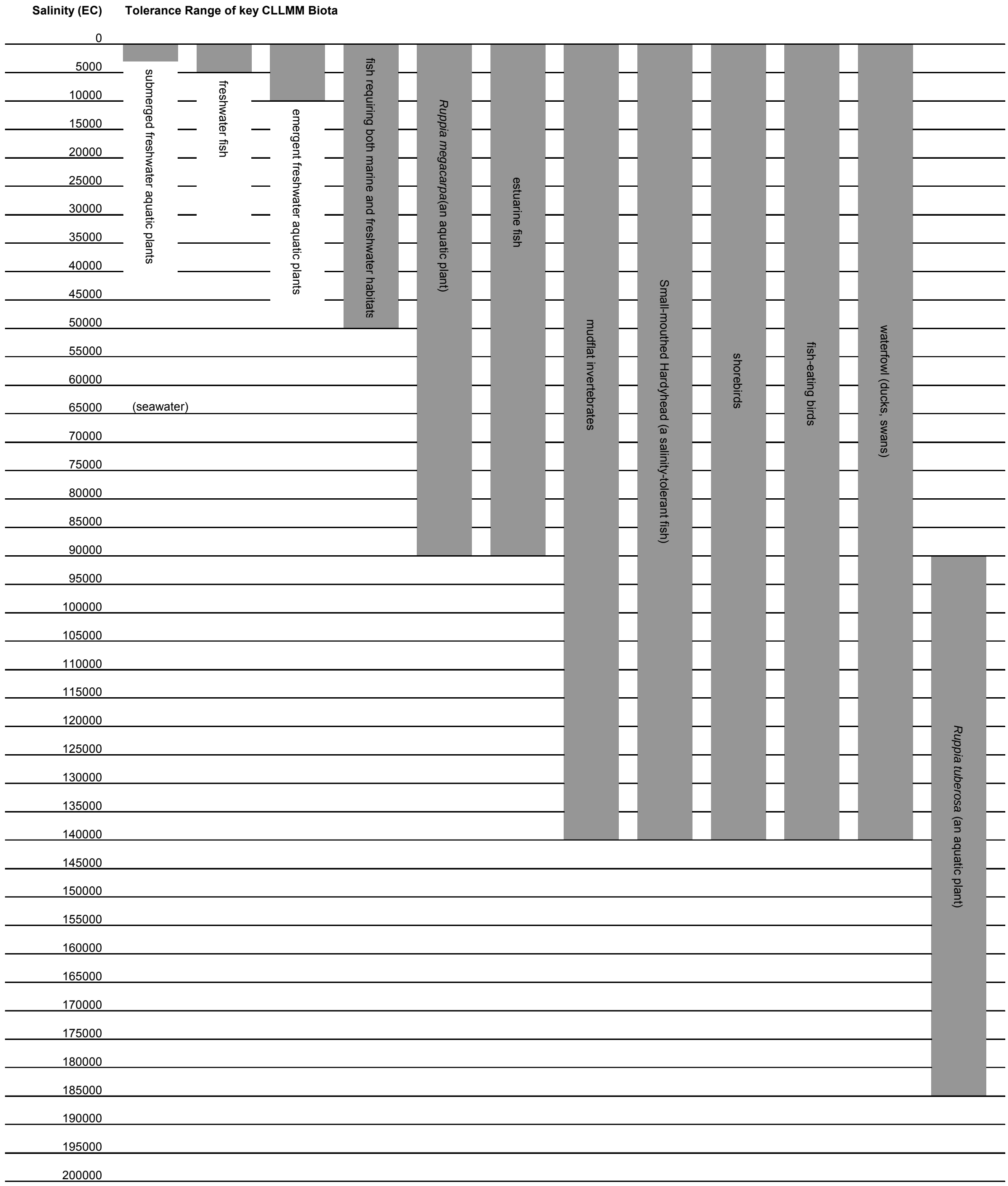

Figure 8. Indicative salinity tolerances for key CLLMM species

Local volunteers continue to provide lifesaving support for the tortoises of the Lower Lakes by rescuing them, cleaning their carapaces of the encrusting tubeworms, and either releasing them in suitable locations or housing them in safe captivity until conditions in the Lower Lakes improve. Local schools have been very active in saving and supporting the tortoises. In particular, both Eastern Fleurieu School Milang Campus and Investigator College have played important roles in rescuing and caring for tortoises.

The security of the water supply for Adelaide and many country towns is also threatened by rising salinity in Lake Alexandrina. There is a risk that saline water could accumulate within the main stem of the river upstream of Lake Alexandrina as a result of wind action. This could contaminate potable water at South Australian pumping locations in the River Murray below Lock 1.

Elevated salinity in the Coorong

Prior to European settlement freshwater flowed into the Coorong at both ends. At the northern end River Murray flows kept the Murray Mouth open and influenced salinity throughout the Coorong [31]. Freshwater flows from the South East of South Australia helped keep the southern end of the Coorong relatively fresh [8,19]. Pre-European salinities in the Coorong South Lagoon were typically 8,300 – 58, 333 EC (i.e. less than seawater)[8].

European settlement of South Australia and the Murray-Darling Basin has seen freshwater inflows to both ends of the Coorong greatly reduced. Construction of the South East drainage network, which commenced in the 1860s [20], greatly reduced flows from the South East. River regulation and irrigation in the Murray-Darling Basin reduced flows into the northern Coorong. South Lagoon salinities of less than seawater have not been recorded since the River Murray floods of 1974/75 [40]. When the CLLMM was listed as a wetland of international importance in 1985, the typical salinity range in the South Lagoon had risen to 90,000 – 230,000 EC [41]. Despite this increase, a healthy ecosystem existed in the South Lagoon and was maintained largely by barrage flows [41]. The South Lagoon featured extensive beds of the aquatic plant Tuberous Tassel (*Ruppia tuberosa*), a high abundance of Small-mouthed Hardyhead fish and mudflats dominated by the larvae of the invertebrate species (a chironomid or non-biting midge) [41]. An important feature of this system was the highly productive seasonal mudflats, inundated in winter/spring and exposed in summer/autumn, that provided feeding habitat for vast numbers of endemic and migratory shorebirds [42]. This ecosystem persisted in the South Lagoon until as recently as 1999 [31].

The current crisis has seen freshwater flows into the northern Coorong - already greatly reduced from historical levels - completely halted. As a consequence, salinity in the South Lagoon has increased rapidly. The ecological consequences of the current crisis have been severe for the Coorong. The Ruppia/Hardyhead/Chironomid ecosystem, and the shorebirds it supported, has largely disappeared from the South Lagoon [31]. It has been replaced by a much simplified system featuring high abundances of highly salt-tolerant Brine Shrimp, Banded Stilt and Chestnut Teal [31]. A vestige of the Ruppia/Hardyhead/Chironomid ecosystem remains in the southern end of the North Lagoon, where its long-term survival is unlikely if current salinity continues to persist.

Fairy Terns are now listed as vulnerable on the IUCN Red List because their abundances have plummeted, particularly in the Coorong. Their ability to breed successfully in the Coorong has been curtailed because of the absence of Hardyhead fish near secure breeding locations in the South Lagoon. The global population for this species is now less than 4,000. In the 1980s in excess of 1350 Fairy Terns used the Coorong – making the Coorong a stronghold for the species. In 2000, nearly 700 Fairy Terns were counted in the Coorong and this has now dropped to around 300. If they continue to fail to breed successfully (as is likely under the current conditions) they will face extinction [43].

Saltmarsh vegetation that occurs around the margins of the Coorong, particularly the South Lagoon, provides feeding habitat for the critically endangered Orange-bellied Parrot. Although the plant species that occur within this vegetation are salt tolerant, the salinity in the South Lagoon is now in excess of the known physicochemical tolerance limits of all known saltmarsh food plant species [44]. Significant dieback of saltmarsh vegetation has been observed. It has been estimated that up to 75 per cent of the saltmarsh vegetation of the CLLMM has been lost/degraded due to excessive salinity and/or inappropriate water levels [37]. Despite increased survey effort, preliminary analysis of May 2009 surveys (a peak period for Orange-bellied parrots in the Coorong) has revealed that their mean number in the Coorong has declined markedly as follows: 23 (2006), 19 (2007), 5 (2008) and 3 (2009) [45].

Due to its proximity to the Murray Mouth the North Lagoon of the Coorong is typically less saline than the South Lagoon, even in periods of low or no barrage flows.

Consequently it has historically supported a different suite of species from the South Lagoon. In the mid 1980s the permanent waters of the North Lagoon contained extensive beds of submerged vegetation, dominated by Large-fruit Tassel (*Ruppia megacarpa*), with Long-fruit Water-mat and Dwarf Grass-wrack also common [41]. Large numbers of waterfowl consumed the leaves, seeds and turions of the Tassel plants, which also provided physical habitat for fish and aquatic invertebrates. These beds of Large-fruit Tassel have now been lost and the more salt tolerant Tuberous Tassel has colonised the southern end of the North Lagoon [31]. Changes to and loss of the aquatic vegetation throughout the Coorong are strongly linked to increased salinity [31].

The submerged aquatic plant Large–fruit Tassel has now been lost from the North Lagoon of the Coorong, where it was once the dominant plant cover. The more salt tolerant Tuberous Tassel was once dominant in the South Lagoon, but is now found in limited areas only in the North Lagoon.

Localised acidification of surface waters

The exposure and subsequent re-wetting of acid sulfate soils in some areas of the Lower Lakes has caused localised acidification of surface waters. For example, pH as low as 2.8 has been recorded in surface water in the Currency Creek area [38]. It is much easier to measure the pH of water than it is to measure the response of the aquatic ecosystem to acidification. However, sampling in the acidified waters of Loveday Bay revealed a complete absence of invertebrates, indicating the potential for biodiversity loss if there is a large scale acidification event. Investigations of the risks to the Lower Lakes ecosystem posed by acidification and associated mobilisation of metals have been undertaken [46]. Most research on the issue is from laboratory studies and is therefore difficult to apply at the whole-of-ecosystem scale. The overall conclusion of risk assessment is that acidification could have devastating effects upon the aquatic ecosystem and that avoidance of acidification is extremely important [46].

Management challenges and approaches

Bioremediation, limestone dosing and the Goolwa Channel Water Level Management Project have been implemented to manage acidification that has already occurred. The introduction of limited amounts of seawater to the site to prevent acidification is a last resort management option, but is being explored.

5.4 Lack of connectivity between the Lower Lakes and the sea

Low water levels in the Lower Lakes have necessitated the closure of the barrages and their associated fishways since March 2007. Thus, the ability for fishes and other aquatic biota to migrate between the marine and freshwater environment of the Lower Lakes has been curtailed. Such migration is critical for a number of species, particularly diadromous fish species (i.e. those that require access to both marine and freshwater environments to complete their lifecycle). The CLLMM is a critical pathway between habitats and the site supports seven diadromous fish species [39].

Diadromous species can be anadromous, living primarily at sea but migrating up rivers to spawn, or catadromous, living primarily in freshwater environments but migrating out to sea to spawn. Catadromous species of the CLLMM historically included Congolli and Common Galaxias and Estuary Perch, while anadromous species included Pouched Lamprey, Short-headed Lamprey and Short-finned Eel [39]. Whilst Estuary Perch may have historically been common [47], in the last 20 years they have been recorded in the CLLMM just twice [48] and may be locally extinct, probably due to a lack of connectivity and loss of estuarine habitat to facilitate breeding and successful recruitment. Evidence suggests that other diadromous species are also under threat of local extinction, particularly Congolli, with lack of connectivity between estuarine/marine and freshwater habitats the probable cause.

Congolli is a small native fish that lives in the Coorong and Lower Lakes and nowhere else in the Murray-Darling Basin. Their average life span is about five years. The completion of their life cycle requires movement between fresh, estuarine and marine waters. In autumn and winter, adult Congolli migrate from freshwater to estuarine and marine waters for spawning. In spring and summer both adults and young migrate back to freshwater. A loss of connectivity between these habitats due to the current crisis has led to a significant decline in the population of Congolli. Congregations of adult Congolli have been observed at Goolwa Barrage, attempting to make their way to the estuary and the sea. Most Congolli captured by researchers in 2009 were about four years old (i.e. nearing the end of the lives). This species is at risk of extinction from the Murray-Darling Basin if suitable connection between the fresh, estuarine and marine environments is not re-established and maintained by winter 2010.

Congolli is the Ngarrindjeri name for this fish. As a Ngarrindjeri ngartji (totem) it is highly valued by Ngarrindjeri people and knowledge of its reliance on interconnected fresh, marine and estuarine environments is deeply embedded in Ngarrindjeri tradition. Ngarrindjeri have been passing their knowledge of ngartjis such as Congolli to non-Indigenous Australians in an attempt to teach them about the ecology of their Yarluwar-Ruwe.

5.5 Social impacts

The combined population in the four local government areas of the CLLMM was estimated to be approximately 44,000 people in the 2006 Census. The Murray Bridge Council area has the largest population with over 17,000 people. The three Lake Albert communities of Meningie, Narrung and Raukkan have a high proportion of Aboriginal people.

While the impacts on people vary, almost everyone who lives around the Lower Lakes or Coorong has been negatively affected by the current conditions.

There are strong community values in the region, related to the beautiful environment, fresh air and birdlife, a feeling of safety, and a history of families who have lived in the area for generations. The residents in the region have a strong sense of community. The area is provided with adequate essential services and a range of assets such as service clubs, sporting clubs, community groups, local government and environmental groups.

However, the economic status and health and wellbeing of the people in the region are being eroded by the impacts of low water levels, drought, economic hard times, rising unemployment and agricultural downturn. Median incomes are relatively low and the labour force has been diminished by skilled workers, especially young people, seeking employment away from home. This has had an impact on family and community life, and has affected volunteering and community service [17].

Social impacts are being seen in an increasing demand for support and counselling services and an increase in individual case management support for welfare and mental health issues. The social impacts include disruption to families, an increase in anger, resentment, depression and even suicide risk. The loss of employment opportunities as a result of economic impacts is encouraging younger people to leave the area.

School numbers have dropped at Meningie Area School from 350 to 220. A teacher from one local school has reported that children have been observed as withdrawn, distracted and anxious, largely due to family concerns over money and employment. In the words of one school child: 'Grandpa was a fisherman, Dad was a fisherman and I was always going to be a fisherman too.'

Many people have expressed a sense of loss as a consequence of the condition of the CLLMM. This is not restricted only to a loss of amenity, but extends also to feelings of emotional or spiritual loss as well. For some people, this is as significant as the economic losses being experienced.

The differing impacts on various sectors of the local communities, coupled with very divergent views on the crisis and the appropriate responses to it, have generated strongly held divisions that have the potential to become entrenched and fracture communities.

The loss of both amenity and environmental values has translated to feelings of psychological and cultural loss for many residents and visitors. For Ngarrindjeri people this is compounded by the damage to spiritual values and the intrinsic link between Ngarrindjeri society and Yarluwar-Ruwe. The importance of these impacts on people should not be underestimated. These are values that can be described as life-affirming and for some people their loss strikes at the heart of the value of life itself.

Management challenges and approaches

Supporting and listening to people and fostering community resilience to the challenges being faced is just as important as building resilience in the ecosystems which are under threat.

5.6 Ngarrindjeri culture

The links between the Lower Lakes and Coorong are central for the Ngarrindjeri and over 4000 Ngarrindjeri people live and work in the area. They have particular responsibilities to care for the land, water and all living things. They have serious concerns about the health of the country and its ecological character, and the current crisis is very stressful for them. In their own words, the Ngarrindjeri people have clearly stated how significantly they are being affected by the loss of ecological character of the CLLMM [49,50].

The following quotes, written years before the current dire conditions, illustrate the gravity of their fears:

We are hurting for our country. The Land is dying, the River is dying, the Kurangk (Coorong) is dying and the Murray Mouth is closing. What does the future hold for us? [10]

With the lack of water in the Murray-Darling system to flush the River, Lakes and Coorong and increased salinity …the ngori [pelican] breeding grounds are shrinking. This ngatji [friend] is no longer thriving in its own ruwi [country]. The stress on the ngatji echoes the stressed ruwi and stressed people [51]*.*

The Ngarrindjeri leadership, in accordance with Ngarrindjeri traditions and responsibilities, has a commitment to minimise damage to the living body of the land and waters, because they understand that the people will also be damaged.

We say that if Yarluwar-Ruwe dies, the waters die, our Ngartjis [totems or special friends] die, then the Ngarrindjeri will surely die. [10]

A Regional Partnership Agreement between the Ngarrindjeri Regional Authority, the Australian Government and the State Government of South Australia, was signed in July 2008. Its aim is to support the development of the Ngarrindjeri Caring for Country program with a focus on sustainable economic development. It specifically addresses the need to increase Ngarrindjeri participation in all aspects of environmental governance in the region. A recent Kungun Ngarrindjeri Yunnan Agreement (*Listen to Ngarrindjeri people talking*) between the South Australian

Government and the Ngarrindjeri Regional Authority complements this regional agreement by providing a framework for developing Ngarrindjeri engagement with long-term Murray Futures programs and planning.

Ngarrindjeri have conducted research into the relationship between loss of ecological character and loss of cultural, economic and social wellbeing. The limited opportunity for the Ngarrindjeri to manage their Yarluwar-Ruwe in accordance with Ngarrindjeri traditions and laws has also significantly contributed to decreased community wellbeing.

Management challenges and approaches

The ecological character of the region needs to be improved through adaptive management that incorporates Ngarrindjeri knowledge and expertise. Ngarrindjeri support ensuring a diversity of healthy wetland habitats and restoring and maintaining connectivity between habitats. Ngarrindjeri cultural flows need to be better understood to inform water allocations, which should acknowledge the fundamental connection between the ecological health of the region and the health of Ngarrindjeri. Incorporating Ngarrindjeri Caring for Country programs into governance and adaptive management is essential.

5.7 Economic impacts

Dairy, irrigation and fishing industries have suffered severe impacts with many businesses closing down and families either leaving the district or making significant changes with a loss of production and income. There is growing concern about the viability of local businesses that are feeling the impacts of declining population and loss of tourism, particularly in Meningie. Ngarrindjeri tourism and cultural education businesses rely on healthy lands and waters. Dairy farmers and graziers have had to reduce stock numbers, and in doing so have lost the benefits of 40 to 50 years of genetic improvement through breeding. Farmers have taken on extra debt and many face the risk of bankruptcy, should current conditions continue. While the value of dryland grazing has not changed significantly, farm incomes have been reduced substantially because of the additional costs associated with alternative feed and water sources.

Between 2002 and 2007 the number of dairy cows reliant on the Lower Murray lakes and swamps declined from over 37,000 to fewer than 11,000, with the value of production dropping from more than $71.7 million to $21 million. There has been an even more drastic decline since 2007. This is a tremendous economic loss to local communities.[2]

Businesses directly connected to water and tourism have experienced a decline in business of up to 80 per cent. This has resulted in loss of employment, some businesses being sold and others being placed on a market with no buyers. Economic impacts within the boating industry extend beyond the CLLMM region because water levels have dropped below Lock 1 at Blanchetown. Hiring of houseboats has dropped by more than 50 per cent in the last five years. Approximately 800 boats have been removed from the Goolwa region because of the low water levels. It is estimated that this has resulted in a direct loss to local businesses of at least $2 million per annum, with significant secondary effects.

In Meningie, Clayton Bay and Milang property values are estimated to have dropped by as much as 30 per cent. While property values appear to have remained stable in Goolwa, there are minimal sales.

[2] Statistics provided by SA Dairy Association and Dairy Australia

6 What is the latest science telling us?

6.1 Consequences of doing nothing more

It is evident that the ecological character of the site has continued to significantly degrade in recent years. As for all ecosystems, there will be a threshold of degradation and fragmentation beyond which recovery will not be possible for some species, species assemblages or components and processes.

It is difficult to predict precisely what this threshold will be, or to predict the potential for the site to recover to the ecological character for which it was nominated as a Wetland of International Significance in 1985, or even the 2006 character, given its current state. However, if no further intervention takes place, it is unlikely that an ecological character that is reminiscent of the historical character of the site can be maintained, and the chance of establishing any type of complex ecosystem will become increasingly unlikely.

The extent of any further ecological damage at this time will affect the long-term outcomes for the site. Short-term management actions are thus critical to ensuring that there is a viable long term future for the site.

If no additional interventions are put in place and a 'do nothing further' approach to management is adopted, it is likely that the following environmental impacts will be observed if current low inflows continue (depending on the timing and volume of future flows of fresh water to the site):

- no flows through the barrages resulting in continued disconnection of the lakes, estuary and Coorong
- continued disconnection of Lakes Alexandrina and Albert from each other
- continued disconnection of the Eastern Mount Lofty tributaries from the Lower Lakes
- loss of the seedbank of keystone aquatic plant species and communities due to desiccation, leading to a loss of habitat for most freshwater fauna
- increased dominance of noxious algae species and increased occurrence of blue-green algal blooms
- acidification of some or all of the water bodies from exposure of acid sulfate soils with resultant loss of fish and other pH sensitive biota
- increased levels of salinity in the Lower Lakes to beyond thresholds for freshwater species
- increased levels of salinity in the Coorong to beyond thresholds for extant species
- increased levels of heavy metals to sub-lethal and/or lethal levels for some species
- increased occurrence of diseases such as epizootic ulcerative disease in fish and possibly Ross River virus in people
- increased levels and episodes of noxious odours
- exhaustion of carbon and key nutrient supplies in the Lower Lakes, estuary and Coorong from lack of plant growth and flow through the site
- continuing loss of specialist or sensitive species particularly diadromous and catadromous fish species (e.g. Congolli)
- continuing declines in populations of endemic and migratory shorebirds and other waterbirds

- increased dominance of generalist species such that re-establishment of complex ecosystems in the future is unlikely
- increased spread of pests such as tube worms with resultant loss of tortoises and crabs and on-going fouling of infrastructure
- continuing hypersalinity and simplification of the Coorong ecosystem
- continuing dredging of the Murray Mouth
- increased carbon footprint at the site from mechanical interventions such as dredging.

6.2 Consequences of introducing seawater

What if seawater were to be introduced temporarily to avert acidification?
In 2009, a major research program was undertaken to fill critical knowledge gaps in relation to acid sulfate soils in the Lower Lakes region. Six research questions were investigated:

1) Was the distribution of acid sulfate soils across the site uniform or patchy? Where were the most high risk areas?
2) How much acid was being formed when soils were exposed to the air, and how quickly was this occurring?
3) Once acid was formed, was it being flushed far from where it was formed? And was it being naturally neutralised?
4) How would the generation of acid and other contaminants be different if the soils were wet with River Murray water, versus seawater?
5) How much could the Lower Lakes naturally neutralise the acid that is being formed?
6) What were the air quality impacts arising from acid sulfate soil exposure?

What we now know:
Approximately 85 per cent of the sediments of the Lower Lakes have the ability to generate net acid upon exposure to the air; however, the severity of this depends upon the soil type. The most severe examples of acid sulfate soils are found in the clay-rich sediments in the middle of Lakes Alexandrina and Albert (particularly the north-western and south-eastern regions of Lake Albert.

The introduction of seawater onto already oxidised acid sulfate soils increased contaminant (acid, metal, metalloid, nutrient) release compared to freshwater, in field and laboratory experiments (i.e. it makes matters worse).

There is a low risk to community health from breathing dust or drinking rain water. The dust was not acidic and there was little indication of acid sulfate soil minerals. However, this assessment was based on limited data and the risk level could change if water levels decline further. Monitoring and evaluation is continuing.

This research project will be completed soon. However, based on what we now know, the best management strategy to avoid the risk of acidification is to ensure sufficient freshwater flows as soon as possible. As an interim measure, the deeper areas of Lakes Albert and Alexandrina should be kept inundated with water to prevent large scale acidification, coupled with the less severe acid sulfate soils being managed locally with, for example, limestone treatment and vegetation plantings. The vegetation plantings will also assist with any potential dust problems.

Pending the final conclusions of the research project and the finalisation of an Environmental Impact Statement into the potential introduction of minimum amounts of seawater to the Lower Lakes, the introduction of seawater is seen as a last resort, short-term response to avert acidification.

What if the barrages were to be removed and seawater were to be introduced as a long term measure?
The opening of the barrages on a permanent basis is not seen as a desirable long-term approach at this current time. Because of limited tidal mixing through the Murray Mouth, the introduction of large amounts of seawater to Lake Alexandrina has been modelled to lead to hypersaline conditions rather than a healthy marine environment, in less than two years. The Murray Mouth is likely to become more congested with sand to the point that water would not be able to flow in and out of Lake Alexandrina with the tides. Without adequate freshwater flows, letting seawater enter Lake Alexandrina on a long term basis is not likely to result in a healthy estuarine or marine ecosystem, but an increasingly degraded hypersaline ecosystem.

The introduction of large amounts of seawater into Lake Alexandrina could also threaten the supply of water for Adelaide and many country areas. Should seawater be introduced in any large volume on a permanent basis, a permanent structure to prohibit seawater entering the off-takes for the potable water supplies, and or a desalination plant would be required.

Furthermore, the South Australian Government is concerned that the introduction of seawater at this time as part of a long term response would adversely impact upon Ngarrindjeri culture and therefore would need to complete discussion with them prior to that occurring.

6.3 How much freshwater is required for longer term management?

A project to determine how much water is required to secure a future for the CLLMM Ramsar Site is currently underway. In the past, several attempts have been made to determine a water target for the site. Although these have usually been based on the best available knowledge, suggested targets have tended to take the form of a single volume, or combinations of a few volumes; the ecological outcomes have often been inferred, rather than directly tested or modelled; and the tradeoffs have not been fully articulated.

Knowledge arising from recent research within the region [31], and the availability of tools such as hydrological and ecological response models, means a more rigorous approach can now be applied to this important question.

The methodology being used is broadly consistent with the approach being promoted by the Murray Darling-Basin Authority to identify the ecosystem water requirements for the key environmental assets of the Murray-Darling Basin, an important component in the current development of the Murray-Darling Basin Plan. The methodology includes the following steps:

Step 1) Identifying ecological objectives for the site.

Step 2) Identifying a range of indicator species and processes that are indicative of the historical character of the region.

Step 3) Determining a flow regime (rather than a single value) that will support the ecological character.

Step 4) Investigating the impact on the ecological character of the region, of smaller flow volumes reaching the site, specifically identifying trade-offs in the components of ecological character that result.

Step 5) Investigating the likely effects of climate change to assess how realistic the identified end-of-system flow is in the future.

Outputs at each step will inform both this Long-Term Plan and serve as inputs to inform the preparation of the Basin Plan. Further work may be undertaken, such as additional modelling to supplement and support these initial investigations.

Progress to date encompasses the first two steps – as follows:

Step 1 findings

The following ecological objectives have been identified for the CLLMM Ramsar site [52]:

1. self sustaining populations
2. population connectivity
3. hydraulic connectivity
4. habitat complexity
5. persistent salinity gradient across the site
6. flow and water level variability
7. redundancy and appropriateness of ecological function
8. aquatic-terrestrial connectivity.

Step 2 initial findings – currently a work in progress

Many species and ecological processes are currently being considered for selection as indicators of what an appropriate water regime may be for the site. These include [52]:

1. 15 vegetation species or species assemblages (such as Tassel species, samphire communities and paperbark woodlands)
2. 12 fish species (such as Murray Cod and Murray Hardyhead)
3. 8 macroinvertebrate species (such as the freshwater mussel, yabbies and tubeworms)
4. 13 ecological processes (such as photosynthesis, decomposition, acidification and salinisation).

Steps 3, 4 and 5 are currently underway

Importantly, Step 4 aims to identify the trade-offs between ecological values that may be required in the event of a longer-term drying climate occurring (see section 6.3 of this document).

What we know:

For the ten year period between 1996 and 2005, the average annual end-of-system flow was around 2,400 GL. During those years, average salinity in the South Lagoon of the Coorong nearly doubled from its previous 114,000 EC units to 212,500 EC units (approaching four times the salinity of seawater). This led to a rapid decline in the ecosystem – aquatic plants, fish and bird life declined dramatically [31]. There is ample documented evidence that many other species were profoundly affected and/or lost by flows at this level [1,31]. Average end-of-system flows of only 2,400 GL per annum have therefore been shown to lead to increasingly hypersaline conditions in the Coorong and detrimental impacts to the ecology of the site.

What we know:

To flush the salt carried down to the site by the River Murray out of the system, there needs to be an adequate head of water above the prevailing sea level to drive a flow through the barrages. Current modelling indicates that River flows substantially below 3,500 GL per annum are insufficient to flush salt to the sea and that the salinity levels in Lake Alexandrina will build up. Even at an end-of-system flow of 3,500 GL per annum, salinity in Lake Alexandrina would be about 1,000 EC units, based on an annual load of two million tonnes of salt.

What we know:

In periods of low flow, costly interventions such as acid sulfate soil treatment, pumping, dredging and more regulators will be required.

6.4 What future climatic scenarios should we plan for?

For the CLLMM, the primary driver of a healthy and functioning environment is the supply of freshwater to the site. Therefore, knowing the likely future availability of freshwater is central to establishing a realistic goal for the future.

In a report to the Murray-Darling Basin Authority [26] the CSIRO recommends that the range of climates that should be planned for should be based on ***both*** the recent dry climate conditions and future climate scenarios using the findings of the Sustainable Yields project [5].

The use of the findings of the CSIRO Sustainable Yields project in planning for future climate scenarios is recommended because they are simple, robust and allow a range of global climate models and global warming scenarios to be considered. This data therefore attempts to represent the range of uncertainly in future climate projections.

Using the recent dry climate conditions as a basis for planning will also allow for the possibility that these conditions may continue and that the current drought could be a part of a global warming trend.

The following table provides an outline of the three key scenarios modelled by CSIRO and the likely implications for water flows to the CLLMM site.

Table 3. Future climate scenarios and their implications for the Coorong, Lower Lakes and Murray Mouth [5].

Climatic Scenario	**Overview**	**Implications for the CLLMM**	**Possible implications for the ecological character of the CLLMM**
Wet 2030 Model Scenario	mean total end-of-system flow = 5,550 GL/y	• 117.3 per cent of mean flow under current development and historic climate at Murray Mouth.	• Water levels in Lake Alexandrina maintained between 0.3 metres AHD and 0.85 metres AHD in most years. In some years water levels may be higher due to the sheer volume of water available. • Wetland systems (including Lakes Alexandrina and Albert, the Coorong, the Murray Mouth and Estuary, the Goolwa Channel and the Tributaries) connected, healthy, resilient and productive. • Tassel species present in both the North Lagoon and South Lagoon of the Coorong. The salinity gradient present in the lagoons promotes the survival of the diversity of biota the Coorong is renowned for.

Climatic Scenario	Overview	Implications for the CLLMM	Possible implications for the ecological character of the CLLMM
Median 2030 Model Scenario	mean total end-of-system flow = 3,482 GL/yr	• 73.6 per cent of mean flow under current development and historic climate at Murray Mouth. • Severe drought inflows to the Lower Lakes (i.e. < 1,500 GL) increase to 13 per cent of years. • Slight increase in the average period between flood events that flush the Murray Mouth. • Maximum period between flood events that flush the Murray Mouth increased to nearly 1 in 8 years. • Average annual volumes of environmentally beneficial floods close to halved.	• Water levels in Lake Alexandrina maintained between 0.3 metres AHD and 0.85 metres AHD for more than 50 per cent of the time. • Wetland systems (including Lakes Alexandrina and Albert, the Coorong, the Murray Mouth and estuary, the Goolwa Channel and the tributaries) connected during these periods. Outside of these times, the Coorong, Murray Mouth and estuary could experience periods of disconnection. • Dredging required to maintain an open Murray Mouth sometimes. • Tassel plants would start to disappear from the South Lagoon of the Coorong.
Dry 2030 Model Scenario	mean total end-of-system flow = 1,417 GL/yr	• 29.9 per cent of mean flow under current development and historic climate at Murray Mouth. • Increase in cease to flow frequency at Murray Mouth to 70 per cent of time. Severe drought inflows to the Lower Lakes (i.e. < 1,500 GL) increase to 33 per cent of years. • Increase in the average period between flood events that flush the Murray Mouth to 1 in 3 years. • Maximum period between flood events that flush the Murray Mouth increased to over 1 in 16 years.	• Water level in Lake Albert dropped to levels close to the acidification trigger of -0.5 metres AHD, with water being pumped from Lake Alexandrina into Lake Albert to avert acidification of the latter. (i.e. these wetland systems would be artificially connected) • Water levels in Lake Alexandrina dropping. • Flows over the barrages would occur approximately every three years in ten. • Dredging would be required to maintain an open Murray Mouth most of the time. • The ecology of the Coorong would be likely to be significantly altered, with Tassel species almost absent from the South Lagoon and contracting from the North Lagoon.

Based on these scenarios, the project predicted that the atypically low annual flows of 2007-08 would continue to occur only 1 per cent of the time under a continuation of the 1997-2006 climate, and 4 per cent of the time under a future ‘dry’ predicted climate to 2030. The succession of dry years we are currently experiencing is therefore expected to be highly abnormal, even under dry future climate scenarios.

However, in addition to these scenarios, we have also described an extreme dry climatic scenario. While this scenario goes beyond that which the science predicts to be common in the future, it is descriptive of the extraordinary situation that is currently being faced by the CLLMM.

Climatic Scenario	Overview	Implications for the CLLMM	Possible implications to ecological character of the CLLMM
CLLMM Extreme-Dry Scenario (based on the conditions currently being experienced)	mean total end-of-system flow = 336 GL/yr	• Severe drought inflows to the Lower Lakes (i.e. <1,500 GL) increase to 100 per cent of years	• Lake Albert disconnected from Lake Alexandrina. • Lake Alexandrina a shallow water body disconnected from Lake Albert, the Coorong, Murray Mouth and Estuary, the Goolwa Channel and the Tributaries. • Large areas of exposed acid sulfate soils in Lakes Alexandrina and Albert, the Goolwa Channel and Tributaries. • No flows over the barrages most of the time. • Coorong becomes hypersaline, and the salinity gradient that supports the diversity of species characteristic of the Coorong non-existent in the South Lagoon and parts of the North Lagoon.

This Plan is therefore based on the three 2030 climate scenarios modelled by the CSIRO Sustainable Yields project and the current dry conditions.

It should be noted that the above tables are based on the current water allocation arrangements, and do not incorporate water recovery targets being achieved by South Australia through the Living Murray initiative or new arrangements which will arise as a result of the development of the Murray-Darling Basin Plan.

The CSIRO Sustainable Yields report assumes the continuation of water sharing arrangements in place at that time. However, the Basin Plan to be developed under the *Water Act 2007* envisages enhanced environmental flows. Therefore, revised water management arrangements in the future could reduce the time the Lower Lakes would be below sea level. For example, it may be possible to improve the ecological character of the CLLMM site by improving water allocation arrangements for the dry and/or median scenarios.

6.5 Is a freshwater future possible?

Drawing from the best available CSIRO information above, it is reasonable to base the starting point for planning for the Lower Lakes around a freshwater future. The development of the first Basin Plan is of central importance in delivering an adequate end-of-system flow of freshwater progressively from 2012.

It is estimated that prior to any development of the Murray-Darling Basin, the average annual flow through the Murray Mouth - the end-of-system flow - was approximately 12,230 GL [5]. It is not possible to return end-of-system flows to this level, but the essential components of the ecological character that make this a wetland of international importance can be re-established and retained even with lower end-of-system flows. Because the flow of freshwater through the Murray Mouth is also critical in maintaining salinity gradients in the Coorong that support the key species for biological processes, a freshwater future for the Lower Lakes also supports a healthy, functioning Coorong [31].

Given these positive predictions for freshwater, an alternative of admitting seawater into the Lower Lakes by opening the barrages on a permanent basis is not seen as necessary nor desirable nor long-term approach at this time.

7 How do we manage for a healthy future?

7.1 A goal for the site, primarily focused on conservation

We have a shared responsibility to conserve the ecological character of the CLLMM – a wetland site recognised for its international importance. In addition to the site's exceptional environmental significance, we are mindful of its cultural, social, recreational and economic value, and our obligation is to promote its wise use.

The goods and services that drive the regional economy and support local social systems stem largely from a healthy and functioning environment. It is therefore critical that our primary focus is to conserve the species, ecological communities and ecosystems services of the site. In doing so, our actions will ensure regional and economic wellbeing in the long term.

Our goal is to secure a future for the CLLMM as a healthy, productive and resilient wetland system that maintains its international importance. Achieving this will directly support the local economy and all its communities.

This goal is consistent with the Ramsar Plan for the site (the overarching statement of its values) and the Icon Site Management Plan (the key operational plan) and will be supported by other operational plans as they are developed.

Achieving our goal for the site will see: *a freshwater Lake Alexandrina, operated with lake levels varying between 0.3 metres and 0.6 metres AHD for the majority of the time, with occasional surcharging to 0.8 metres AHD. A salinity target of 0.68 g/L (1000 µS /cm; EC) on a rolling five year mean should be met for Lake Alexandrina, to ensure that the freshwater components and processes can be supported. Occasional surcharging is beneficial for floodplain processes, such as recruitment of long-lived vegetation (e.g. samphire, paperbark stands) and native fish.*

Achieving our goal for the site will see: *the return of captive Southern and Yarra Pygmy Perch fish to wild habitats in the lakes and around the lake islands that are connected and well-vegetated to support proliferation of these fish into secure populations.*

Achieving our goal for the site will see: *a freshwater Lake Albert, possibly operated at a lower level than prior to 2006, so healthy paperbark, reed beds, grasslands and samphire communities could be established at the higher lake beds. A target salinity of 1500 EC or less, on a five-year average, should be met to ensure that any increases in salinity, would not be too rapid nor extreme for the establishment of complex wetland mosaics.*

Achieving our goal for the site will see: *the Murray Mouth kept open mostly by river discharges that maintain the connection between the Coorong, the Lower Lakes and the Southern Ocean.*

Achieving our goal for the site will see: *enhanced connectivity within the region with the removal of all temporary regulators and enhanced bio-passage through the barrages.*

Achieving our goal for the site will see: *a dynamic estuarine zone, varying between the Murray Mouth and Pelican Point in times of low flow and extending beyond this zone in periods of high flow.*

Achieving our goal for the site will see: *variable River Murray and Eastern Mount Lofty Ranges tributary inflows to the lakes and discharges from the lakes to the estuary, Coorong and Southern Ocean that mimic natural flow patterns and optimise ecological benefits across the different wetland habitats.*

Achieving our goal for the site will see: *a salinity and water level gradient along the Coorong, with average annual salinities closer to the long term average of around 40 g/L (approximately 57000 EC) across the system.*

Achieving our goal for the site will see*: no additional channels in the system. No connection between Lake Albert and the Coorong, or new connections between the Coorong and the ocean, for example. Neither would contribute to the ecological resilience of the system, and both are likely to result in further loss of ecological character for the region.*

Achieving our goal for the site will see: *the return of amenity for local residents and their communities.*

Achieving our goal for the site will see: *adequate flows of water of a suitable quality to promote a living Ngarrindjeri cultural life.*

Achieving our goal for the site will see: *a prosperous tourism industry, with conditions suitable for boating and recreational fishing, supporting a wide range of accommodation, hospitality and other tourism-related local businesses.*

Achieving our goal for the site will see: *the continuation of agricultural industries, albeit in a modified form.*

7.2 What is our approach?

In Section 4 of this document, a number of ecological, social and economic threats to the site were identified. Acid sulfate soils, elevated salinity, ecosystem degradation and a lack of connectivity between the Lower Lakes and the sea were identified as consequences arising from low freshwater inflows to the site. The key threats to the site include the over-allocation of water across the Murray-Darling Basin system, drought, climate change, future sea level rise, stable lake water levels and the disconnection of the Coorong from the South East wetlands.

Many, if not all of these threats, impacts and consequences are interrelated and cannot be addressed in isolation. Many appropriate actions at the site also address multiple threats, impacts and consequences.

To comprehensively address these threats, impacts and consequences, and to achieve our goal, we will manage the site using the following two approaches:

1. Implement **mitigation** actions which aim to:

- reduce the rate of ecological degradation
- remediate damaged areas
- prevent immediate and permanent ecological collapse
- maintain the ecosystem until conditions improve.

2. Implement **adaptation** actions which aim to:

- build and maintain a resilient ecology at the site which can adapt and respond to a drier future climate.

Given that the outlook for the future climate will see changes in terms of freshwater availability, it is important that both approaches outlined above are undertaken concurrently. These approaches are therefore not considered to represent stages in the implementation of management actions for the site - necessary 'short-term' mitigation measures must be undertaken in tandem with 'longer-term' adaptation measures.

Nonetheless, given the current extremely dry conditions, the mitigation actions must be delivered urgently.

This method of management recognises that the ecological character of the site is changing, and will continue to change over time. The concept of rehabilitation to a former state is not applicable. However, it is possible to maintain a wetland of international importance, albeit a changed and changing wetland.

This method of management will also ensure that short-term remedies do not limit future management options for providing long-term positive ecological outcomes in an uncertain future climate. How the various mitigation and adaptation actions can be applied to address the management issues arising from the future climate scenarios identified in section 6.4 is discussed further in Section 11 and Appendix 8 of this document.

Furthermore, the information arising from the project to determine how much freshwater is required for the longer-term management of the site (see section 6.2) should assist in determining how trade-off decisions will be made among ecosystem values in the event of a longer-term dry climate occurring.

8 What has already been done?

The South Australian Government has worked closely with other levels of government, local communities, scientists, the Ngarrindjeri Regional Authority, technical experts and engineers to identify and implement appropriate response measures to the challenges at the site. Measures which have been implemented thus far can be classified as 'mitigation', 'adaptation', 'enabling', 'complementary' and 'last resort', to address the various issues that have occurred, or are expected to occur, at the site.

8.1 Mitigation measures

These measures are designed to lessen the impacts resulting from the continuation of low or non-existent end-of-system flows. They have been implemented to prevent continued ecological degradation, until conditions improve. Some of these mitigation measures are of a temporary nature, to deal with immediate challenges, and not suitable for long-term application.

Initial response measures

Initial response measures were implemented as a result of low or non-existent end-of-system flows to reduce the rate of ecological degradation and maintain the ecosystem. The measures implemented since 2002 include:

- Dredging to keep the Murray Mouth open.
- Improving the sealing of the barrages to reduce seawater intrusion to Lake Alexandrina and Goolwa Channel.
- Recovery of the South Australian 35 GL target share from the Living Murray initiative. The Coorong and Lower Lakes, as one of the six Icon Sites, is entitled to a portion of the 500 GL water recovery initiative, which was a first step of the national program.

Acid sulfate soils

A primary threat at the site is the presence and potential for increased exposure of acid sulfate soils as a result of declining water levels. A series of emergency mitigation measures aimed at preventing and controlling soil acidification has been put in place, including:

- Goolwa Channel Water Level Management Project works, including the installation of regulators at Clayton Bay and Currency Creek to retain freshwater, maintain soil saturation and prevent further soil acidification.
- Limestone application in Currency Creek, Finniss River and Goolwa Channel to manage acidity released from acidified soils.
- Revegetation and bioremediation including seeding of several thousand hectares of exposed lakebed sediments with annual crops, supported with funding by the Australian Government.
- Purchase of freshwater on the temporary water market to maintain higher water levels.

Revegetation works in the Lower Lakes

A trial involving seeding large areas of the Lower Lakes has been carried out to stabilise soils and prevent soil erosion in the coming spring and summer. As well as addressing soil erosion, the trial will also test how effective the technique is in managing acid sulfate soils on this scale. The project included aerial seeding of approximately 4,500 hectares around the barrage islands in Lake Alexandrina and exposed areas in Goolwa Channel, machine seeding of approximately 500 hectares in Lake Albert and the northern shorelines of Lake Alexandrina, and applying over 300 tonnes of shallow rooted ground cover seed. Initial results show the seeding has successfully covered the exposed shoreline. Close monitoring is now being carried out to find out how well the trial addresses soil erosion and acid sulfate soils in the region.

- Construction of a bund at the Narrung Narrows between Lake Alexandrina and Lake Albert. The bund allows the Lakes to be managed independently of each other while the current crisis continues. Pumping from Lake Alexandrina to Lake Albert was undertaken until June 2009 to maintain water levels in Lake Albert above the predicted acidification trigger point. Further pumping of 35 GL in 2010 is anticipated to maintain saturation within the central area of Lake Albert.
- An acid sulfate soil research program, including mapping of soils, acid generation mobilisation and transport, and the potential effectiveness of sub-surface barriers.

Increased salinity
In response to increasing salinity levels in Lake Albert, a 'fish down' has been implemented to remove as many fish as possible before a predicted fish kill takes place.

Biodiversity loss
A number of measures have been implemented to reduce the risks of loss of biodiversity from the Lower Lakes, including:

- ex situ conservation of fish species at risk of local extinction as a consequence of declining water quality and quantity
- environmental watering of high priority wetlands through programs including The Living Murray
- the rescue, treatment and care of tortoises that have been encrusted by tubeworms
- assessing the viability of vegetation seedbanks.

Fish conservation

The threat of local extinction of fish species has led to specific conservation measures. Yarra Pygmy Perch are being bred in captivity at Cleland Wildlife Park. Environmental water has been delivered to Boggy Creek on Hindmarsh Island to conserve a population of Murray Hardyhead, while a captive population has also been established. Environmental water has also been delivered to Turvey's Drain near Milang to conserve Southern Pygmy Perch, Murray Hardyhead, Tamar Goby and Dwarf Flat-headed Gudgeon.

8.2 Adaptation measures

As conditions may not return to the historical state that supported the site, measures must be taken that allow for the site to function under stable but altered conditions. The purpose of adaptation measures is to develop long-term sustainable solutions for the site. Some of these measures are still at a developmental stage and will be fully implemented in the future. Development has been initiated on the following measures:

- installation of potable and irrigation pipelines and standpipes to reduce reliance of communities on water from the Lower Lakes, as part of the Murray Futures program and supported with funding by the Australian Government
- investigations into the options for reducing salinity in the Coorong's South Lagoon, including re-establishing water flows from the South East and pumping hypersaline water to the ocean
- improving efficiencies in irrigation practices
- commencing investigations to determine end-of-system flows to maintain the ecological integrity and resilience of the system.

Determining the end-of-system flow is a fundamental and critical adaptation measure for the entire region. End-of-system flows seek to define the amount and frequency of water required to sustain an acceptable ecological character. An end-of-system flow is not intended to provide a single annual flow value, but to identify the range and variability required to meet the ecological needs of the system. It is expected that the end-of-system flows will incorporate a rolling flow average including a frequency or time component.

8.3 Enabling actions

Enabling actions are those taken in order to facilitate the implementation of emergency response or mitigation actions. Without these enabling actions, other measures within the region would not be possible. These actions include:

- Signing of the Kungun Ngarrindjeri Yunnan Agreement, an overarching consultation agreement between the Ngarrindjeri people and the South Australian Government.
- Continuing research into both the natural and socio-economic systems of the region.
- Input into the preparation of the Murray-Darling Basin Plan to set more sustainable policies for the use of water and policies to manage risks to water resources across the entire Murray-Darling Basin.
- Building up local community and Ngarrindjeri community involvement in on-ground actions to revegetate and bioremediate the Lower Lakes. These actions are part of a $10 million program funded by the Australian Government, plus a Goolwa to Wellington Local Action Planning Group initiative – the Coorong and Lower Lakes Community Eco-Action Project – to increase community involvement in helping the area adapt to a rapidly changing environment during the current period of extreme low end-of-system flows.
- Water Allocation Planning for both the Eastern Mount Lofty Ranges and South Australian Murray-Darling Basin System to address social, economic and environmental water needs.

8.4 Complementary actions

These are actions put forward by the South Australian Government and which will have an overall benefit for the region. Benefits from these initiatives are indirect since they reduce the community reliance on the river and lakes for drinking water. Complementary actions also seek to improve the equity of water sharing within the Basin.

- the Water for Good plan [53] to secure water for South Australia's future and reduce South Australia's reliance upon the River Murray
- investment in waste water recycling and storm water re-use and the commencement of construction of a $1.83 billion desalination plant for Adelaide [53]
- the South Australian Government is pursuing a constitutional challenge to upstream States to protect South Australia's rights to water.

8.5 Last resort measures

Last resort measures are those that the South Australian Government does not want to take, but must be prepared to consider in the event that critically low end-of-system flows continue for some time. There are two such potential last resort measures:

- a temporary weir near Pomanda Island to protect South Australia's water supply below Lock 1, should the salinity or acidification risk in Lake Alexandrina become unacceptable
- technical investigations and the commencement of an Environmental Impact Statement on the environmental implications of the introduction of a minimal amount of seawater to Lake Alexandrina to maintain its level above the trigger level for acidification.

PART 2

9 Identifying mitigation and adaptation measures for the longer term

Selecting the right actions to be undertaken to secure the future of the CLLMM site has been based on an extensive review of the science and knowledge of the site, a broad public consultation process, and technical feasibility assessment of likely actions. This process was undertaken as a series of steps.

9.1 The first step

The first step in this process was to identify and collate a list of the many proposals and ideas for addressing the management challenges facing the site. These were drawn from a recent Senate inquiry [54] and an extensive community consultation process undertaken in April-June of 2009 and August–September 2009 in particular.

9.2 The second step

The second step was to assess the list of proposals using the decision framework depicted below.

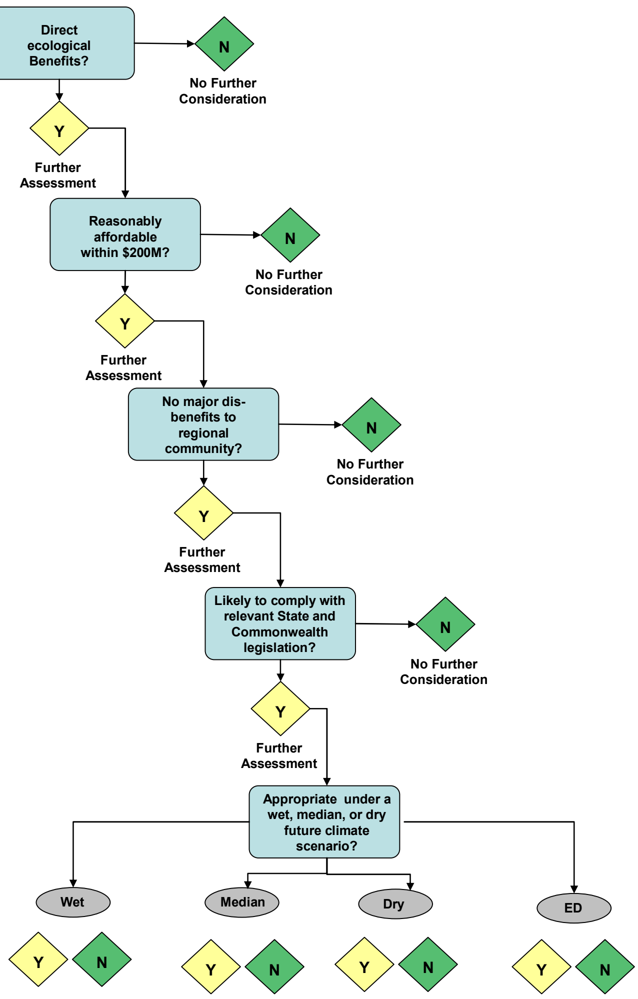

Figure 9. Decision framework for selecting proposals for detailed technical feasibility assessment.

For an explanation of the future climate scenarios used for the above assessment process see Section 6.4 of this Plan.

9.3 The third step

This list of proposals was then prioritised using three hierarchical criteria (i.e. Criterion 1 was considered the most important, with Criterion 3 the least important).

Criterion number	Criteria	Rationale
1	Actions which provide for ecological benefits during the most 'high risk' situation (i.e. during a dry or extremely dry future climatic scenario).	These actions would best prevent immediate and irreparable ecological collapse.
2	Actions which provide for ecological benefits across the full range of climatic scenarios.	These actions would best build a resilient ecology, one which is able to adapt and respond to any possible future climate.
3	Actions which provide for ecological benefits under at least one climatic scenario, and no negative effects under the other climatic scenarios.	These actions are identified as 'no regrets' actions.

9.4 The fourth step

Those proposals which were prioritised during the third step then underwent detailed technical feasibility assessment. These technical feasibility assessments provide detailed analyses of the objective, rationale, critical assumptions and costings of implementing the action or intervention. An overview of this information is provided within Section 10 of this plan in relation to each of the proposed management actions.

9.5 The benefits of this selection process

This process has identified management actions which:

- provide ecological benefits to the site under a range of possible future climatic scenarios, in particular during dry or extremely dry periods
- are affordable within the $200 million budget
- create positive social and economic impacts where possible
- are technically feasible
- provide value for money
- are interdependent and complementary, with actions to be undertaken as a package rather than as stand-alone, and with an emphasis on the total site.

This is considered to be an efficient approach to planning for the site because it does not rely on the development of multiple plans to cover the multiple potential future climatic scenarios. Furthermore, our limited ability to predict the future climate in any detail means that we cannot readily shift our management response between, for example, implementing a detailed plan for a 'wet' climate scenario and a detailed plan for a 'dry' climate scenario. The process outlined above has identified actions which will be implemented using an adaptive management approach which responds to any of the likely climatic scenarios. This is outlined in more detail in Section 11.

Other management actions which were considered

Some of the management actions considered for the site were found to be unsuitable for the future of the site after detailed examination. A description of the key actions in this category can be found in Appendix 4.

10 Priority management actions (2010 – 2014)

While this Plan is indeed a plan for the long-term, the time horizon adopted in detailed planning for the management actions at the site assumed a worst case climate scenario over the next five years, as a starting point. This time horizon also broadly links with the timeframe for implementation of the Murray-Darling Basin Plan.

As indicated earlier in this document, there is no substitute for freshwater in adequate volumes to ensure a future for the site. Hence implementation of the Basin Plan, with its emphasis on environmental outcomes, from approximately 2014 onwards is the key strategy for a sustainable future.

10.1 Environmental water management actions

The health of the CLLMM is dependent on what is happening across the entire Murray-Darling Basin. It is the responsibility of all Basin governments and whole of basin solutions are required. Over-allocation of the water resources of the Basin has been a factor in the ecological degradation of the Lower Lakes and Coorong under historical climate. Current water sharing arrangements do not ensure that the environmental water needs of the site are met during dry periods and times of drought. Climate change may exacerbate this situation.

The key long-term management action for the site is to secure adequate freshwater and to ensure monitoring is in place to demonstrate that the flow is sufficient to support the desired ecological character. Without adequate freshwater flows, the success of the actions proposed here will be compromised.

Options for securing adequate freshwater include; establishing sustainable diversion limits throughout the Basin through the Murray-Darling Basin Plan, securing environmental entitlements through the Commonwealth Environmental Water Holder and The Living Murray initiative and better management of unregulated flow events for environmental outcomes.

The Basin Plan must incorporate provisions that return the Basin to sustainable levels of extraction and ensure environmental flows for the CLLMM. The environmental watering plan established under the Basin Plan must contain an environmental management framework that will provide adequate environmental water regimes for the site.

The Commonwealth Environmental Water Holder (CEWH), under the Water for the Future program, is purchasing water entitlements that will become available for Murray-Darling Basin ecological assets. Water availability is currently restricted but the CEWH has the potential to hold up to 3,000 GL of entitlement in coming years.

As an Icon Site the CLLMM site is already prioritised to receive water through The Living Murray initiative. Depending upon climatic factors, up to 485 GL of water will be available to be shared between six sites. Restrictions currently limit this volume, and the CLLMM site has only received very small volumes of water over the last 12 months for several refuge sites around the lakes. Representatives of NSW, Victoria and South Australia, through the Murray Darling Basin Authority Environmental Watering Group, develop an annual environmental watering plan to prioritise use of The Living Murray water each year and allocate through consensus decision making in response to water bids.

The River Murray Environmental Manager has the responsibility for managing, allocating and delivering environmental water for the main stem of the River Murray in South Australia. It utilises an environmental watering framework to develop annual environmental watering proposals subject to monitoring outcomes and water availability.

In order to avert irreversible environmental damage, South Australia aims to secure a water reserve to enable the state to supplement and enhance environmental water delivery to ecological assets including the CLLMM. The South Australian Government intends to, subject to inflows during 2009-10, secure a minimum of 120 GL for the Lower Lakes (in addition to 50 GL purchased during 2008-09). Delivery of this water could commence as soon as possible according to an optimised delivery pattern.

South Australia will continue to actively bid for environmental water from both the CEWH and The Living Murray. While the water that is currently available from The Living Murray and CEWH is not sufficient to provide for all the environmental water requirements for the CLLMM site, any additional water can make an important difference to the site during this crisis period where the main focus is to prevent acidification and salinisation at the site.

To achieve a management strategy that will assist the site to recover beyond the drought, the South Australian Government will work with the Australian Government and the Murray-Darling Basin Authority to develop an agreed strategy for the provision of an annual environmental water allocation to the CLLMM.

In addition, South Australia will work with the Murray-Darling Basin Authority and other Basin jurisdictions to explore improved water sharing arrangements under the Murray-Darling Basin Agreement that will deliver better environmental outcomes for the site.

Until the Basin Plan takes effect and the water needs of the ecosystem are met, there are a number of additional actions that will feasibly and cost effectively:

- reduce the rate of ecological degradation
- remediate damaged areas
- prevent immediate and permanent ecological collapse
- maintain the ecosystem until conditions improve
- build a resilient ecology at the site to adapt and respond to a drier climate.

These actions also take into account the complex nature of the ecology of the CLLMM. For this reason, it is unlikely that one action on its own will be sufficient, and many actions are dependent upon others. In considering what is required to address the many threats to the site and their impacts and consequences, the following actions should therefore be considered as a package rather than stand-alone actions.

The list of actions which follow, adopt the ***mitigation*** and ***adaptation*** terminology of Section 8. Actions have been classified as 'mitigation', 'mitigation and adaptation' 'adaptation' and 'enabling' measures.

10.2 Priority mitigation measures

10.2.1 Maintenance of an open Murray Mouth

Maintaining an open Murray Mouth is critical for maintaining a healthy Coorong and Lower Lakes environment. Under normal flow situations, the Coorong is fed with freshwater from the River Murray and Lake Alexandrina as it drains to the Murray Mouth through the barrages. But in dry periods with no flow over the barrages to the seaward side and the Coorong, the primary water input to the Coorong is through the Murray Mouth. Since 2002 barrage flows have been inadequate to maintain an open Murray Mouth without management intervention.

This action is one of three complementary measures designed to improve the health of the Coorong. The other two related actions are described in Sections 10.1.2, 10.2.4 and 10.3.1.

The benefits of an open Murray Mouth include that it:

- maintains tidal variation and salinity levels which are conducive to the ecology in the Coorong and estuary
- allows cool, well oxygenated seawater into the Coorong to assist in the life cycle of the key species which make up the ecological character of the site
- enables the construction of channels to finally discharge the accumulated salt, from the River Murray upstream, out of the Murray-Darling Basin.

The current dredging program has been in place at the Murray Mouth site since 2002 and is currently operated by the Murray-Darling Basin Authority. It is funded to continue until June 2014. To ensure that dredging remains the best value for money and most effective option to keep the Murray Mouth open, the technical feasibility of this activity was examined with a number of alternative options. Based on this assessment, the continuation of dredging at the current level of effort remains the preferred option in the current circumstances for the following reasons:

- the current program is meeting the key performance indicators
- dredging, when there are insufficient flows through the barrages to maintain an open Murray Mouth, offers the lowest cost solution to achieving an open Murray Mouth
- the current dredging effort has shown significant reductions in operating costs over the previous three years and methods continue to be investigated to further reduce and refine this spending
- dredging offers a high level of flexibility and adaptability through its contract operating regimes
- dredging offers a less invasive and less permanent construction alternative than other options considered.

In a snapshot

Location of activity: Murray Mouth

Activity addresses: the lack of connectivity between the Lower Lakes and the sea, elevated salinity and ecosystem degradation arising from low inflows.

For more information, see: Maintenance of an open Murray Mouth Technical Feasibility Assessment.[4]

10.2.2 Coorong Salinity Reduction Program – Pumping hypersaline water out of the Southern Lagoon of the Coorong

This action is one of three complementary actions designed to improve the health of the Coorong. Currently salinity levels in parts of the Coorong are at least five times higher than seawater. This action, together with the maintenance of the Murray Mouth and the diversion of southeast drainage flows to the Coorong, will reduce salinity in the South Lagoon, slow or prevent a future increase in salinity levels and maintain connectivity between the Coorong and the sea.

Currently the salt loads of the Coorong South Lagoon is so high that a major flood in the River Murray with barrage flows in excess of 10,000 GL would be required to restore target salinities, in the absence of any other intervention. This action is a one-off suite of structural interventions aimed at reducing salinity by exporting salt out of the system.

The benefits of this action include:

- immediate reductions in salinity in the North and South Lagoon of the Coorong
- facilitation of the ecological recovery of the South Lagoon by reducing salinities to within target levels for the *Ruppia/chrinomid/hardyhead* ecosystem
- increased seagrasses (and allowing for the transplanting of native aquatic plants), return of wading birds and fish in the Coorong.

There have been concerns that this pumping could lead to a higher level of dredging to maintain an open Murray Mouth, due to increased transport of sand with the inflows of replacement seawater through the Mouth. Recent modelling suggests that the pumping is likely to have a very small impact on the efficiency of the Murray Mouth dredging program. It must be noted that pumping alone does not offer a permanent solution to the current condition of the Coorong. Regular, fresh river flows over the barrages are the only permanent solution.

In a snapshot

Location of activity: South Lagoon of the Coorong

Activity addresses: the lack of connectivity between the Lower Lakes and the sea, elevated salinity in the Coorong and substantial ecosystem degradation arising from low inflows.

For more information see: Coorong Salinity Reduction Program – Pumping hypersaline water out of the Southern Lagoon of the Coorong Technical Feasibility Assessment [55]

10.2.3 Limestone dosing

The limestone dosing process is expected to play a critical role in the continuing management of acid sulfate soil treatment throughout the site. Limestone dosing is one of three complementary measures aimed at managing acid sulfate soils. The other actions include those described in 10.1.4 and 10.1.5.

The nature of this treatment allows it to be used for emergency management of areas of high acidity risk. Limestone can be applied quickly through the construction of limestone barriers, applying a limestone slurry or aerial dosing.

Limestone dosing trials have been carried out at Currency Creek and Finniss River to test a range of dosing methods. Trials have generally been successful at raising low pH levels, particularly when applied using aerial dosing methods. Aerial dosing has also proven effective at treating water acidity in inaccessible or remote areas. Key strengths of the trials have included:

- identification of a variety of limestone application methods
- the scale of the action provides flexibility and suits an ‘as needs’ approach
- has been proven to be an effective tool for managing acid sulfate soils.

The continuing process for implementation is:

- continued monitoring of pH levels throughout the site to ensure that acidity does not exceed prescribed thresholds
- limestone application in acid sulfate hotspots as required
- refining the techniques for large-scale delivery of limestone now that the delivery method for limestone on a medium scale (for example, within Currency Creek) is understood.

In a snapshot

Location of activity: Lake Albert, Lake Alexandrina and the tributaries

Activity addresses: acid sulfate soils arising from low inflows.

For more information see: Managing Acid Sulfate Soils Technical Feasibility Assessment [56]

10.2.4 Installation of sub-surface barriers

Sub-surface barriers are designed to manage areas of high acid sulfate soils risk by increasing soil moisture. This limits the oxidation of pyritic soils and prevents acidity moving to the remaining water body. Several locations throughout the CLLMM site have been identified as areas that may benefit from this action. Trials are underway to ascertain the feasibility of barrier construction and to determine the feasibility of this approach.

Construction of sub-surface barriers typically includes the excavation of trenches which are then filled with a control material that assists with the retention of subsurface groundwater. Trials are taking place to determine the most effective method of barrier construction, but processes may include:

- sub-surface bentonite slurry wall
- sub-surface trench backfilled with dry bentonite
- surface and sub-surface impermeable barriers.

Sub-surface barriers have been considered for specific locations in Lake Albert and Lake Alexandrina. If successful, the barrier approach could be designed and installed in other areas of the region.

The trials of this approach are intended to determine whether the barriers will increase the retention of sub-surface moisture and saturation of soils with groundwater, thus reducing the rate of oxidation of pyritic soils and the amount of acidity formed.

In a snapshot

Location of activity: Lake Albert, Lake Alexandrina (if deemed feasible)

Activity addresses: acid sulfate soils arising from low inflows.

For more information see: Managing Acid Sulfate Soils Technical Feasibility Assessment [56]

10.2.5 Lake Albert Water Level Management Program

With Lake Albert water levels at critically low levels, this management action proposes the pumping of approximately 35 GL of water from Lake Alexandrina to Lake Albert between January and June 2010. This project includes the stabilisation of the Narrung bund, the installation of pumps and pipes and the commencement and monitoring of pumping activity to ensure requirements are fulfilled.

The level for the lake will be maintained at no lower than -1.0 metres AHD in 2010. This will ensure that the highest risk acid sulfate soils would be kept inundated.

Maintaining a water level of -1.0 metres AHD will still result in nearly half of the lake bed being exposed, but these areas will be managed by alternative methods such as limestone dosing (see Section 10.1.3) and vegetation plantings (see Section 10.2.1).

The pumping of water into Lake Albert, with no significant change to the Narrung bund, is seen as the most appropriate course of action to take in the immediate term, due to:

- the perceived urgency shown by water level modelling for the coming summer
- the very high risk of large scale acidification in Lake Albert if water levels drop too low.

Alternative options (eg different quantities of water to be pumped) will be considered based on the conditions that may arise in the future.

In a snapshot

Location of activity: At the Narrung Narrows between Lake Albert, Lake Alexandrina (for the benefit of Lake Albert)

Activity addresses: acid sulfate soils, elevated salinity and ecosystem degradation arising from low inflows.

For more information see: Lake Albert Water Level Management Technical Feasibility Assessment [57]

10.3 Priority mitigation and adaptation measures

10.3.1 Vegetation plantings

Vast areas of previously inundated sediment at the CLLMM site are becoming exposed due to declining water levels. These exposed sediments are creating the following impacts:

- vulnerability to wind erosion
- creation of health and environmental issues from dust
- prevention of the regeneration of flora
- loss of habitat
- an environment which is unappealing aesthetically to the community and tourists
- acidification of soils in areas within the lake beds.

This action proposes the large-scale vegetation of exposed sediments at the site at the following locations:

- Currency Creek, Finniss River and Goolwa Channel
- Lake Albert
- Lake Alexandrina
- Barrages and around islands.

Specific site selection will be based on current land use, site access and fencing requirements. The approach will be adaptive and involve a combination of activities such as direct seeding, machine seeding and tube stock planting. Species selection will be determined by factors such as moisture availability, sun exposure, soil type, salinity and acidity. A combination of plant species will be utilised with the objective of contributing to the ecological and aesthetic value of each site selected.

The action is technically feasible. Large-scale revegetation has been used successfully and widely to rehabilitate many types of land, including degraded farming land, saline sites and extractive industry sites. Wherever possible the action will leverage existing farming and revegetation machinery and operations. The action will also involve numerous community nurseries to ensure large scale cost-effective production of the selected species.

The benefits of this action include:

- vegetation will bind surface soils together to reduce erosion
- vegetation will encourage the growth of soil based bacteria which can inhibit and reverse the mobilisation of acid sulfates in the soils, and keep the soils in an inert state
- vegetation can contribute to the prevention of mobilisation of heavy metals and keep those metals inert in the soils
- vegetation can provide a more positive environment for other native flora and fauna to inhabit the affected areas.

The necessary fencing, weed and vermin control measures will also be undertaken as part of this activity to increase the likelihood of remediation success.

Fencing is proposed around the following areas:

Location	Coverage
Currency Creek, Finniss River and Goolwa Channel	40 km
Barrages and islands	30 km
Lake Albert	60 km
Lake Alexandrina	135 km

Table 3. Proposed fencing works

In a snapshot

Location of activity: Lake Albert, Lake Alexandrina, Goolwa Channel and around Hindmarsh Island

Activity addresses: ecosystem degradation and acid sulfate soils arising from low inflows.

For more information see: Vegetation Program Technical Feasibility Assessment [58]

10.3.2 Construction of artificial wetland at Meningie

Meningie is the gateway township to the Coorong National Park and is a popular recreational bird-watching, boating and tourist destination. Low water levels in Lake Albert have significantly reduced the aesthetics of the foreshore. Based on examples of successful wetland projects in other areas, the construction of an artificial wetland at Meningie is proposed to help to restore a more appealing environment there.

Detailed feasibility assessments of the Meningie foreshore and trials of local revegetation indicate that the area is suitable for this management action which aims to regenerate habitats for local and migratory wildlife and native plant species. This measure is currently in a conceptual design phase.

The action proposes the construction of a series of interlinking ponds, a one kilometre boardwalk and revegetation of the foreshore.

The Meningie wetland proposal will address and deliver on the following outcomes:

- prevent further exposure of acid sulfate soils in the area adjacent to the Meningie township,
- rehabilitate the areas exposed currently and enable the site to respond when lake levels increase,
- create ecological resilience at the site and provide habitat for fauna and flora,
- increase knowledge and understanding in the community regarding wetlands.

In a snapshot

Location of activity: Lake Albert, adjacent to Meningie

Activity addresses: ecosystem degradation and Acid sulfate soils arising from low inflows.

For more information see: Managing Acid Sulfate Soils Technical Feasibility Assessment [56]

10.3.3 Protecting Critical Environmental Assets Program – Critical Fish Habitat and Refuge

This management action aims to protect critical environmental assets through the active management of threatened native fish populations, unique to the CLLMM region. This management action involves captive breeding and/or translocation of fish between captivity and the wild depending upon the site conditions within the CLLMM region.

On ground management actions include:

- environmental watering
- maintenance of refuge habitats
- the rescue of endangered and threatened species
- the establishment of captive breeding programs
- the identification of surrogate refuge sites as a medium term option for the protection of threatened small-bodied, native fish species.

The project will be adopted across a range of high priority sites as identified by a specifically designed matrix tool.

As well as protecting the various species from the effects of acidification, heavy metals in the soils and high salinity, this action is aimed at ensuring compliance with the national *EPBC Act* requirements.

Fish species being addressed in this action include:

- Yarra Pygmy Perch
- Murray Hardyhead
- Southern Pygmy Perch
- River Blackfish
- Southern Purple-spotted Gudgeon.

In a snapshot

Location of activity: Coorong, Lake Alexandrina, Lake Albert and Tributaries

Activity addresses: ecosystem degradation arising from low water levels and acid sulfate soils.

For more information see: Protecting Critical Environmental Assets Program – Critical Fish Habitat and Refuge.[14]

10.3.4 Dredging of sills at Parnka Point

Parnka Point is situated between the Coorong's North and South Lagoons. This area acts as a natural sill between the two lagoons at times of low water levels. By dredging the sills at this point, the width and depth of the channel can be increased to allow greater movement of water between the two lagoons, thereby:

- improving ecological connectivity
- improving water mixing thus reducing the salinity of the South Lagoon
- assisting the transition to a complex estuarine ecology to support improved ecological character.

Greater connectivity and water mixing is important to manage the salinity gradient and also relies on pumping of hypersaline water out of the Southern Lagoon of the Coorong (see action 10.1.2 above).

This proposed action is still in the investigation stage, both for its heritage and technical implications.

In a snapshot

Location of activity: between the North and South Lagoon of the Coorong

Activity addresses: the lack of connectivity between the Lower Lakes and the sea, elevated salinity and ecosystem degradation arising from low inflows.

10.3.5 Translocation of Large-fruit Tassel (*Ruppia megacarpa*) and Tuberous Tassel (*Ruppia tuberosa*)

Transplanting of *Tassel* is planned once salinity levels improve in the Coorong. As a keystone water plant, Tassel provides habitat and food for many biological components of the ecosystem.

Increased salinity and altered water levels have seen the reduction in the presence of this plant at the site. Transplanting Tassel successfully is heavily reliant on appropriate hydrology and salinity levels. Combined with separate management actions 10.1.2 and 10.3.1, successful transplanting of Tassel will assist to:

- support the re-establishment of vegetation communities
- increase habitat coverage and complexity for macroinvertebrates and migratory birds.

In a snapshot

Location of activity: in the North and South Lagoon of the Coorong

Activity addresses: the lack of connectivity between the Lower Lakes and the sea, elevated salinity and ecosystem degradation arising from low inflows.

For more information see: Ruppia Translocation in the Coorong Technical Feasibility Assessment [59]

10.4 Priority adaptation measures

10.4.1 Diverting freshwater from the South East to the Coorong

Historical flows from the South East used to play an important role in the maintenance of ecologically appropriate salinities within the Coorong South Lagoon. These flows currently discharge directly into the ocean via artificial drains, to prevent the inundation of developed land in the lower and upper South-East.

The action proposes using a combination of natural watercourses, an engineered floodway system and existing drains, to divert water from the lower South East towards the Coorong South Lagoon.

This action will reduce rising salinity levels in the Coorong South Lagoon. It is one of four complementary measures to manage salinity levels in the Coorong. The related actions are management actions 10.1.1, 10.1.2 and 10.2.4. The benefits of this measure are:

- reduced salinity by the supply of median of 32 GL/annum of freshwater from the South East to the Coorong
- enhanced ecosystem resilience
- greater flexibility for management of the Coorong by supplying an additional water source to the South Lagoon
- potential to restore, improve and provide long-term support to a considerable area of wetland habitat, for example to ensure salinities remain within the target range for the health of the *Ruppia/Chironomid/hardyhead* system in the long-term.

The action has undergone feasibility studies funded by the Murray-Darling Basin Authority which show it to be technically feasible. Further investigations are required before the action is ready for implementation.

The benefit of the action is that it is one of few options available that deliver additional freshwater to the site and surrounding wetland environments. It helps address the decline in ecological health of the Coorong by reducing salinity, but is only part of the approach required to restore the Coorong ecosystem and an appropriate level of end-of-system flows.

In a snapshot

Location of activity: South Lagoon of the Coorong

Activity addresses: the lack of connectivity between the Coorong and South East wetland system, elevated salinity and ecosystem degradation arising from low inflows and the artificial disconnection of the Coorong from the South East wetlands.

For more information see: South East Flows Restoration Technical Feasibility Assessment [2]

10.4.2 Construction/installation of fishways

Fish passages (fishways) assist in re-establishing connectivity between the individual parts of the site by allowing greater water mixing and movement of biota throughout the system. When connectivity of once-linked waterways is lost due to low water levels and no, or limited, water mixing, diadromous fish and other biota are unable to travel between the different habitats that they rely on throughout their lifecycles.

Construction of fish passages is proposed for up to eight sites within the CLLMM site. The action will assist in preparing the site for recovery and will facilitate estuarine ecological processes. Whilst the function of fishways may be at their lowest during low water levels, it is the optimum time for their installation. They are cheaper and easier to construct when there is no water.

This management action has several objectives:

- to protect and retain native fish species within their natural range at the barrages of Tauwitchere, Goolwa and Mundoo
- to monitor and undertake research on the effectiveness of the structures in ensuring the passage of native fish species
- to ensure that the fishways are properly maintained and operated over their lifecycle in order to maintain their effectiveness.

Different fishway options are available and selection will take into account the specific requirements of each site. Proposed works will include the construction of rock ramps, new fish locks, fish culverts, vertical slots, navigation locks and the removal of structures that obstruct the passage of fish.

In a snapshot

Location of activity: at up to eight sites, principally through the barrages.

Activity addresses: the lack of connectivity between various components of the system and ecosystem degradation arising from low inflows.

For more information see: Fishways Technical Feasibility Assessment [60]

10.4.3 Manage variable lake levels

Before the current situation within the Lower Lakes, the primary objective of water level management had been to facilitate water extraction from the Lower Lakes, rather than achieve specific ecological objectives.

Now that human use of water can be provided from the new pipeline projects funded through the Murray Futures program, it is possible to consider operating the Lower Lakes with more specific ecological objectives in mind.

A significant amount of work towards the development of a new Lake Operating and Water Release Strategy has already been completed through The Living Murray Icon Site program of the Murray-Darling Basin Authority, with an 'envelope' of the desired minimum and maximum lake water levels on a month by month basis having been developed. Further work is required to finalise this strategy. Implementation can only occur once lake levels and water flows return to suitable amounts.

The benefits of a new Lake Operating and Water Release Strategy which promotes ecological objectives include:

- a greater extent and diversity of aquatic vegetation in the Lower Lakes
- wetlands fringing the Lower Lakes which can cope with greater variability in future water availability
- reduced system water requirements.

In a snapshot

Location of activity: entire system

Activity addresses: ecosystem degradation arising from stable water levels.

For more information see: Managing Variable Lake Levels Technical Feasibility Assessment [3]

10.5 Enabling measures

Enabling actions are those taken to facilitate the implementation of mitigation and adaptation actions. Without these enabling actions, other measures put into place within the region would not be possible. These actions include:

- implementing an adaptive management regime (this is explained in Section 11)
- ensuring appropriate governance arrangements involving the community, and continuing to develop partnerships with the Ngarrindjeri (this is explained in Section 12).

11 Managing the site as one complex, interconnected ecosystem

Effective management of the CLLMM site begins with an understanding that the ecological functioning of the components of this site are all interconnected. They rely on this ecological connectivity and none can be managed in isolation. Therefore, while any particular management action may appear to target only one area of the site, the action needs to take into account its impact on the other components, so that the overall result is a healthy, productive and resilient wetland system.

To assist in our understanding of the interconnectedness of the components of this site, and the potential implications of the management actions, process models or diagrams [61] have been developed for each of the water bodies of the region. These diagrams depict how a particular management action may alter an ecosystem, or more simply, the results that are likely to occur following an action being undertaken (see Appendix 5 for an example). Such models map out expected outcomes from changes to the system and form the basis for the appropriate application of adaptive management (see below).

11.1 How to deal with uncertainty

The size and complexity of the site and the natural seasonal fluctuations that it faces mean that there is not a complete information base (e.g. one covering changes in river regulation, changes in climate, and responses by the ecosystem) from which to choose appropriate management actions.

Any enduring management response for this site must contain a mechanism for dealing with a high degree of uncertainty about the future, include ways to improve our understanding of the effect of our management decisions and have the flexibility to revise management decisions in response to new information.

Adaptive management provides such a rigorous mechanism - using the best available knowledge while at the same time learning by doing [62]. Learning is then fully incorporated into future decision making and management decisions are improved over time, accordingly. Adaptive management is not a trial-and-error approach. Instead, monitoring is carefully designed to measure the actual outcome of a particular management response and compare it with the expected outcome. A strong connection between scientific investigation and management decision making is an essential component of adaptive management. Management-focused research is undertaken to improve the understanding of how the system operates and changes over time.

There are six steps involved in the adaptive management process (Figure 10). The steps integrate the knowledge gained during implementation to improve the management of the site and focus research on the priority knowledge gaps.

The six steps in adaptive management

1. plan management actions
2. implement the plan
3. monitor the activities and performance of the environment (or the research)
4. analyse the outcomes against the expectations
5. adapt the plan of action (or research)
6. learn from the activities.

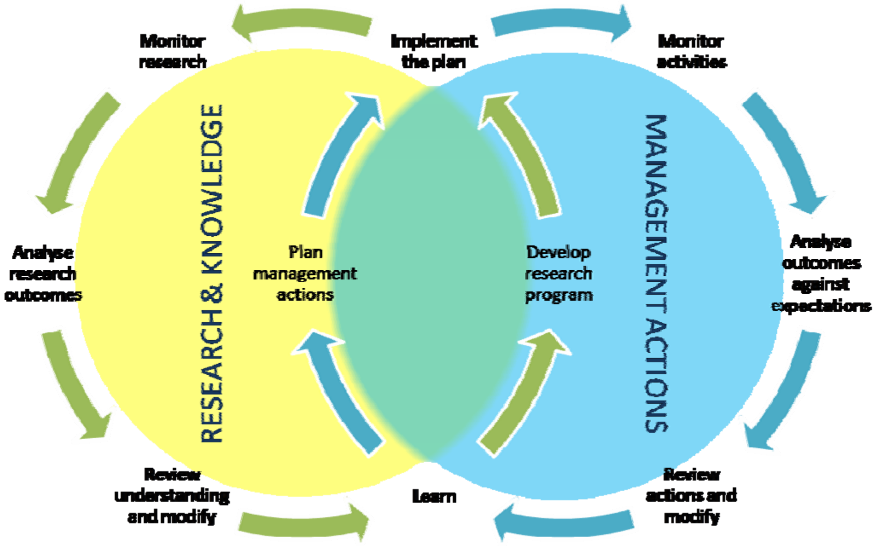

Figure 10. Six steps are involved in the adaptive management process. The steps are integrated within the research and knowledge and the management sectors.

By applying the six steps of the adaptive management framework presented above, positive ecological, cultural, social and economic outcomes can be achieved, despite the complexity of the CLLMM site and anticipated future challenges, such as the current dry conditions and climate change.

For the CLLMM site, this will occur by monitoring the individual management actions under a variety of environmental conditions, testing the expected response of ecosystems to specific actions, and targeting research to fill key knowledge gaps.

11.2 Reviewing the appropriateness of our management response

Two formal cycles of review have been defined for the CLLMM site - an annual review of short-term plans and actions, and a three-yearly strategic review that includes assessing the overall process.

The annual review will focus on the more immediate plans and actions and will evaluate the management of the previous year to:

- determine whether planned actions have been completed
- evaluate the success of actions
- determine if actions should continue, be discontinued, or modified
- assess new circumstances which may require management, such as continuing dry conditions or changes in water inflows.

The annual review will also incorporate planning for the following year, based on predictions of River Murray inflows.

The three-yearly strategic review will make a broader assessment of the overall success of the management of the CLLMM site. This review provides the opportunity to re-assess: the management goals for the site; the strategies for achieving these goals; and the monitoring and research priorities within the region. Within this cycle, the adaptive management arrangements themselves will be reviewed to ensure that the principle of improved management over time is being achieved.

11.3 Adjusting our management response to a changing climatic conditions

The priority management actions for 2010-2014 were chosen (as indicated in Sections 9 and 10) because of the existing condition of the site, and the likelihood of a poor climate outlook.

Regardless of conditions that are encountered in any one season, the best available management response drawing from this list of actions can be constructed. If, for example, conditions were to improve from the worst case dry situation that we have planned for, the mix of management measures will be reconsidered and revised to be more appropriate for wetter conditions.

Each measure will have a carefully defined target which outlines the proposed start and end triggers which are directly associated with ecological conditions at the site.

How long these current dry conditions will endure, or when freshwater inflows will resume at more normal levels, is unknown. Because of this uncertainty, it is impossible to accurately predict how long many of the mitigation actions will be required. For example, with improved river inflows at some point in the future, it will be possible to 'scale back' some of the acid sulfate soil treatment measures as the acidification risk would have been reduced. Equally, with improved water levels, it will be possible to 'scale back' some of the vegetation plantings as there will be less exposed lakebeds prone to wind erosion. Over time, with improved freshwater inflows, a greater emphasis can be placed on those actions that build a resilient ecology at the site, for example the management of lake levels at variable levels, and the redirection of freshwater from the South East.

In this way, the mix of measures that is undertaken at the site will change, over time, depending on changing ecological conditions. If freshwater flows recommence, mitigation measures will gradually cease as the condition of the site improves, and adaptation measures will become the focus. If the current dry conditions continue, current mitigation measures will continue, with new measures being introduced if necessary.

This gradual shift in balance between the mitigation measures and adaptation measures across the site can be thought of as a shift in the level of overall financial investment at the site (**Figure 11**). The shift is from higher levels of immediate investment associated with supporting the ecosystem through the current situation and small amounts of investment in positioning the site for the long-term to a gradually greater investment in the long-term positioning of the site and less in mitigation measures.

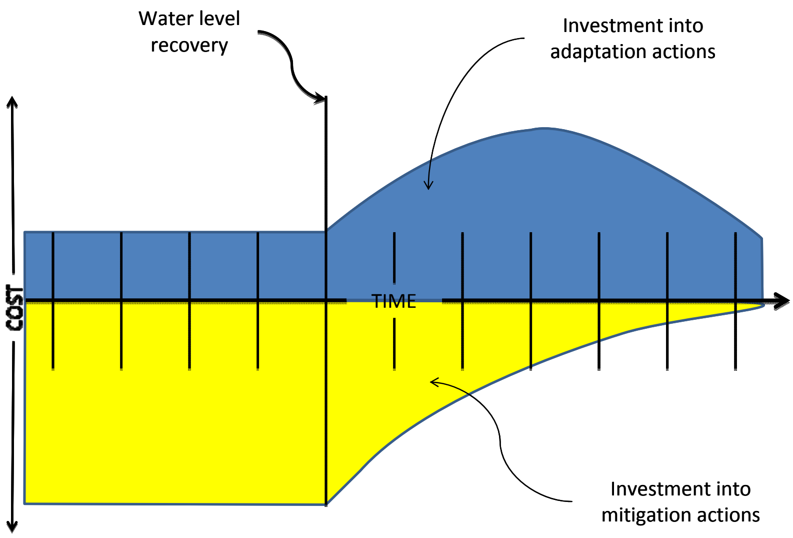

Figure 11. Diagram showing the shift in financial investment over time in relation to mitigation measures and adaptation measures.

By defining when each measure should be undertaken, including any measures upon which it depends, and when it should cease, management of the site will occur in a manner that is appropriate, whether the future is wet, dry or extremely-dry. Adaptive management provides a framework to maximise the ecological condition of the CLLMM region whatever the future holds.

11.4 Applying adaptive management in the CLLMM region

As the adaptive management framework is progressively implemented across the CLLMM region, decisions regarding the most appropriate management measures will be made, using the framework outlined above. Three specific elements of the framework are also under development:

- A monitoring and evaluation plan which links condition monitoring and continuing management 63.
- A research plan outlining the key areas for targeted research is also under development. This identifies the key information gaps which, when filled, will assist in both the immediate and longer-term management of the site. Documentation standards will be based in part on ISO:14000 framework to enable standardisation of the recording of information.
- The structure of the CLLMM Project will be based around the key 'plan-do-monitor' aspects of adaptive management. A Technical Advisory Group will be established as part of the governance of the site (refer to Section 12) to ensure that the best available technical and scientific advice forms part of the decision-making processes on management actions.

An example of the application of adaptive management in the Coorong, Lower Lakes Murray Mouth region, relating to salinity in the South Lagoon of the Coorong, is detailed in Appendix 6.

11.5 What can be expected in the next five years?

As indicated earlier in Section 11.3, the exact mix of management actions used at any one time will depend on the precise conditions at the time and the best understanding of the outcomes of those actions.

The following is an outline of how the future **might** unfold at the site, assuming a continuation of the current dry conditions as the starting point. (Refer also to Appendix 7 for an outline of one such implementation schedule and Appendix 8 for an indication of how the mix of management actions will vary depending on the climate).

11.5.1 Summer 2009-2010

In the past three years we have seen unprecedented lows in water inflow to the Lower Lakes and Lake Alexandrina drop steadily each summer to -1.0 metres AHD. This is a worst case scenario. This recent winter has seen *better than worst case* direct rainfall and *better than worst case* inflows from the River Murray are planned over the next few months – for a total of at least 120 GL.

The first priority for the extra water is to prevent soils from acidifying – i.e. prevention first. The greatest risk is in Lake Albert with its central core of clayey soils. Extra water is planned to be pumped there in early 2010.

Early 2010 is also expected to see Lake Alexandrina drop to at least -1.0 metres AHD – a similar level to early 2009. Lake Albert will be held at no lower than -1.0 metres AHD.

At least 150-200 km² of soils will be exposed to air over summer (depending on the level to which lake levels drop). Most of these will generate acidity in the soils, but this is expected to have a limited impact only on the alkalinity levels in the lake bodies. There will be wind-blown sand from these exposed areas. There will be a significant fish kill in Lake Albert in early 2010 as the salinity in this lake rises due to evaporation.

11.5.2 Autumn 2010

In autumn of 2010, widespread seeding of those soils exposed over summer is planned. This may be an area of 150-200 km², depending on the evaporation losses from the Lakes through summer. The seeding will be timed to make the most of the autumn rains and produce a cover crop over winter/spring 2010 – thus holding the soil and feeding the carbon cycle of bioremediation. Where seeding occurred in the 2009 trials, a second layer of crop will be planted, building upon the previous year's achievements.

The autumn and winter rains will pose challenges as rewetting mobilises acidity in the soils exposed over summer. Acid hotspots will be created in some areas. If there are substantial flows or downpours, the two lakes will experience additional acid loads. Their natural alkalinity should deal with the majority of the acidity in 2010 – however, some limestone treatment may be required as a supplement. The construction of the Goolwa regulators in 2009 will have prevented any substantial acid formation and mobilisation in that area through the summer, as the minimum water level in this pool is planned to have been held at no lower than 0.0 metres AHD.

11.5.3 Winter 2010 onwards

The extent of inflows from the Murray-Darling Basin from upstream in late 2010 and early 2011 will determine how conditions develop in the latter part of 2010 and during 2011. If inflows are sufficient to hold the lakes at no lower than those for this coming summer then the situation should not deteriorate. Any improvements in lake water level should ideally be gradual to enable rewetting of exposed soils to occur in a managed way, and for the resultant mobilised acidity to be dealt with by the lakes' alkalinity, or added limestone or bioremediation processes.

If however low inflows lead to further lowering in the lake levels, the scientific investigations that are currently being undertaken will be particularly relevant. These will advise whether the use of seawater is possible as a last resort. It is known that seawater can provide additional alkalinity and saturation of soils. However depending on the extent of acidification which has already occurred in the soils, the addition of seawater may generate additional acidity and metal releases. The additional salinity introduced by seawater will also pose problems both for the life-forms in the lake and for the nature of its eventual recovery.

Should seawater not be a practical option, then there is no choice but to dry the lakes down and continue with a process of bioremediation on the exposed soils. There will be practical limits to the extent to which limestone can be used as a treatment option. If these circumstances arise, the process of rewetting the lakes will be extremely challenging – attempting to refill them slowly so that acid releases can be managed. Recovery will take many years.

If inflows are not sufficient for improvement in the water levels, but not so low that the lakes fall below the level at which they acidify, the best strategy will be one of attempting to acquire sufficient freshwater to prevent acidification of the lakes and use of limestone and bioremediation as treatment options – recognising that they are only a partial answer to acidification problems. If we were to have five more dry years, for example, the approach would be to try and 'buy another winter' each year with freshwater, and supplement with bioremediation and limestone as appropriate, depending on the conditions in that year.

Ideally, however, a continuation of the improvements in inflows seen in 2010 will see a gradual restoration of the site. As this occurs, the various management actions planned can have their full effect. The Goolwa regulators can be removed once flows have been restored and acid levels are satisfactory. Similarly, once Lake Albert has been gradually refilled and acid levels managed, the bund at the Narrows can be removed. Flows through the barrages will start to flush out the salt load in the Lakes and freshen the Coorong. Fish can be restored to the site from their ex situ storages. The translocation of Tassel to the South Lagoon of the Coorong will have been already assisted by the pumping out of South Lagoon to the sea, and fish and bird life will be returning to the Coorong.

Finally, as the Basin Plan begins to have effect, environmental flows at levels sufficient to maintain the environmental values of the site should return.

12 Governance

12.1 Purpose of governance arrangements

As described earlier in this plan, the CLLMM site has significance for many people and organisations: its Traditional Owners – the Ngarrindjeri, Commonwealth, state and local government, business and community members.

The South Australian Government has consulted widely in the development of the Long-Term Plan. Governance arrangements for the implementation phase will build on the decision-making processes, relationships and momentum established in the development phase.

The project governance arrangements for the CLLMM aim to ensure that:

- accountability for the overall delivery of the project rests with a single organisation and is clear and transparent
- there is strong, relevant and timely communication across the project, with the Australian Government (funder), the South Australian Government, the Ngarrindjeri, key stakeholders and the community
- there is alignment with Australian and South Australian Government objectives and priorities
- there is sound and responsible financial management over the life of the CLLMM project
- risks are identified and mitigated across the life of the project.

12.2 Context for governance arrangements

The CLLMM project forms part of the overall Murray Futures program, for which the Minister for the River Murray is the lead Minister and signatory to the Funding Deed. The Murray Futures program includes a number of projects – amounting to $610 million in all – and is overseen by a Murray Futures South Australian Priority Projects Steering Committee comprising State and Commonwealth officers. The delivery of the Murray Futures program is managed in South Australia through:

- the Commissioner for Water Security (and Executive Director Murray Futures, in the Office for Water Security) for overall delivery against the Funding Deed
- the Department of Water, Land and Biodiversity Conservation (DWLBC) for financial accountability against the Funding Deed.

The nature of the project means that there are many levels of linkage with agencies in all levels of government and their programs, in addition to key community bodies – for advice, endorsement of proposed decisions or for decision-making. As examples:

- The CLLMM site is part of the River Murray and is therefore linked to the policies, programs and operations of the Murray-Darling Basin Ministerial Council and the Murray-Darling Basin Authority. This includes programs such as the Living Murray and Icon site management which are delivered through the SA Murray-Darling Basin Natural Resource Mangement (NRM) Board.
- Its need for adequate supplies of freshwater to sustain it, means that the CLLMM site is also a key topic, both for South Australian water policy (through South Australia's Water Security Council, Lower Murray Action Group, and the SA Murray-Darling Basin NRM Board) and broader River Murray policy (through the High-Level Steering Committee of the Murray-Darling Basin Authority).

- Lowered water levels in recent years mean that the current reduced state of the CLLMM site is of profound importance to the Ngarrindjeri – its Traditional Owners – with whom a Kungun Ngarrindjeri Yunnan consultation agreement has been developed to progress remediation projects.
- Its significance as a Ramsar wetland – a wetland of international importance and the subject of three agreements relating to migratory birds – means that it is of considerable interest to the Department of the Environment, Water, Heritage and the Arts (DEWHA) and the South Australian Ramsar Task Force – involving community and government oversight of the Ramsar management plan.
- In addition, the large scale of the project involves policy and project decisions at multiple levels – Cabinet, Minister, Chief Executive, Director and project.

There are numerous other bodies (often community-based) which have an interest or stake in the way in which the site is managed – particularly for consultation purposes. These include the Lower Murray Drought Reference Group, and two groups hosted by the Murray-Darling Basin NRM Board – an Icon Site Community Reference Committee and a Scientific Advisory Committee – amongst others.

12.3 Proposed governance arrangements

The proposed governance arrangements incorporate the following elements:

- A clear accountability line from Cabinet through the Minister, the CLLMM Project Board and Steering Committee to the Program Delivery, Development and Planning functions for decision-making in respect of the implementation of the Plan.
- Responsibility for on-ground delivery of the Plan lies with the Department for Environment and Heritage. Responsibility for financial accountability lies with DWLBC. Responsibility for overall delivery for the Funding Deed with the Australian Government remains with the Commissioner for Water Security.
- The Australian Government's interests will be managed through the Murray Futures South Australian Priority Projects Steering Committee which oversights all of the projects which fall within the $610 million Murray Futures program (including this $200 million project). The Joint Liaison Committee will enable direct input from DEWHA, and the Murray-Darling Basin Authority.
- Coordination across River Murray issues within the South Australian Government will continue to be provided by the Lower Murray Action Group, and policy development on overall water security issues by Water Security Council.
- Coordination across water projects such as this Murray Futures project and South East Drainage programs to ensure synergies and eliminate duplicated effort will be undertaken by DWLBC.
- Technical advice on proposals and policy issues will continue to be provided through the Water Security Technical Working Group to the Water Security Council. A CLLMM Technical Advisory Group is to be established to involve expert technical advice in the decisions about adaptive management of the site.
- Arrangements are already in place for consultation with Ngarrindjeri through the Kungun Ngarrindjeri Yunnan consultation agreement.

- A Community Advisory Board will be established to provide community views on the implementation of management actions and their environmental, economic and social impact. In addition, specific purpose, time-limited, community reference groups will be established where needed. As an example, a group chaired by the Mayor of the Coorong District Council has been essential in progressing an alternative management strategy for Lake Albert over the period July 2009 to November 2009. These groups would vary in size, membership and character depending on the nature and timeframes associated with the particular issue or project.
- In the implementation phase, the structure of the Program Delivery team will change to reflect the adaptive management approach being adopted for the site and establish the following functions – program development and planning, program delivery, and monitoring and evaluation.

The key elements of the proposed governance structure are depicted in **Figure 12** below, with details of the core role of each of the key bodies chaired or sponsored by CLLMM Projects provided in Appendix 9.

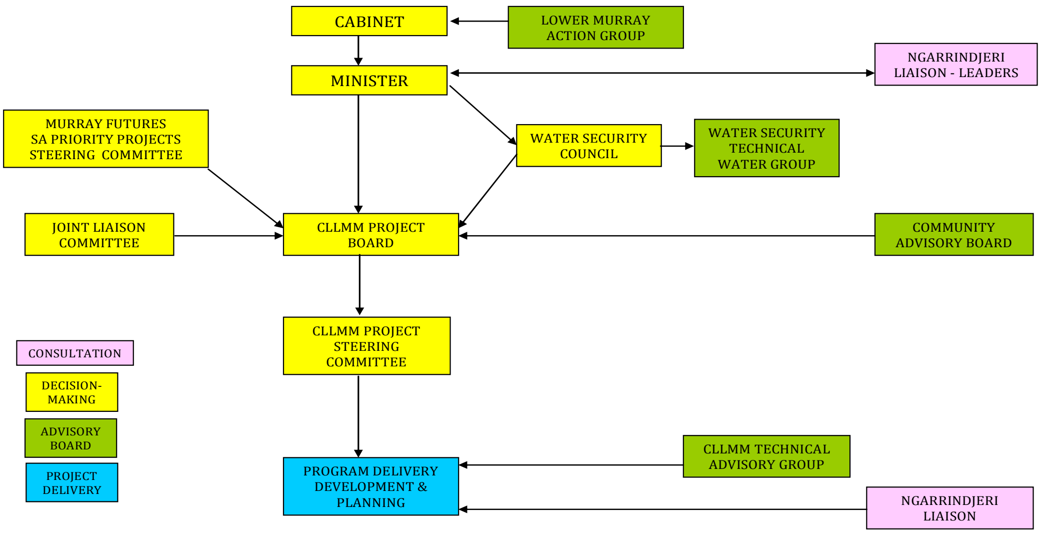

Figure 12. Governance arrangements

APPENDICES

Appendix 1: Legislative and policy context

A range of international agreements and Commonwealth and state legislation and policies govern the management of the CLLMM. An overview of these is presented in the table following, and some of the most important ones are discussed briefly below.

International agreements	*Convention on Wetlands of International Importance* *Convention on the Conservation of Migratory Species of Wild Animals* *Japan-Australia Migratory Bird Agreement* *China-Australia Migratory Bird Agreement* *Republic of Korea-Australia Migratory Bird Agreement*
Commonwealth Legislation	*Environment Protection and Biodiversity Conservation Act 1999* *Water Act 2007* *Native Title Ac, 1993* *Aboriginal and Torres Strait Islander Heritage Protection Act 1984*
Multi-jurisdictional strategies & plans	*Living Murray, 2002* *The Lower Lakes, Coorong, and Murray Mouth Icon Site Environmental Management Plan, 2006-2007* *The Murray-Darling Basin Authority's Basin Plan, 2007* *Commonwealth Wetlands Policy, 1997* *Water for the Future, 2008* *Ngarrindjeri Regional Partnership Agreement, 2008* *Closing the Gap*
State Legislation	*Waterworks Act 1932* *National Parks and Wildlife Act 1972* *Coast Protection Act 1972* *Native Vegetation Act 1991* *Environment Protection Act 1993* *Development Act 1993* *Water Resources Act 1997* *Aboriginal Heritage Act 1988* *River Murray Act 2003* *Natural Resources Management Act 2004* *Fisheries Management Act 2007* *Marine Parks Act 2007* *Climate Change and Greenhouse Emissions Reduction Act 2007* *Water (Commonwealth Powers Bill) 2008* *Murray-Darling Basin Act 2008*
Relevant State strategies plans and agreements	*Coorong, and Lakes Alexandrina and Albert Ramsar Management Plan, 2000* *Wetlands Strategy for South Australia, 2003* *Living Coast Strategy for South Australia, 2004* *State Natural Resources Management (NRM) Plan, 2006* *South Australia's Strategic Plan, 2007* *No Species Loss, 2007* *Tackling Climate Change: South Australia's Greenhouse Strategy 2007-2020* *Murray Futures, 2008* *South Australian Murray-Darling Basin Natural Resource Management Board Regional NRM Plan, 2009-2019* *Water for Good, 2009* *Kungun Ngarrindjeri Yunnan Agreement, 2009.* *Ngarrindjeri Nation Yarluwar-Ruwe Plan, 2007.*

International agreements

The Ramsar Convention on Wetlands of International Importance underpins the management requirements for the Coorong, Lakes Alexandrina and Albert Ramsar site. The central tenet of the Ramsar Convention is the wise use of wetlands, which is defined as:

> *the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development.* [64]

The history of over-allocation of water from the Murray-Darling Basin is a history of development that is not sustainable and has resulted in a continuing loss of ecological character. Meeting Australia's commitments under the Ramsar Convention requires a reversal of long-term trends across the Basin, rather than maintenance of the status quo. There is also a requirement to take into account Indigenous cultural values in the management of Ramsar wetlands.

The three agreements on migratory birds all place related obligations on signatory governments.

- The Japan-Australia Migratory Bird Agreement states that 'Each Government shall endeavour to take appropriate measures to preserve and enhance the environment of birds protected under this Agreement.' [65]
- The China-Australia Migratory Bird Agreement states that each Government will 'take appropriate measures to preserve and enhance the environment of migratory birds.' [66]
- The Republic of Korea-Australia Migratory Bird Agreement similarly requires each Government to take 'appropriate measures to conserve and improve the environment of birds protected under Article 1 of this Agreement.' [67]

Commonwealth legislation, initiatives and plans

The *EPBC Act* provides a legal framework for protecting the environment, especially matters of national environmental significance, including Ramsar wetlands, other ecological communities, heritage sites and listed migratory and threatened species.

The *Water Act 2007* established the Murray-Darling Basin Authority whose main function is to address over-allocation and protect, restore and provide for the ecological values and ecosystem services of the Murray-Darling Basin. This will be achieved through a Basin Plan, to commence in 2011. Among other things, it will specify: limits on the amount of water (both surface water and groundwater) that can be taken from Basin water resources on a sustainable basis; an environmental watering plan to optimise environmental outcomes for the Basin; and rules about trading of water rights in relation to Basin water resources. The Basin Plan under the *Water Act 2007* must be prepared so as to give effect to relevant international agreements. Among other things, the Basin Plan must also promote the conservation of declared Ramsar Wetlands. The *Water Act 2007* also sets out in Schedule 1 the water sharing arrangements between New South Wales, South Australia and Victoria.

The Australian Government's Water for the Future strategy (2008) is a national framework that integrates rural and urban water issues. Buying back water to restore the environment is one of the priorities of Water for the Future. The Australian Government is investing $3.1 billion in buying back water in the Murray-Darling Basin over 10 years. The water must be used to protect and restore environmental assets.

A component of *Water for the Future* is the Sustainable Rural Water Use and Infrastructure Program, a 10 year, $5.8 billion program. State Priority Murray Futures projects will be funded from the Program, with South Australia receiving up to

$610 million for a range of activities including the purchase of water entitlements from willing sellers, with water to be held by the Commonwealth Environmental Water Holder. As part of the South Australian Priority Project activities, the Australian Government is providing up to $200 million to South Australia to support an enduring response to the environmental problems facing the CLLMM. This includes a $10 million feasibility study of the long-term options for the management of the site.

The Australian Government Nation Building has committed $10 million to the South Australian Department for Environment and Heritage for bioremediation and revegetation in newly identified suitable sites in and around the Lower Lakes. This initiative builds on the outcomes of smaller-scale bioremediation trials undertaken by the South Australian Government on the shores of Lake Albert and seeks to engage and involve the community.

Multi-jurisdictional initiatives

The Living Murray initiative was established in 2002 in response to concerns about the declining health of the River Murray system. A major focus of the Living Murray initiative is on improving the environment at six designated Icon sites. The program's first step was to recover 500 GL of water by 30 June 2009 which can be deployed for environmental purposes at the six Icon sites into the future. (South Australia has achieved its target share by recovering its 35 GL.)

The Living Murray Icon Site Environmental Management Plan for the CLLMM has recognised that the site's social, cultural and economic values are under threat due to diminished flows. The Plan establishes three ecological objectives for the site:

- an open Murray Mouth
- enhanced migratory water bird habitat in the Lower Lakes and Coorong
- more frequent estuarine fish spawning and recruitment.

State legislation, plans and strategies

Three particularly relevant South Australian Acts are the *River Murray Act 2003*, the *Murray-Darling Basin Act 2008* and the *Aboriginal Heritage Act 1988.* The *River Murray Act 2003* specifies a number of objectives for a healthy River Murray, which include:

- the protection of key habitat features, ecological processes, high value floodplains, wetlands of international and national significance and native species
- ecologically significant natural flow regimes, fish passage areas and connectivity between and within environments within the River Murray System
- overall improvement of water quality (including salinity, nutrient levels and pollutants) within the River Murray system to sustain ecological processes, environmental values and productive capacity
- human dimensions such as community interests, community knowledge and the importance of a healthy river to the economic, social and cultural prosperity of communities.

The *Murray-Darling Basin Act 2008* specifies that the Murray-Darling Basin Authority must be informed of any proposal that may significantly affect the flow, use, control or quality of any water in the River Murray in South Australia.

The Authority's approval is required in order to carry out any works (for example, a temporary weir) not already provided for under the agreement. In considering an authorisation, the Murray-Darling Basin Authority must assess any possible effects on the water, land or other natural resources within the Murray-Darling Basin.

The *Aboriginal Heritage Act 1988* provides protection for Aboriginal sites, cultural traditions, objectives and human remains.

Murray Futures, 2008

This is South Australia's priority project to secure the future for Murray-Darling Basin industries and communities reliant on the environment. Murray Futures positions South Australia to respond to the threats and challenges facing the River Murray in a future of reduced water availability and climate change.

The ten-year integrated package aims to ensure that South Australia will respond proactively to climate change by adopting flexible, adaptive environmental management practices to achieve long-term community, industry and environmental outcomes. It aims to maximise the use of existing environmental water and target water to key priority sites, while also providing environmental water savings. It is designed to ensure the river system and its communities are more 'climate ready'.

Importantly, Murray Futures, which is supported by the Australian Government, also supports national and Murray-Darling Basin initiatives, in recognition of the shared responsibilities to:

- address over-allocation
- address the immediate and worsening crisis in the Lower Lakes and Coorong
- develop a 'One River' approach
- set and meet a sustainable target for end-of system flows into the future.

Appendix 2: Land use map

Appendix 3: Indicative ecological response to declining water levels and quality

Lake Level (metres AH D)	Total Volume (GL) (Lakes Alexandrina and Albert combined)	Total Surface Area (hectares)	Average Annual Net Loss (GL)	Measured / Modelled Lake Alexandrina Salinity (EC)	Ecological and Management Implications
0.8	1,924	82,171	802	400 – 2,300	Lower Lakes surcharge level under pre-drought conditions.
0.75	1,883	82,014	800	400 – 2,300	Lower Lakes full supply level.
0.7	1,842	81,857	799	400 – 2,300	
0.6	1,761	81,669	797	400 – 2,300	
0.5	1,679	80,976	790	400 – 2,300	Lower Lakes preferred minimum level under pre-drought conditions. Barrage opening not possible below this level under current operational arrangements. Therefore: • fish that require both marine and freshwater habitats are unable to migrate between sea and Lower Lakes and are therefore unable to complete their life cycles • water level and salinity targets for the Coorong are not met due to inadequate freshwater flows. Therefore all Coorong biota (aquatic plants, mudflat invertebrates, fish, shorebirds, fish-eating birds, waterfowl) are threatened • dredging required to maintain an open mouth. Mouth closure leads to: – salinisation of estuary and exacerbation of inappropriate salinity and water levels in Coorong – all Murray estuary biota threatened.
0.4	1,599	79,899	779	400 – 3,000	
0.3	1,519	78,820	769	400 – 3,000	Likely exposure of all fringing submerged and emergent aquatic vegetation around the shoreline of the Lower Lakes and tributary wetlands. Therefore: • loss of fringing vegetation, unless exposure is temporary • likely loss of many freshwater fish and waterbird species.
0.2	1,441	77,754	759	400 – 3,000	
0.1	1,364	76,664	748	400 – 3,000	
0	1,288	75,349	735	400 – 3,000	
-0.1	1,213	73,919	721	3,000	

Lake Level (metres AH D)	Total Volume (GL) (Lakes Alexandrina and Albert combined)	Total Surface Area (hectares)	Average Annual Net Loss (GL)	Measured / Modelled Lake Alexandrina Salinity (EC)	Ecological and Management Implications
-0.2	1,140	72,414	706		
-0.3	1,068	70,972	692	3,250	Lakes Alexandrina and Albert become disconnected at this level. Therefore: • fish communities in each lake become isolated.
-0.4	998	69,405	677	3,500	
-0.5	930	67,787	661	4,000	Acidification of Lake Albert occurs at this level and lower. Therefore: • all biota in Lake Albert threatened • salinity in Lake Alexandrina exceeds threshold for most freshwater fish • likely loss of freshwater fish from Lake Alexandrina and tributary wetlands.
-0.6	863	66,106	645		
-0.7	797	64,278	627	4,500	
-0.8	734	62,456	610	5,000	
-0.9	673	60,614	592	5,500	
-1	613	58,471	571	5,750	
-1.1	556	55,356	541	6,250	
-1.2	502	52,858	514	6,700	
-1.3	451	49,771	486	7,000	
-1.4	403	45,715	447	7,500	
-1.5	359	42,391	414	7,800	Acidification of Lake Alexandrina occurs at this level and lower. Therefore: • all biota in Lake Alexandrina and tributary wetlands (estuarine fish, waterfowl, fish-eating birds) threatened.
-1.6	318	40,347	395	8,000	
-1.7	278	38,598	377	8,300	
-1.8	241	36,996	362	8,700	
-1.9	205	3,4830	341	8,900	
-2	171	32,676	320		

Lake Level (metres AH D)	Total Volume (GL) (Lakes Alexandrina and Albert combined)	Total Surface Area (hectares)	Average Annual Net Loss (GL)	Measured / Modelled Lake Alexandrina Salinity (EC)	Ecological and Management Implications
-2.1	140	29,770	291		
-2.2	112	26,217	256		
-2.3	87	22,545	220		
-2.4	66	19,431	190		
-2.5	48	16,827	165		
-2.6	33	13,044	128		
-2.7	22	10,176	99		
-2.8	13	7,251	71		
-2.9	7	4,759	47		
-3	3	2,978	29		

Appendix 4: Alternatives considered but not proceeded with

In the preparation of this plan, many submissions and proposals were received and we are grateful for the time and effort that people have put into making these suggestions. However, not all of them appear in the list of recommended actions. Some of these proposed actions were suggested by multiple contributors. The intention of this section is to provide a preliminary response as to why those proposals are not being supported in this Plan.

Piping water from northern Australia

There were many suggestions that water could be piped from locations such as the Ord River from far northern Western Australia or from north east Queensland. Costings of these proposals demonstrate that moving large volumes of water long distances soon becomes very expensive. Depending on the source, the cost of water brought from northern Australia would range between $6 and $9 per kilolitre [68]. At these rates, it would cost a minimum of $4.2 billion per annum just to cover the evaporative losses from the Lower Lakes. This is not affordable.

Desalination

Desalination is a component of providing water security for urban communities in South Australia. However, the volumes of water required for human water security and the volumes of water required for a healthy Coorong, Lower Lakes and Murray Mouth, are of different orders of magnitude. The desalination plant being constructed at Port Stanvac for Adelaide's water supply will produce 100 GL per annum. This is very significant in terms of urban water security (200 GL needed per annum) and is affordable for that purpose. But it is not a significant amount of water in relation to the needs of the Coorong and Lower Lakes. While it is much cheaper than bringing water from northern Australia, it would still cost in the region of $1 billion per annum just to cover the evaporative losses from the Lower Lakes.

Marine lakes including barrage removal

There were a number of proposals suggesting that either in total, or in part, the Lower Lakes should be allowed to become marine in nature. These proposals require either a permanent weir on the lower Murray to prevent seawater moving up the river or a large internal bund within Lake Alexandrina to separate the freshwater from the seawater.

There is no doubt that there were occasional incursions of seawater well into the Lower Lakes and the lower reaches of the River Murray prior to the development of the Murray-Darling Basin. However, there is solid evidence that the Lower Lakes were predominantly freshwater, and the established ecological character reflects that history.

If the barrages were opened in the absence of adequate freshwater flows, the evaporation of water from the surface of the Lakes, coupled with the limited mixing of water that can take place through the Murray Mouth, mean that there would be an increasing concentration of salt, leading to extremely saline conditions. Modelling indicates that if seawater were to enter Lake Alexandrina in sufficient volume, then in the absence of adequate freshwater flows, the great majority of the Lake will be hypersaline within two years [39]. Without adequate freshwater flows, letting seawater enter Lake Alexandrina is a recipe, not for a healthy estuarine or marine ecosystem, but for an increasingly degraded hypersaline one.

Removal of the barrages would also make the Lower Lakes more vulnerable to projected sea level rise.

Increased stormwater harvesting, greywater recycling, aquifer recharge, rainwater tanks

All of these are components of urban water security, as described in the 'Water for Good' Plan. However, the quantities of water available through these means are not significant relative to the minimum requirements for a healthy Coorong and Lower Lakes with an open Murray Mouth. They are, however, significant in relation to the quantities of water required for water security for urban purposes and are being pursued accordingly.

Cloud seeding

There have been successful examples of cloud seeding in various locations around the world. However, it is not believed to be practical to carry out cloud seeding on such a scale that it could have a significant impact on end-of-system flows for the Murray-Darling Basin.

Even if such large scale cloud seeding were practical, it would mean that enhanced rainfall over the Murray-Darling Basin may well be at the cost of reduced rainfall elsewhere. This would have negative impacts on the ecological and economic values of areas outside the Murray-Darling Basin.

Additional outlets to the sea for the Lower Lakes and/or the Coorong

The Murray Mouth has only been kept open in recent years through constant dredging. In the absence of adequate end-of-system flows of freshwater, any additional openings to the sea will rapidly be blocked by sand movement without continual dredging, and will have the effect of infilling the Coorong with sand, while the rate of closure of the current Mouth will accelerate.

Modeling has shown that the current dredging program is by far the most effective means of keeping the Coorong and Estuary connected to the sea until end-of-system flows improve [69]. Resetting the salinity of the South Lagoon through pumping out hypersaline water, diverting freshwater from the South East, and the return of end of system flows are more feasible ways of contributing to a healthy Coorong.

Constructing a channel between Lake Albert and the North Lagoon of the Coorong

Connecting Lake Albert to the Coorong in the absence of adequate flows of freshwater would result in saline water from the Coorong replacing the evaporative losses from Lake Albert. This would not freshen Lake Albert, but result in hypersaline conditions.

Appendix 5: Ecosystem process diagram for the CLLMM

The process models are built at two levels. The first level represents the water bodies associated with the region (grey boxes). Freshwater sources (yellow ovals) and outflows to the sea (light green ovals) are also included to illustrate where water enters and leaves the overall system. Arrows within this level of the model indicate the directional flow of water between water bodies.

The second level of the model includes sets of management actions relevant for particular water bodies. Currently, four sets of actions are represented by the model, since management actions are to be targeted at Lake Alexandrina, Lake Albert, tributaries/Goolwa Channel and the South Lagoon of the Coorong. A sub-model begins with a management action (red box) and is linked to a water component with an open arrow. From this point, the solid arrows indicate the flow or direction towards various staged results. For simplicity, results have been illustrated using green or orange ovals to indicate increase or decrease, respectively, in the parameter listed. Blue ovals represent management or ecological objectives. Green and yellow diamonds represent changes occurring after some initial objective has been met. Condition changes (white boxes) most often represent an alteration from the current degraded ecological character which assists in leading to a desired objective.

Regardless of the measures taken, ecosystems will be altered. These models illustrate only the expected and desired pathways of change.

While based on the best available science, the results of management actions are still theoretical. This region is undergoing unprecedented change, so there are no documented effects from such dramatic alteration to ecosystems. Given this, there is currently little understanding about the amount of time that is required for ecological transition. As presented in the control models for this region [70,71], it is likely that this area will recover to a state that differs from the historical state, although one that is an improvement on current conditions.

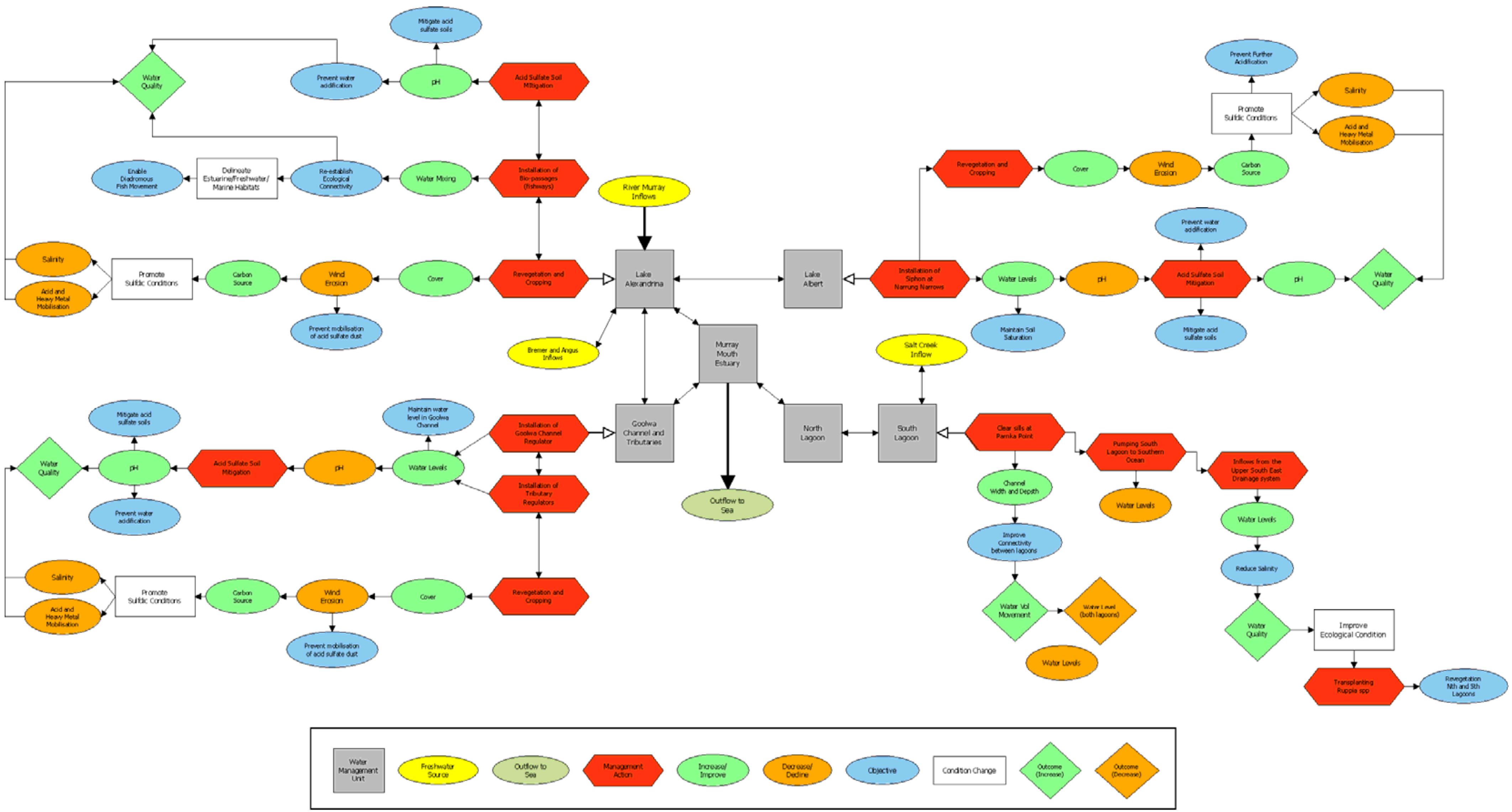

Figure 13. Ecosystem process diagram for the Coorong, Lower Lakes and Murray Mouth

Appendix 6 Adaptive management for salinity in the South Lagoon.

Adaptive management for salinity in the South Lagoon

Increases in salinity in the South Lagoon of the Coorong have had serious impacts on keystone species such as Tuberous Tassel Small-mouthed Hardyhead and chironomids. All of these species are food sources for various bird species that historically occupied the South Lagoon and their loss can be linked to the reduced bird use of this management unit.

Conceptual models of the ecology of the South Lagoon and the ecology of these species indicates that by a reduction in salinity and the maintenance of appropriate water levels, the management action should result in improved water quality. This, in turn, will allow recovery of Tassel through recolonisation from the North Lagoon facilitating future recolonisation of historical aquatic habitat by the other food species.

Historical salinity maxima for the South Lagoon were 100 parts per thousand (ppt) but now, summer salinity in the South Lagoon is greater than 180 ppt, and has at times exceeded 200 ppt. Such high salinities place the South Lagoon outside of the limits of acceptable change for Tassel, based on the 1985/2006 ecological character description.

The adaptive management process proposed for the site would include the following steps (based on the process outlined in Section 11):

Step 1: Develop a plan of management actions

Identify the problems

The key problems for the South Lagoon are increasing salinity and decreased water levels during summer each year. Conceptual models of ecology and hydrology indicate this principally results from reduced freshwater inflows, resulting in the loss of Tuberous Tassel as a food source for black swans. This, combined with the salinity increase, has resulted in the loss of Small-mouthed Hardyhead and chironomids as a food source for other bird species.

Scope actions

Based on a conceptual model of the South Lagoon, two management actions were identified as ways to reduce salinity in the South Lagoon:

- increasing freshwater outflow across the barrages, or
- increasing freshwater inflow from the Upper South East Drainage scheme.

It was determined that insufficient freshwater was available to achieve these actions within a suitable timeframe to avoid the risk of ecological collapse.

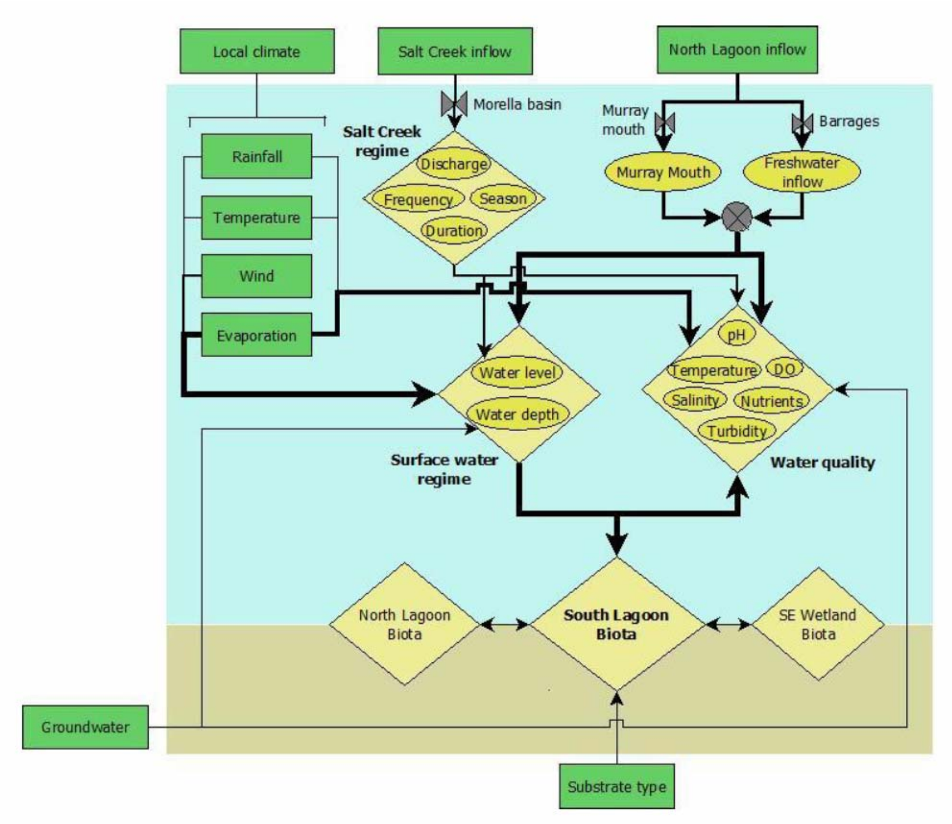

Figure 14. Conceptual model of the South Lagoon (Souter, 2009)

Additional actions which were proposed for the South Lagoon included:

- construction of a regulator at Parnka Point
- dredging the constriction at Parnka Point
- pumping hypersaline water from the Coorong into the Southern Ocean.

The potential impacts of these various actions on water level, salinity and ecosystem states were examined using modelling products developed during CLLAMMecology (CLLMM futures modelling and the CSIRO one dimensional hydrodynamic models).

Select actions

The outcomes, timeliness and cost of the various actions were assessed: the best action to implement was pumping saline water from the South Lagoon to the Southern Ocean. The benefit would be greater when combined with dredging at Parnka Point to minimise the adverse impacts of pumping on water levels during summer.

Additional modelling was then conducted using a more detailed hydrodynamic model to determine:

- pumping rates
- impacts on water quality
- dredging impacts at Parnka Point
- timing for commencement.

The next steps were to progress:

- implementation of a pumping program to reduce salinity in the South Lagoon, including preparation of all necessary permits and approvals
- investigation of impacts on fauna at discharge point

- continue investigations into the redirection of additional freshwater inflows from the South East of South Australia.

A process or results chain was then developed to outline the expected results from the management action.

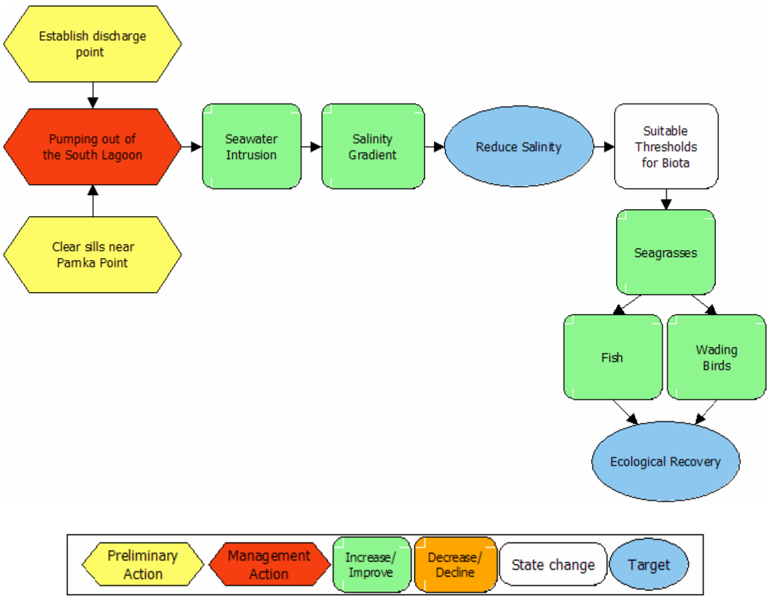

Figure 15. Process chain for the pumping of hypersaline water from the South Lagoon

Develop plan of implementation

The implementation plan outlines the logistics, necessary approvals, risk assessment and management responses. The implementation plan includes triggers for reviewing the action, based on modeled performance at specific pumping rates, to achieve the target water quality based on the tolerances of the target species.

Outline objectives and targets

The objective for the site is to restore severely degraded habitat in the South Lagoon of the Coorong by reducing the extremely high salinity levels. Targets for the site are set as in the table below.

Water Quality Targets	**Ecological Targets**
• Summer maximum of 100 g/L salinity for summer and 60 g/L salinity for winter • Water level targets also set for summer and winter.	• Recovery of Tuberous Tassel in the South Lagoon to 80 per cent of the historical distribution by 2016 • Recovery of wader habitat, such that 80 per cent of available habitat is occupied by 2016 • Recovery of Hardyhead distribution to include a presence at 50 per cent of sites sampled by 2016.

Set timeframe

Assuming implementation of the action no later than August 2010, pumping is expected to require a minimum of 18 months to achieve the target salinities such that interim targets or trigger points are expected at the times presented in the Table below.

2010	2011	2012
December		December
	March	March
	June	June
	September	September

Develop monitoring program

A monitoring plan has been prepared to determine that the action is achieving the interim targets that guide implementation and may alter the implementation of the action or may be resulting in unexpected consequences. The plan outlines monitoring of:

- the physical environment, especially salinity and water levels, at relevant locations in the South Lagoon
- the physical environment near the outfall
- ecological responses of keystone species and bird populations
- species interactions, as determined by a risk assessment carried out during the preparation of a referral to the Australian Government under the *EPBC Act*.

Re-establishment of keystone species is expected to occur from Coorong North Lagoon refuges, but Tuberous Tassel may need a revegetation program to ensure recovery occurs and is informed by the monitoring program. Triggers are still to be established for the implementation of this action, although a feasibility study has been undertaken to demonstrate it is possible and it has been costed for inclusion in the Long-Term Plan.

Beyond achieving the desired salinity, continuing monitoring of water quality, water levels and ecosystem biology will be required to determine if pumping is required again in the future to keep salinity near target levels. This would require the setting of a trigger salinity level for re-starting pumping, should that be required.

Specify triggers and Limits of Acceptable Change

The tolerances of key species are:

- tuberous Tassel tolerates 100 parts per thousand, plus needs adequate water levels, which are dropping
- chironomids (midges) tolerate up to 120 ppt
- small-mouthed Hardyhead fish tolerate up to 120 ppt.

These salinity tolerances establish important benchmarks for management action to ensure the restoration of ecological character in this part of the CLLMM site, due to their role as keystones of the ecology.

Step 2: Implement the plan

Implementing the plan involves undertaking the action in the manner and timeframe specified in the implementation plan developed during Step 1. Similarly, any research or predictive modelling is implemented as planned.

Step 3: Monitor the activities

The ecological monitoring is coordinated around pumping saline water from the South Lagoon. This monitoring complements the regular condition monitoring that already occurs. Implementation summaries will be regularly provided to the CLLMM Board via the CLLMM Technical Advisory Group as briefings and the findings will be entered into the Decision Support System. In this way, the monitoring program allows managers to assess the success of the action.

Step 4: Analyse outcomes against expectations

At quarterly intervals, results of the action will be compared with the water quality expectations from the implementation plan. At this time, questions such as 'Did the action achieve the desired water quality as predicted for this period?' will be answered by examining water quality changes against the interim targets. If the desired salinity targets are achieved outside of the expected timeframe (early or late), an investigation will be initiated to determine the reasons for this (i.e. anticipated pumping rates may have not been met due to mechanical failure). If required, the models used for water quality will be altered to reflect the changes.

Following achievement of the desired water quality objectives and ecological outcomes, further questions will be considered to explicitly evaluate the success of each action or decision. These may include: 'Did the action solve the problem?' or 'Did other factors affect the success of the action (e.g. drought)?'

Step 5: Review and adapt the actions

Based on the information gained from Step 4, one of the following recommendations will be made to the CLLMM Board:

- *Continue action*: if water quality is within the range of expected results within an expected time frame
- *Cease action:* if the targets for salinity and water levels have been achieved within an expected time frame
- *Review causes:* if water quality is not within the range of expected results.

Following this review, a further recommendation will be made to:

- proceed with the action if the issues can be resolved. Models and targets used will be reviewed and updated, and timelines will be extended
- suspend the action until uncertainty or identified issues are addressed, or
- terminate the action.

A Decision Support System will be used to document decisions and supporting evidence.

Step 6: Learn from the activities

Key findings from Step 5 are used to evaluate the conceptual and qualitative models of the site. These revised models are then used to develop future management objectives and targets for the site. In this way, knowledge gained from past actions improves decision making for future actions and programs.

Appendix 7: Implementation Schedule

			2010				2011				2012				2013				2014			
Location	**Program**	**Activity**	**Jan - Mar**	**Apr - Jun**	**Jul - Sept**	**Oct - Dec**	**Jan - Mar**	**Apr - Jun**	**Jul - Sept**	**Oct - Dec**	**Jan - Mar**	**Apr - Jun**	**Jul - Sept**	**Oct - Dec**	**Jan - Mar**	**Apr - Jun**	**Jul - Sept**	**Oct - Dec**	**Jan - Mar**	**Apr - Jun**	**Jul - Sept**	**Oct - Dec**
Murray Mouth	Maintaining an open Murray Mouth	Dredging the Murray Mouth as per existing strategy	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Coorong	Coorong salinity reduction	Design work on restoring flows from the Upper South East to the Coorong	✓	✓	✓	✓																
		Diverting water from the South East to the Coorong (First stage)				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Pumping out about 50 GL of hypersaline water from the South Lagoon	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
		Dredging of sills at Parnka Point																				
	Tassel (*Ruppia* sp.)translocation	Translocation of Large-fruit and Tuberous Tassel						✓	✓			✓	✓			✓	✓					
Lake Alexandrina	Managing acid sulfate soils	Limestone dosing		✓	✓			✓	✓			✓	✓			✓	✓			✓		
		Environmental Impact Statement studies on impacts of seawater	✓	✓																		
	Vegetation	Revegetation – tubestock		✓				✓				✓				✓				✓		
		Revegetation – aerial seeding		✓	✓			✓	✓			✓	✓			✓	✓			✓		
		Cropping to stabilise soils		✓				✓				✓				✓				✓		
		Weed control		✓		✓		✓		✓		✓		✓		✓		✓				
		Vermin control		✓		✓		✓		✓		✓		✓		✓		✓				
		Fencing		✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓	✓				
	Fishways	Construct/install fishways				✓	✓			✓	✓			✓	✓			✓	✓			
Lake Alexandrina	Protecting critical environmental assets	Conservation of threatened species	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Maintenance of refuge habitats	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

			2010				2011				2012				2013				2014			
Location	**Program**	**Activity**	Jan - Mar	Apr - Jun	Jul - Sept	Oct - Dec	Jan - Mar	Apr - Jun	Jul - Sept	Oct - Dec	Jan - Mar	Apr - Jun	Jul - Sept	Oct - Dec	Jan - Mar	Apr - Jun	Jul - Sept	Oct - Dec	Jan - Mar	Apr - Jun	Jul - Sept	Oct - Dec
Lake Albert	Managing acid sulfate soils	Construction of artificial wetland		✓	✓																	
		Limestone dosing		✓	✓			✓	✓			✓	✓			✓	✓			✓		
		Installation of sub-surface barriers in the Lake bed	✓			✓	✓															
	Vegetation	Revegetation – tubestock		✓				✓				✓				✓				✓		
		Revegetation – aerial seeding		✓	✓			✓	✓			✓	✓			✓	✓			✓		
		Weed control	✓			✓		✓		✓		✓		✓		✓		✓				
		Vermin control	✓			✓		✓		✓		✓		✓		✓		✓				
		Fencing		✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓	✓				
		Cropping to stabilise soils		✓				✓				✓				✓				✓		
	Lake Albert water level management	Install a siphon at Narrung bund for one way water flow from Lake Alexandrina				TBD																
		Pumping water from Lake Alexandrina to keep Lake centre inundated	✓	✓																		
Goolwa Channel and Tributaries	Managing acid sulfate soils	Construction of regulators: Clayton and across Currency Creek	Operate																			
	Protecting critical environmental assets	Off-site conservation of threatened species for re-introduction	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Maintenance of refuge habitats	✓	✓				✓				✓				✓						
Entire site	Adaptive management	Monitoring and adaptive management program	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Research program	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Community engagement	Community engagement and communications	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Ngarrindjeri engagement	Ngarrindjeri partnerships and involvement	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	All programs	Direction, governance and planning	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Appendix 8: How the mix of management actions may change, depending upon climate scenario

Program	Activity	Climate Scenario			
		Extreme Dry	Dry	Median	Wet
Maintaining an open Murray Mouth	Dredging the Murray Mouth as per existing strategy	✓	✓	↓	X
Coorong salinity reduction	Design work on restoring flows from the Upper South East to the Coorong	✓	↑	↑	↑
	Diverting water from the South East to the Coorong (First stage)	✓	↑	↑	↑
	Pumping out about 50 GL of hypersaline water from the South Lagoon	✓	✓	↓	X
	Dredging of sills at Parnka Point	✓	✓	↓	X
Tassel translocation	Translocation of Large-fruit (*Ruppia megacarpa*) and Tuberous Tassel (*Ruppia tuberosa*)	✓	✓	✓	✓
Managing acid sulfate soils	Limestone dosing	✓	↓	X	X
	Installation of sub-surface barriers in the Lake bed	✓	↓	X	X
	Studies on impacts of seawater	✓	↓	X	X
	Construction of artificial wetland	✓	✓	↓	X
Vegetation	Revegetation – tubestock	✓	↑	↑	↑
	Revegetation – aerial seeding	✓	✓	✓	↓
	Cropping to stabilise soils	✓	✓	↓	X
	Weed control	✓	↑	↑	↑
	Vermin control	✓	✓	↑	↑
	Fencing	✓	✓	↓	X
Fishways	Construct/install fishways	✓	✓	↓	X
Protecting critical environmental assets	Conservation of threatened species	✓	✓	↑	↑
	Maintenance of refuge habitats	✓	✓	✓	✓
Lake Albert water level management	Pumping water from Lake Alexandrina to keep Lake centre inundated	✓	✓	↓	X
Adaptive management	Monitoring and adaptive management program	✓	✓	✓	✓
	Research program	✓	✓	✓	✓
Community engagement	Community engagement and communications	✓	✓	✓	✓
Ngarrindjeri engagement	Ngarrindjeri partnerships and involvement	✓	✓	✓	✓
All programs	Direction, governance and planning	✓	✓	✓	✓

✓= Action is appropriate under these conditions

↑ **=** Action becomes more important under these conditions, compared to extreme dry conditions

↓ **=** Action becomes less important under these conditions, compared to extreme dry conditions

X = Action is not required under these conditions

Appendix 9: Key governance bodies established or supported by CLLMM projects

1. CLLMM Joint Liaison Committee

Role: Overall Commonwealth-State oversight of the project and its delivery

Membership:

- Project Funder, First Assistant Secretary, Water Reform, DEWHA
- Project Owner, Chief Executive, Department for the Environment and Heritage (DEH) and South Australian Government representative
- Member, Murray-Darling Basin Authority.

Frequency of meeting: Fortnightly initially, then adjusted as required by the needs of the project.

2. CLLMM Project Board

Role: Responsible for ensuring:

- the overall carriage of the project and endorsing its key business decisions
- that an overall project plan is developed (and kept under review)
- that the outcomes of the project (goals and deliverables) are achieved within time and budget
- the appropriate use of Commonwealth and State government funds
- effective project governance, in accordance with the agreed project governance structure for the CLLMM project.

Membership:

- Project owner (Chief Executive, DEH) (Chair)
- Member (Deputy Chief Executive, Treasury and Finance or proxy)
- Member (Chief Executive, DWLBC or proxy)
- Member (Commissioner for Water Security, or proxy)
- Expert Adviser (Chair, Water Security Technical Working Group)
- CLLMM Project Director, DEH.

Frequency of meeting: Monthly initially, then adjusted as required by the needs of the project.

3. CLLMM Project Steering Committee

Role: Responsible for ensuring that the project meets the outcomes, milestones and timelines provided in the project plan. Key decision points for the Committee include:

- endorses the business decisions for the project
- develops and inputs to progress against the project plan
- resolves issues, acting as a clearing house for whole-of-government project issues that may arise with the project implementation
- examines ways to improve project delivery via resources, information and knowledge sharing and procurement practices
- acts as a conduit for information sharing across government on the project.

Membership:

- Project owner, Chief Executive, DEH or proxy (Chair)
- CLLMM Project Director, DEH
- Member, Executive Director, Murray Futures
- Member, Executive Director, Policy and Planning, DWLBC
- Member, Chair, Water Security Technical Working Group, DWLBC
- Member, Director, Nature Conservation DEH
- Member, Head of Strategic Projects, SA Water
- Member, River Murray Environmental Manager, DWLBC
- Member, Group Manager River Murray Works and Measures, DWLBC.

Frequency of meeting: fortnightly initially, then adjusted as required by the needs of the project.

4. CLLMM Technical Advisory Group

Role: To participate actively in the adaptive management process for the CLLMM Project, including:

- contributing to the continuing review of monitoring of the CLLMM site and the implementation of CLLMM projects
- advising on emerging technical, ecological and environmental issues
- advising on research that may be needed to support the implementation of the project.

Membership:
Panel members will be drawn from specialists with required knowledge in the following areas: ecology and the environment, hydrology, water resources, vegetation, fish, birds, wetlands, estuarine systems, engineering and marine and coastal environments.

Frequency of meeting: Monthly initially, then adjusted as required by the needs of the project.

5. CLLMM Community Advisory Board

Role:

- to provide to the Minister a representative range of views of the CLLMM communities on the implementation of the management actions and environmental, economic and social impacts of significance within the CLLMM site
- to assist the implementation of the CLLMM project by disseminating information within communities in a way that promotes clear understanding of the context and rationale, and enhances their ownership and adoption.

Membership:
The Community Advisory Board will comprise between 10 and 15 members drawn from:

- local government
- Murray-Darling Basin NRM Board
- Ngarrindjeri
- community groups
- individuals with specific expertise in the site.

The chair will be drawn from these members. Executive support will be supplied by the CLLMM Projects team.

Frequency of meeting: Quarterly initially, then adjusted as required by the needs of the project.

6. CLLMM Project Reference Group(s)

Role: To provide specific community input and feedback about a particular issue or project to the CLLMM Projects team. A recent example was the Lake Albert Community reference Group chaired by the Mayor, Coorong District Council.

Membership: Drawn from the set of community stakeholders affected by the particular issue or project. The chair will be drawn from these members. Executive support will be supplied by the CLLMM Projects team.

Frequency of meeting: As required by the nature of the issue or project. It is expected that each such reference group would have a sunset clause.

7. Project Coordination Committee/Project Assurance Group(s)

Role: To support the Project Manager by providing oversight to the development, scoping and implementation of each specific project which forms part of the CLLMM Long-Term Plan and business case.

Membership: Drawn from the Project Sponsor and relevant agencies which provide expertise or resources to the project.

Frequency of meeting: As required by the nature of the project.

8. Ngarrindjeri Liaison

Liaison with the traditional owners of the CLLMM during the implementation of the CLLMM project will be guided by the Kungun Ngarrindjeri Yunnan Agreement, negotiated in June 2009 between the State Government and the Ngarrindjeri.

This presently involves:

- A Leaders' meeting, involving the Ngarrindjeri Regional Authority, Minister for Water Security and Minister for Environment and Conservation, as required.
- A Kungun Ngarrindjeri Yunnan meeting, held fortnightly, involving the Ngarrindjeri Regional Authority and its advisers, representatives of key Government agencies within the scope of the Agreement and the Crown Solicitor's Office. This meeting deals particularly with heritage matters arising from the planning and implementation of projects in the CLLMM site.

List of scientific names

Common name	Scientific name
Chestnut Teal	*Anas castanea*
Austral Seablite	*Suaeda australis*
Australasian Bittern	*Botaurus poiciloptilus*
Banded Stilt	*Cladorhynchus leucocephalus*
Beaded Samphire, Beaded Glasswort, Glasswort or Samphire	*Sarcocornia quinqueflora*
Big-bellied Seahorse	*Hippocampus abdominalis*
Black Swan	*Cygnus atratus*
Bony Herring	*Nematalosa erebi*
Brine Shrimp	*Parartemia zietziana*
Cape Barren Goose	*Cereopsis novaehollandiae*
Chironomid	*Tanytarsus barbitarsus*
Common Galaxias	*Galaxias maculatus*
Common Reed	*Phragmites australis*
Congolli	*Pseudaphritis urvillii*
Curlew Sandpiper	*Calidris ferruginea*
Dwarf Grass-wrack	*Zostera muelleri var.*
Dwarf Flat-headed Gudgeon	*Philypnodon macrostomus*
Eastern Curlew	*Numenius madagascariensis*
Estuary Perch	*Macquaria colonorum*
Fairy Tern	*Sterna nereis*
Freshwater Eel-tailed Catfish	*Tandanus tandanus*
George's Groundsel	*Senecio georgianus var. georgianus*
Golden Perch	*Macquaria ambigua ambigua*
Hooded Plover	*Charadrius rubricollis*
Large-fruit Tassel	*Ruppia megacarpa*
Latham's Snipe	*Gallinago hardwickii*
Lewin's Rail	*Rallus pectoralis*
Little Tern	*Sterna albifrons*
Long-fruit Water-mat	*Lepilaena cylindrocarpa*
Metallic Sun-orchid	*Thelymitra epipactoides*
Milfoils	*Myriophyllum spp.*
Mount Lofty Ranges Southern Emu-wren	*Stipiturus malachurus intermedius*
Murray Cod	*Maccullochella peelii peeli*
Murray Hardyhead	*Craterocephalus fluviatilis*
Orange-bellied Parrot	*Neophema chrysogaster*
Pondweeds	*Potamogeton spp.*
Pouched Lamprey	*Geotria australis*
Red-necked Avocet	*Recurvirostra novaehollandiae*
Ribbon Weed	*Vallisneria americana*
River Blackfish	*Gadopsis mormoratus*
Rushes	*Juncus spp.*

Sea Heath	*Frankenia pauciflora*
Sharp-tailed Sandpiper	*Calidris acuminata*
Short-finned Eel	*Anguilla australis*
Short-headed Lamprey	*Mordacia mordax*
Shrubby Glasswort	*Tecticornia arbuscula*
Silver Perch	*Bidyanus bidyanus*
Small-mouthed Hardyhead	*Atherinosoma microstoma*
Southern Bell Frog	*Litoria raniformis*
Southern Pygmy Perch	*Nannoperca australis*
Swamp Paperbark	*Melaleuca halmaturorum*
Tamar Goby	*Afurcagobius tamarensis*
Tuberous Tassel	*Ruppia tuberosa*
Tubeworms	*Ficopomatus enigmaticus*
Water Ribbons	*Triglochin procerum*
Yarra Pygmy Perch	*Nannoperca obscura*
N/A	*Typha sp.*

Glossary

Aquatic	Consisting of, relating to, or being in water; living or growing in, on or near the water. An organism that lives in, on, or by the water.
Acid sulfate soils	Sulfate rich soils, common in low lying coastal regions, that when exposed to aerobic conditions (e.g. exposed to air through lowering of water levels) can produce highly acidic leachate.
Adaptive management	A process of "learning by doing", where learning is fully incorporated into future decision-making (Holling 1978). Adaptive management allows decisions to be made using the best available knowledge at the time, rather than requiring complete understanding of all possible consequences.
AHD	Australian height datum – national survey datum corresponding approximately to average sea level.
Alkalinity	An expression of the ability of a solution to neutralise acids, measured as the milliequivalents of hydrogen ions neutralised by a litre of water (expressed as $CaCO_3$ in mg/L).
Anthropogenic	Of or relating to human activity. An anthropogenic action or effect is one brought about by humans.
Barrages	A series of five structures that separate the fresh waters of the River Murray and Lake Alexandrina from the more saline waters of the Murray Mouth estuary and Coorong lagoons. These barrages, Goolwa, Mundoo, Boundary Creek, Ewe Island and Tauwitchere, were constructed in the 1930s between the mainland and Hindmarsh, Mundoo, Ewe and Tauwitchere Islands, which are situated between the Lower Lakes and the Coorong.
Basin Plan	A plan to be prepared by the Murray-Darling Basin Authority in consultation with Basin states, Indigenous groups and local communities, that will specify limits on the amount of water that can be taken from Basin waters on an environmentally sustainable basis. It will also include an environmental watering plan to optimise environmental outcomes and implement a management plan for water quality and salinity and rules about the trading of water rights.
Biodiversity	The variety of different species, the genetic variability of each species, and the variety of different ecosystems that they form.
Bioregion	A territory defined by a combination of biological, social and geographical criteria rather than by geopolitical considerations; generally, a system of related interconnected ecosystems.
Bioremediation	Promoting naturally occurring bacteria to return contaminated environments to a healthy state.'Sulfate reducing' bacteria in the soil can reverse the process of acid sulfate soils forming sulfuric acid. They use sulfate in the acid as well as iron and organic matter to do this, so making sure these are available is an important part of bioremediation. Growing plants (revegetation) can create more organic matter and iron, but it is only one part of the longer-term bioremediation process.
Biosequestration	The conversion of a compound through biological processes to a form that is chemically or physically isolated
Biota	All living organisms of a region.
Calcareous	A sediment, sedimentary rock, or soil type which contains a high proportion of calcium carbonate.
Catadromous	Fish species that spawn at sea but use freshwater environments during their juvenile and sub-adult life stages.

Coorong	The Coorong is a long, shallow saline lagoon that stretches more than 100 km and is separated from the Southern Ocean by a narrow sand dune peninsula.
CSIRO Murray-Darling Basin Sustainable Yields Project	A series of reports which assess the current and future water availability in the Murray-Darling Basin.
Diadromous species	Species that require access to both marine and freshwater environments to complete their lifecycle.
Diatoms	Microscopic single-celled algae with a hard outer shell that are deposited in the sediments of the Lower Lakes and Coorong.
Dredging	The process of sand pumping to maintain an open Murray Mouth to the Southern Ocean.
EC	Electrical conductivity – a measure of water's ability to conduct electricity. EC units (measured in µs/cm – micro Siemens per centimetre) are used to express salinity levels in soil and water. When salt is dissolved in water the conductivity increases, hence higher salinities are directly related to higher EC values.
Ecological character	The sum of the biological, physical and chemical components of an ecosystem, and the interactions, that maintain it and its products, functions, and attributes.
Ecological communities	Any naturally occurring group of species inhabiting a common environment, interacting with each other especially through food relationships and relatively independent of other groups. In the *Environment Protection and Biodiversity Conservation Act 1999* they are defined as assemblages of native species that inhabit particular areas in nature.
Ecosystem	A dynamic assemblage of plant, animal, fungal and micro–organism communities and the associated non–living environment interacting as an ecological unit.
Ecosystem services	The benefits provided by ecosystems.
Emergent	Protruding from the water (e.g. emergent vegetation, growing out of the lake water surface).
End of system flows	The volume of water that flows through the Murray Mouth.
Endangered	An ecological community is eligible to be included in the endangered category at a particular time if, at that time: (a) it is not critically endangered; and (b) it is facing a very high risk of extinction in the wild in the near future, as determined in accordance with the prescribed criteria outlined in the *Environment Protection and Biodiversity Conservation Act 1999*.
Environmental Impact Statement (EIS)	Outlines the potential impacts on matters of National Environmental Significance defined under the *Environment Protection and Biodiversity Conservation Act 1999.*
Ephemeral (river)	A watercourse or body that exists for only a short time following substantial rainfall.
Erosion	The continuing process of landscape development as a smoothing or levelling of the Earth's surface by removal of weathered material. Natural erosion is due only to the forces of nature; accelerated erosion occurs as a result of human activities. In each case, the same processes operate and the distinction is often only a matter of degree and rate.

Estuarine	Conditions encountered in an estuary. Estuaries are generally characterised by higher salinities and high biological diversity. (NB: The term estuarine may be used to describe raised salinity in an environment which is naturally non-estuarine; in such a case it does not necessarily imply high biological diversity).
Estuary	The area where river water meets and dilutes salt water of the sea. The zone where a river mixes with the sea.
Evaporative losses	The amount of water that is lost to the atmosphere via evaporation.
Fauna	Animal species.
Federation Drought	Period of drought from 1895 to 1902.
Fishway	Engineered structure on or around artificial barriers to facilitate the natural migration of fish.
Flora	The assemblage of plant species within a defined collection or area.
Geomorphology	General term referring to the description of topography (form or geometry of the land surface, including elevation, slope angle, relative relief, contour configuration and profile form), and an assessment of the past and present factors that shape it. Includes determining the influence of rock materials and structures and past and present tectonic, climatic and biological processes.
GL	Gigalitre - 1 billion litres or approximately 444 Olympic swimming pools.
Goolwa Channel Water Level Management Project	A project being implemented by the South Australian Government as an emergency response required to avert the acidification of the Goolwa Channel and its tributaries (Finniss River and Currency Creek). The project has seen the construction of two environmental flow regulators - one in the Goolwa Channel, and one in Currency Creek. Construction of a third regulator for Finniss River has been put on hold.
Groundwater	Water that is below the Earth's surface, generally occupying the pores and crevices of rock and soil.
Habitat	The place in which an organism lives; comprising its physical structure, such as reef, sediments or water column properties, as well as biological structures, such as the dominant plant types. Specific place where a plant or animal lives.
Head	Water level gradient. Water flows in a direction of high hydraulic head to points of low hydraulic head.
Heavy metals	A metal or metalloid with a specific gravity greater than about 5.0, such as lead, cadmium or mercury. Because they cannot be degraded or destroyed, heavy metals are persistent in all parts of the environment.
Hydrodynamic	Pertaining to, or derived from, the dynamical action of water.
Hydrology	The science dealing with surface waters and groundwaters of the Earth; their occurrence, circulation and distribution; their chemical and physical properties; and their reaction with the environment.
Hypersaline	Water that is extremely saline and saltier than the sea.

Icon Site Management Plan	The Living Murray Icon Site Environmental Management Plan for the Coorong, Lower Lakes and Murray Mouth has recognised that the site's social, cultural and economic values are under threat due to diminished flows. The Plan establishes three ecological objectives for the site: • An open Murray Mouth • Enhanced migratory water bird habitat in the Lower Lakes and Coorong • More frequent estuarine fish spawning and recruitment.
Keystone species	A species that has a disproportionate effect on other organisms within an ecosystem. Such species affect many other organisms in an ecosystem and help to determine the composition and abundance of various others species in a community.
Levee banks	Levee banks were originally constructed along both sides of the River Murray to allow floodplains and wetlands along the river to be used for agriculture purposes. They also prevent flooding when river levels are high. As well as providing access to properties, the levee banks provide for recreational uses such as walking, cycling and fishing.
Limestone dosing	Adding of finely ground limestone and limestone slurry (dry limestone mixed with water) to the lakebed and the water to keep the water's pH high enough to buffer acid released from the exposed soils in the region.
Living Murray Initiative	Program established in 2002 in response to concerns about the declining health of the River Murray system. It is a partnership of the Australian, NSW, Victorian, South Australian and ACT governments. A major focus of the Living Murray initiative is on improving the environment at six designated Icon sites. The program's first step was to recover 500 gigalitres (GL) of water by 30 June 2009 which can be deployed for environmental purposes at the six Icon sites into the future. (South Australia has achieved its target share by recovering its 35GL.)
Lower Lakes	Lake Alexandrina and Lake Albert form the Lower Lakes of the River Murray.
metres AHD	Unit of elevation measurement used to describe the height (altitude) above the Australian Height Datum – AHD (i.e. given in metres AHD). The mean sea level for 1966 – 1968 was assigned the value of zero at multiple tide gauges around Australia.
Macro invertebrate	Invertebrates visible to the naked eye.
Migratory species	Migratory species are those animals that migrate to Australia and its external territories, or pass though or over Australian waters during their annual migrations. Examples of migratory species are species of birds (e.g. albatrosses and petrels), mammals (e.g. whales) or reptiles. Migratory species listed in the Environment Protection and Biodiversity Conservation Act 1999 also include any native species identified in an international agreement approved by the Minister.
Mono-sulfidic black ooze	Gelatinous soil that consist of iron sulfide; formed under anoxic and often increased saline conditions; once distubed can rapidly deoxygenate overlying waters.
Murray Futures	Funded by the Australian Government's $12.9 billion Water for the Future program, Murray Futures is South Australia's priority project to secure the future for Murray-Darling Basin industries and communities reliant on the environment. Murray Futures positions South Australia to respond to the threats and challenges facing the River Murray in a future of reduced water availability and climate change.The ten-year integrated package aims to ensure that South Australia will respond proactively to climate change by adopting flexible, adaptive environmental management practices to achieve long-term community, industry and environmental outcomes. It aims to maximise the use of existing environmental water and target water to key priority sites, while also providing environmental

	water savings. It is designed to ensure the river system and its communities are more 'climate ready'.
Murray Mouth	The terminus of Australia's largest river system and the only site where water contaminants such as silt, salt and nutrients can be exported from the Murray-Darling Basin.
Narrung Narrows	A narrow channel near Port Malcolm connecting Lake Albert and Lake Alexandrina.
Narrung Narrows regulator	Structure that separates the waters of Lakes Alexandrina and Albert and allows the Lakes to be managed independently of each other while the current water crisis continues.
North Lagoon	North Lagoon of the Coorong, defined as the lagoonal area between Parnka Point and Pelican Point.
Oxidation	The loss of electrons (loss of hydrogen) or increase in oxidation State (e.g. gain of oxygen) in a chemical reaction. In short – a change in oxidation number (oxidation State).
pH	A measure of the acidity or alkalinity, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity. The pH scale commonly in use ranges from 0 to 14.
Pyritic	Relating to the common mineral pyrites (iron disulfide).
Ramsar	Also known as the Ramsar Convention (first convened in Ramsar, Iran 1971). It is an intergovernmental treaty with global wetland sites designated for inclusion in the list of wetlands of international importance. In 2000, Australia had 56 Ramsar sites. The Coorong, Lakes Alexandrina and Albert was nominated and accepted in 1985 as a Wetland of International Importance, commonly known as a 'Ramsar Site'.
Ramsar Management Plan	The overarching statement of the values of the Coorong, and Lakes Alexandrina and Albert Ramsar site.
Regulator	Structure to regulate the flow of water, raise water levels and keep acid sulfate soils saturated. In doing so, acidic soils will remain wet, and limit the formation of acid that would otherwise be generated.
Resilience (ecosystem)	The capacity of an ecosystem to cope with disturbances without shifting into a qualitatively different State.
River Regulation	Anthropogenic modifications to the flow regime, channel shape or immediate floodplain to control a river for human needs.
Salinity	Salinity is a measure of the salt concentration of water. Higher salinity means more dissolved salts. Electrical Conductivity (EC) is the measurement of salinity. Dissolved salt in soil or water creates a stronger electrical current, so the more salt in the soil or water, the higher the EC units will be.
Sediment	Solid material (predominantly small particles of sand, silt, rock and vegetable material) that have been transported by water and deposited or settled out of suspension. Unless otherwise specified, sediments are generally assumed to be inorganic.
South Lagoon	South Lagoon of the Coorong, defined as the lagoonal area between Parnka Point and 42 Mile Crossing.
Stream flow	The amount of water that is flowing in a stream.
Submerged	Existing beneath the surface of the water.

Sub-surface barrier	Sub-surface barriers typically include the excavation of trenches which are then filled with a control material that assists with the retention of subsurface groundwater. Sub-surface barriers are designed to manage areas of high acid sulfate soils risk by increasing soil moisture. This limits the oxidation of pyritic soils and prevents acidity moving to the remaining water body.
Sulfidic soils	Submerged or waterlogged sulfide containing soils are generally referred to as 'potential' acid sulfate soils or sulfidic sediments. They have soil acidity levels ranging between pH 4 and pH 9 and on exposure to oxygen have the potential to form sulfuric acid.
Sulfuric	When sulfidic materials are exposed to oxygen the soil can become acidic (pH <4) through the oxidation of sulfides in the sediment to form sulfuric acid. At this point, these sulfidic materials are then referred to as 'actual' acid sulfate soils.
Surface waters	All waters whose surface is naturally exposed to the atmosphere, for example, rivers, lakes, reservoirs, streams, seas, estuaries, etc., and all springs, wells, or other collectors directly influenced by surface water.
Sustainable	An activity able to be carried out without damaging the long-term health and integrity of natural and cultural environments.
Swamps of the Fleurieu Peninsula	Important habitat for the endangered Mount Lofty Ranges Southern Emu-wren. Areas defined as Fleurieu Peninsula Swamp occur at the confluence of Lake Alexandrina and the Tookayerta and Currency Creeks and the Finniss River.
Technical feasibility	Technical feasibility assessments provide detailed analyses of the objective, rationale, critical assumptions and costings of implementing an action or intervention.
Threatened species	Any species that is likely to become an endangered species within the foreseeable future, throughout all or a significant part of its range. A species of wildlife or plants listed as 'threatened' in a specific Act. The *Environment Protection and Biodiversity Conservation Act 1999* lists threatened native species in the following categories: extinct; extinct in the wild; critically endangered; endangered; vulnerable; conservation dependent.
Threatened ecological communities	The *Environment Protection and Biodiversity Conservation Act 1999* lists threatened ecological communities as: critically endangered; endangered; or vulnerable.
Tributary	A stream that joins another larger stream or body of water. A stream or other body of water, surface or underground, which contributes its water, even though intermittently and in small quantities, to another and larger stream or body of water.
Turbidity	The muddiness, cloudiness or milkiness of water. Related to the amount of suspended sediment in the water. Generally measured in Nephelometric Turbidity Units (NTU).
Vulnerable species	A threatened native species listed in the *Environment Protection and Biodiversity Conservation Act 1999* that is not critically endangered or endangered but is facing a high risk of extinction in the wild in the medium–term future.
Water allocation	Amount of water that can be diverted from a watercourse.
Water for Good	South Australia's plan to secure sustainable water supplies for our health, our way of life, our economy and our environment - both now and in the future and reduce South Australia's reliance upon the River Murray.

Water for the Future	The Australian Government Water for the Future strategy is a long-term national framework to secure the water supply of all Australians. Buying back water to restore the environment is one of the priorities of Water for the Future. The Australian Government is investing $12.9 billion over ten years through Water for the Future to address four key priorities: • Using water wisely • Supporting healthy rivers • Taking action on climate change • Securing water supplies
Water quality	The condition of water in the context of one or more beneficial uses. Usually described in terms of water quality indicators (such as pH, temperature and concentrations of nutrients or contaminants).
Weir pool	The body of water immediately upstream of a weir structure. In a relatively steep river or stream, a weir pool is expected to be more obvious while in a less steep river (such as the River Murray below Lock 1) a weir pool is expected to appear similar to the river in its natural State if the weir spillway height is not higher than the natural river level.
Wetland of International Importance	See 'Ramsar'.
Wetlands	Inland, standing, shallow bodies of water that may be permanent or temporary, fresh or saline. Areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres. A low–lying area of land that is saturated with moisture, especially when regarded as the natural habitat of wildlife. Marshes, swamps, and bogs are examples of wetlands.
Wind seiche	The term for the movement of water by wind energy.

References

[1] Phillips, W. and Muller, K. (2006). ***Ecological Character of the Coorong, Lakes Alexandrina and Albert Wetland of International Importance***. Department for Environment and Heritage, Adelaide, South Australia.

[2] DEH (in prep.). ***Coorong Salinity Reduction Program - South East Flows Restoration. Technical Feasibility Assessment (DRAFT)***. Department for Environment and Heritage, Adelaide, South Australia.

[3] DEH (in prep.). ***Managing Variable Lake Levels. Technical Feasibility Assessment (DRAFT)***. Department for Environment and Heritage, Adelaide, South Australia.

[4] DEH (in prep.). ***Maintenance of an Open Murray Mouth. Technical Feasibility Assessment (DRAFT)***. Department for Environment and Heritage, Adelaide, South Australia.

[5] CSIRO (2008). ***Water availability in the Murray-Darling Basin. A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project***. CSIRO, Australia.

[6] Fluin, J., Haynes, D., and Tibby, J. (2009). ***An Environmental History of the Lower Lakes and the Coorong. Report prepared for the Department for Environment and Heritage***. School of Earth and Environmental Sciences, University of Adelaide, Adelaide, South Australia.

[7] Sim, T. and Muller, K. (2004). ***A fresh history of the Lakes: Wellington to the Murray Mouth, 1800s to 1935***. River Murray Catchment Water Management Board, Strathalbyn, South Australia.

[8] Gell, P. and Haynes, D. (2005). ***A Palaeoecological Assessment of Water Quality Change in The Coorong, South Australia.*** Diatoma, The University of Adelaide and Department of Water, Land and Biodiversity Conservation, Adelaide, South Australia.

[9] Deborah Haynes, University of Adelaide, unpublished data.

[10] Ngarrindjeri Tendi, Ngarrindjeri Heritage Committee, and Ngarrindjeri Native Title Management Committee (2006). ***Ngarrindjeri Nation Sea Country Plan. Caring for Ngarrindjeri Country and Culture***. Ngarrindjeri Land and Progress Association, Meningie, South Australia.

[11] NRA, AG, and SGSA (2008). ***Ngarrindjeri Regional Partnership Agreement***. Ngarrindjeri Regional Authority, Australian Government and State Government of South Australia,

[12] Orange-Bellied Parrot Recovery Team (2006). ***National Recovery Plan for the Orange-Bellied Parrot (Neophema chrysogaster)***. Department of Primary Industries and Water, Hobart, Tasmania.

[13] DEWHA (2008). ***Species Profile and Threats Database. Litoria raniformis - Growling Grass Frog, Southern Bell Frog, Green and Golden Frog, Warty Swamp Frog***. Last updated, Accessed 30/10/2009, Available at http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=1828

[14] DEH (in prep.). ***Protecting Critical Environmental Assets Program - Critical Fish Habitat and Refuge. Technical Feasibility Assessment (DRAFT)***. Department for Environment and Heritage, Adelaide, South Australia.

[15] Millenium Ecosystem Assessment (2005). ***Ecosystems and Human Well-being: Synthesis***. Island Press, Washington, DC.

[16] Murray-Darling Basin Commission (2006). ***The Lower Lakes, Coorong and Murray Mouth Icon Site Environmental Management Plan 2006-2007***. Murray-Darling Basin Commission, Canberra, ACT.

[17] Sobels, J. D. (2007). ***Social Impacts of the Drought, Lower Murray, South Australia. A Scoping Study for the Lower Murray Drought Impact Community Reference Group***. Rural Social Science,

[18] DEWHA (2009). ***Water for the Future. Water locations. Murray-Darling Basin***. Last updated 19/10/2009, Accessed 30/11/2009, Available at http://www.environment.gov.au/water/locations/murray-darling-basin/index.html

[19] England, R. (1993). ***The Cry of the Coorong. The History of water flows into the Coorong. From feast to famine?*** Rob England, Kingston, South Australia.

[20] South East Drainage Board (1980). ***Environmental Impact Study on the Effect of Drainage in the South East of South Australia***. South Eastern Drainage Board, Adelaide, South Australia.

21 DWLBC (2008). *Surface Water Archive*. Last updated, Accessed 27/10/2009, Available at http://e-nrims.dwlbc.sa.gov.au/swa/

22 Timbal, B. (2009). The continuing decline in South-East Australian rainfall: update to May 2009. *Centre for Australian Weather and Climate Research Letters* (2): 1.

23 National Climate Centre (2007). *Six years of widespread drought in southern and eastern Australia, November 2001 - October 2007, Bureau of Meteorology, Special Climate Statement 14*. Australian Government Bureau of Meteorology, Melbourne, Victoria.

24 Leblanc, M.J., Tregoning, P., Ramillien, G., Tweed, S.O., and Fakes, A. (2009). Basin-scale, integrated observations of the early 21st century multiyear drought in southeast Australia. *Water Resources Research* 45 1.

25 IPCC (2007). *Climate Change 2007: The Physical Basis. Contributions of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, New York.

26 Chiew, F. H. S., Cai, W., and Smith, I. N. (2009). *Advice on defining climate scenarios for use in the Murray-Darling Basin Authority Basin Plan modelling, CSIRO report for the Murray-Darling Basin Authority. MDBA Publication no 33/09*. Murray-Darling Basin Authority, Canberra, ACT.

27 Matthews, C. (2005). *Seal Level Rise and Climate Change: Implications for the Coorong and Lakes Alexandrina and Albert Ramsar Site. A Preliminary Investigation*. Conservation Programs South East, Regional Conservation, Department for Environment and Heritage, Mount Gambier, South Australia.

28 Short, A. and Cowell, P. (2009). *Coorong Sea Level Rise Vulnerability Study (DRAFT). Report prepared for the South Australian Department for Environment and Heritage*. School and Geosciences, University of Sydney, Sydney, NSW.

29 Ecological Associates (2009). *River Murray System Operations Review. Backgrounder: Lower Lakes and Coorong, Barrages and the Murray Mouth (DRAFT). Report prepared for the Murray-Darling Basin Authority*. Ecological Associates Pty Ltd, Malvern, South Australia.

30 Phillips, B., Muller, K., and Higham, J. (2008). *Coorong and Lakes Alexandrina and Albert Ramsar Management Plan (Revised). Pre-consultation Draft*. South Australian Department for Environment and Heritage, Adelaide, South Australia.

31 Brookes, J. D., Lamontagne, S., Aldridge, K. T., Benger, S., Bissett, A., Bucater, L., Cheshire, A. C., Cook, P. L. M., Deegan, B. M., Dittmann, S., Fairweather, P. G., Fernandes, M. B., Ford, P. W., Geddes, M. C., Gillanders, B. M., Grigg, N. J., Haese, R. R., Krull, E., Langley, R. A., Lester, R. E., Loo, M., Munro, A. R., Noell, C. J., Nayar, S., Paton, D. C., Revill, A. T., Rogers, D. J., Rolston, A., Sharma, S. K., Short, D. A., Tanner, J. E., Webster, I. T., Wellman, N. R., and Ye, Q. (2009). *An Ecosystem Assessment Framework to Guide Management of the Coorong. Final Report of the CLLAMMecology Research Cluster*. CSIRO Water for a Healthy Country National Research Flagship, Canberra, ACT.

32 Fitzpatrick, R. W., Grealish, G., Shand, P., Simpson, S. L., Merry, R. H., and Raven, M. D. (2009). *Acid Sulfate Soil Assessment in the Finniss River, Currency Creek, Black Swamp and Goolwa Channel, South Australia. CSIRO Land and Water Science Report 26/09*. CSIRO Land and Water, Australia.

33 Lester, R., Webster, I., Fairweather, P., and Langley, R. (2009). *Predicting the ecosystem response of the Coorong to the South Lagoon Salinity Reduction Scheme. A report prepared for the South Australian Murray-Darling Basin Natural Resources Management Board*. Flinders Research Centre for Coastal and Catchment Environments, Flinders University and CSIRO Land and Water, Adelaide, South Australia.

34 Bice, C., Wilson, P., and Ye, Q. (2008). *Threatened Fish Populations in the Lower Lakes of the River Murray in spring 2007 and summer 2008. SARDI Publication Number F2008/000801-1*. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, South Australia.

35 Wedderburn, S. and Barnes, T. (2009). *Condition Monitoring of Threatened Fish Species at Lake Alexandrina and Lake Albert (2008-2009)*. The University of Adelaide, Adelaide, South Australia.

36 Ecological Associates (2009). *Literature review of the ecology of birds of The Coorong, Lakes Alexandrina and Albert Ramsar wetlands (DRAFT). Ecological Associates report CC-014-1-A prepared for the Department for Environment and Heritage*. Ecological Associates Pty Ltd, Malvern, South Australia.

[37] Ehmke, G., Birds Australia, personal communication, 22/10/2009.

[38] EPA (2009). *Lower Lakes Water Quality Monitoring*. Last updated 6/10/2009, Accessed 8/10/2009, Available at http://www.epa.sa.gov.au/lower_lakes.html

[39] Bice, C. and Ye, Q. (2009). *Risk assessment of proposed management scenarios for Lake Alexandrina on the resident fish community (DRAFT)*. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, South Australia.

[40] Webster, I. T. (2005). *An Overview of the Hydrodynamics of the Coorong and Murray Mouth. Technical Report No. #/2005*. CSIRO: Water for a Healthy Country National Research Flagship,

[41] Geddes, M. C. (1987). Changes in salinity and in the distribution of macrophytes, macrobenthos and fish in the Coorong Lagoons, South Australia, following a period of River Murray flow. *Transactions of the Royal Society of South Australia* **111**(4): 173.

[42] Rogers, D. and Paton, D. (2009). *Spatiotemporal Variation in the Waterbird Communities of the Coorong*. CSIRO Water for a Healthy Country National Research Flagship, Canberra, ACT.

[43] Paton, D., Rogers, D., Aldridge, K., Deegan, B., and Brookes, J. (2009). A future for the Coorong and Lower Lakes. *Pacific Conservation Biology* **15** 7.

[44] Ehmke, G., Herrod, A., R., Green, and Tzaros, C. (2009). *Habitat Protection and Restoration Plan for the Orange-bellied Parrot Neophema chrysogaster in the South East of South Australia*. Birds Australia, Melbourne, Victoria.

[45] Ehmke, G. (2009). 'Habitat' in Focus - the Coorong. *Trumped Up Corella - The Newsletter of the Orange-bellied Parrot Recovery Program* (3): 2.

[46] Fredberg, J. and Ye, Q. (2009). *The potenital impacts of heavy metals and acidity on the fish communities in the lower Lakes ana Coorong area, due to the exposure of acid sulfate soils: A literature review. A report to the SA Department for Environment and Heritage*. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, South Australia.

[47] Eckert, J. and Robinson, R. D. (1990). The fishes of the Coorong. *South Australian Naturalist* **65** 5.

[48] Lintermans, M. (2007). *Fishes of the Murray-Darling Basin: An introductory guide*. Murray-Darling Basin Commission, Canberra, ACT.

[49] Birckhead, J., Greiner, R., Hemming, S., Rigney, M., Trevorrow, G., Trevorrow, T., and Rigney, D. (2008). *Economic and Cultural Values of Water to the Ngarrindjeri People of the Lower Lakes, Coorong and Murray Mouth. Report prepared as part of the CSIRO's Water-for-a-Healthy-Country Flagship Project*. Institute for Land, Water & Society, Charles Sturt University,

[50] Hemming, S., Trevorrow, T., and Rigney, M. (2002). in *The Murray Mouth - Exploring the implications of closure or restricted flow* (ed. N. Goodwin and S. Bennet). Murray-Darling Basin Commission and Department for Water, Land and Biodiversity Conservation, Adelaide, South Australia.

[51] Bell, D. (2008). *Kungun Ngarrindjeri Miminar Yunnan: Listen to Ngarrindjeri Women Speaking*. Spinifex Press, North Melbourne, Victoria.

[52] Lester, R. E., Fairweather, P. G., Muller, K., and Higham, J. (2009). *Describing a "healthy, resilient wetland of international importance": Description of ecological objectives and associated outcomes*. Department for Environment and Heritage, Adelaide, South Australia.

[53] Government of South Australia (2009). *Water for Good. A plan to ensure our water future to 2050*. Office of Water Security, Government of South Australia, Adelaide.

[54] Commonwealth of Australia (2008). *Water management in the Coorong and Lower Lakes (including consideration of the Emergency Water (Murray-Darling Basin Rescue) Bill 2008). Report prepared by the Senate Rural Affairs and Transport References Committee*. Department of the Senate, Parliament House, Canberra, ACT.

[55] DEH (in prep.). *Coorong Salinity Reduction Program - Pumping hypersaline water out of the Southern Lagoon of the Coorong. Technical Feasibility Assessment (DRAFT)*. Department for Environment and Heritage, Adelaide, South Australia.

56 DEH (in prep.). *Managing Acid Sulfate Soils (Limestone, sub-surface barriers and wetland). Technical Feasibility Assessment (DRAFT)*. Department for Environment and Heritage, Adelaide, South Australia.

57 DEH (in prep.). *Lake Albert Water Level Management. Technical Feasibility Assessment (DRAFT)*. Department for Environment and Heritage, Adelaide, South Australia.

58 DEH (in prep.). *Vegetation Program. Technical Feasibility Assessment (DRAFT)*. Department for Environment and Heritage, Adelaide, South Australia.

59 DEH (in prep.). *Ruppia translocation in the Coorong. Technical Feasibility Assessment (DRAFT)*. Department for Environment and Heritage, Adelaide, South Australia.

60 DEH (in prep.). *Fishways. Technical Feasibility Assessment (DRAFT)*. Department for Environment and Heritage, Adelaide, South Australia.

61 Margoluis, R., C. , Stem, C. , Salafsky, N, and Brown, M. (2009). Using conceptual models as a planning and evaluation tool in conservation. *Evaluation and Program Planning* **32** 138.

62 Holling, C.S. (1978). *Adaptive environmental assessment and management*. John Wiley and Sons, London, England.

63 Lester, R., Fairweather, P., Hamilton, B., and Langley, R. (2009). *Developing a framework to monitor the effect of management in the Coorong, Lower Lakes and Murray Mouth region. A report prepared for the South Australian Department for Environment and Heritage*. Flinders Research Centre for Coastal and Catchment Environments, Adelaide, South Australia.

64 Ramsar Convention on Wetlands (2005). *Resolution IX.1, Annex A: A Conceptual Framework for the wise use of wetlands and the maintenance of their ecological character*. Last updated 12/12/2005, Accessed 17/11/2009, Available at http://195.143.117.139/res/key_res_ix_01_annexa_e.htm

65 DFA (1981). *Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment. Australian Treaty Series 1981 No 6*. Department of Foreign Affairs, Canberra, ACT.

66 DFAT (1988). *Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment. Australian Treaty Series 1988 No 22*. Department of Foreign Affairs and Trade, Canberra, ACT.

67 DFAT (2007). *Agreement between the Government of Australia and the Government of the Republic of Korea on the Protection of Migratory Birds. Australian Treaty Series (2007) ATS 24*. Department of Foreign Affairs and Trade, Canberra, ACT.

68 Government of South Australia (2004). *Water Proofing Adelaide. Exploring the issues - a discussion paper*. Government of South Australia, Adelaide.

69 WBM (2004). *Murray Mouth Management Review of Alternative Schemes*. WBM Oceanics Australia, Spring Hill, QLD.

70 Souter, Nicholas (2009). *Control models for the Coorong, Lakes Alexandrina and Albert Wetland of International Importance. 1. Freshwater system unit and inland wetland types*. Terrestrial Exosystem Services Pty. Ltd. , Adelaide.

71 Souter, Nicholas (2009). *Control models for the Coorong, Lakes Alexandrina and Albert Wetland of INternational Importance. 2. Estuarine-saline system unit and marine/coastal wetland types and Coorong State and Transition model*. Terrestrial Ecosystem Services Pty. Ltd., Adelaide.

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