MURRAY**FUTURES**
Lower Lakes & Coorong Recovery

Securing the future

A long-term plan for the Coorong, Lower Lakes and Murray Mouth

June 2010

Government of South Australia

WATER FOR GOOD

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Foreword

The situation facing South Australia's Coorong, Lower Lakes and Murray Mouth region is unprecedented.

Years of drought and over-use of water have left internationally significant wetlands dry, the lakes disconnected, communities and industries under significant stress and native species at risk of being lost.

Everyone should be concerned with the state of the Murray-Darling Basin – and the Coorong and Lower Lakes in particular – but not surprised. The extremes of climate and rainfall, and the history of drought in our nation, are well known. While the extent of the problems facing the Coorong, Lower Lakes and Murray Mouth region may have only become apparent relatively recently, ecological degradation has been taking place for decades. Over-allocation of water across the entire Murray-Darling Basin has played a significant part in this.

The long-term plan for the Coorong, Lower Lakes and Murray Mouth region has been prepared to ensure the region and its people have a healthy, viable and sustainable future in the context of variable climatic conditions and water resources.

Input from scientists, industries, and the community has played a vital role in developing the management actions proposed in the long-term plan. Considerable emphasis has been placed on direct engagement with the region's communities through representative committees, regular meetings and direct contact with community members.

The development of the long-term plan has included three community consultation phases that generated useful feedback. The result is a plan that recognises the implications of the current situation for a range of groups and individuals and proposes responses based on the best available science and local knowledge.

Critical to this plan is the relationship between the State Government and the Ngarrindjeri people – the Traditional Owners of the region – and the Kungun Ngarrindjeri Yunnan Agreement (KNYA), a framework for consultation and negotiation with the Ngarrindjeri Regional Authority.

The long-term plan proposes actions that can be adapted to suit prevailing climate and inflow conditions and that are responsive to community and cultural needs. Importantly, work will be closely monitored, so that information gained and lessons learned can be incorporated into future actions.

A healthy Coorong, Lower Lakes and Murray Mouth region will depend on everyone accepting responsibility for its future. This document provides a foundation on which everyone can work together to build a sustainable and viable environment for future generations.

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EXECUTIVE SUMMARY

Introduction

The Coorong, Lower Lakes and Murray Mouth (CLLMM) region has been recognised internationally as one of Australia's most significant wetlands, satisfying at least eight of the nine criteria for listing under the Ramsar Convention when last assessed.

The region is of central significance to the life and culture of the Ngarrindjeri people, who continue to live on their traditional country, and is the basis for a local economy that has supported thriving communities, many with a focus on utilising the lakes for tourism or recreation and primary industries. Australia has a responsibility to care for this area through its international commitments.

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

Given the external influences driving the current ecological condition within the CLLMM region, an aim of complete restoration of all historic ecological values is neither practical nor realistic. However, restoring ecological function is an achievable goal and would establish an aquatic ecosystem that is resilient to external pressures and provides a diversity of ecological, social and economic values which reflect its international significance, albeit within an altered wetland environment.

Due to the barrages holding back seawater, substantially lower flows from upstream have led to the water levels in both Lake Alexandrina and Lake Albert falling to below sea level. The wetlands fringing the lakes are dry and no longer connected to the main water bodies, and 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. Four years' worth of salt carried down from the Murray-Darling Basin by the river is currently sitting in Lake Alexandrina, unable to be discharged since the last flows over the barrage in 2006-2007, and the increasing salinity is having a serious impact on the ecology of the Lower Lakes. The failure to discharge the salt is a problem owned by all states in the Murray-Darling Basin.

The Coorong has lost much of its productivity. Conditions within this section of the 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, and there has been an impact on the cultural life of the Ngarrindjeri people.

There is no precedent for dealing with environmental impacts on this scale. The CSIRO Murray-Darling Basin Sustainable Yields Project predicts that changing climatic conditions will result in changes in freshwater availability, but the precise timing and impacts of these changes are uncertain.

The regional economic, cultural and social values derived from the site depend on a healthy and functioning wetland environment. Furthermore, the River Murray and Lower Lakes, from Lock 1 at Blanchetown downstream to the barrages, form one weir pool. It follows that when lake levels are lowered and water quality is compromised, this also occurs within the River Murray channel – with serious environmental, social and economic consequences. Management of the CLLMM region must therefore also be considered within the wider context of the area downstream from Lock 1 and vice versa.

Purpose and context of the plan

The purpose of this plan is to provide a clear direction for the future management of the CLLMM region as a healthy, productive and resilient Wetland of International Importance.

During the next 20 years, this Long-Term Plan will work towards keeping adequate freshwater in the CLLMM system, with the implementation of complementary management actions when necessary. The proposed management actions aim to maintain the ecosystem in a state from which recovery to a healthy, productive and resilient wetland is possible (Part 2). As conditions may not return to those that historically supported the site, measures must be taken that allow for the site to function under stable but altered conditions (Part 2).

The plan is to be used as an active management document, which will be regularly reviewed. This review process is to ensure that emerging information, science and knowledge (for example in relation to acid sulfate soils management and the environmental water requirements of the site) are appropriately considered and incorporated.

This plan's approach to management, while based on science and interpreted with local knowledge, will also be responsive to cultural and community guidance and direction, new forms of governance, and the development of a close working relationship with the Ngarrindjeri Regional Authority.

New information and revised Long-Term Plan documents will be made available as required online from the Department for Environment and Heritage website at www.environment.sa.gov.au/cllmm

The plan is designed to deliver environmental outcomes, and in achieving these support the local economy and community.

The plan envisages that:

- Lake Alexandrina and Lake Albert remain predominantly freshwater and operate at variable water levels
- The Murray Mouth is predominantly kept open by end-of-system river flows
- There is a return of salinity gradients along the Coorong that are close to historic trends with a corresponding response in species abundance
- There is a dynamic estuarine zone
- The biological and ecological features that give the CLLMM wetlands their international significance, albeit a changed and changing wetland (Section 7), are protected
- There is a return of amenity for local residents and their communities
- There are adequate flows of suitable quality water to maintain Ngarrindjeri cultural life
- Tourism and recreation businesses can utilise the lakes and Coorong
- Productive and profitable primary industries continue.

While this is a long-term plan, it also proposes a number of short-term actions and interventions. Without these, the longer-term goals for the CLLMM region 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 resulting from continuing extremely low end-of-system flows, all proposed actions are being taken with a view to maximising future management options.

The Australian Government has implemented a number of measures that are associated with the actions of this program. As part of the Australian Government's Water for the Future program, the Australian Government has invested substantially in buying back water for the Murray-Darling Basin and implemented a program for Sustainable Rural Water Use and Infrastructure.

At the July 2008 Council of Australian Governments' meeting, the Australian Government agreed to provide, subject to due diligence, up to $200 million to support an enduring response to the environmental problems facing the CLLMM region. To accelerate this work the Australian Government agreed to advance $10 million to South Australia to undertake the feasibility work necessary to advance this important project.

As part of this feasibility work, this Long-Term Plan has been developed, as well as a Business Case, to address Australian Government due diligence criteria. This Long-Term Plan is a high level strategic document, underpinned by a suite of technical feasibility assessments that have been developed for each proposed management action. These assessments, also funded through the $10 million feasibility study, provide more specific detail on the feasibility of each action and the technical detail of how they will be carried out.

Another South Australian Priority Project underway in the region which complements this $200 million project is the $120 million Lower Lakes Integrated Pipeline Project.

The plan does not exist in isolation. Government legislation, international agreements and policies influence the CLLMM area and its management (listed and explained in Appendix 1). Two particularly important pieces of legislation are the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, which provides particular legal protection for wetlands of international importance, and the *Water Act 2007*, which both implements the process for developing the Murray-Darling Basin Plan and establishes the water-sharing arrangements between New South Wales, South Australia and Victoria. The scope of this plan does not cover all the changes to water management throughout the Murray-Darling Basin that would enable adequate River Murray flows to be returned to the CLLMM site, the management of the Murray River between Lock 1 and Wellington, nor the proposed weir at Pomanda Island near Wellington if it were to become necessary as a last resort measure. These issues will 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 on River Murray inflows during the next few years and beyond, as addressed in the adaptive management section of this document. For this reason, this plan proposes a suite of management interventions that may be undertaken to varying degrees under different inflow scenarios.

The Basin Plan, currently being developed by the Murray-Darling Basin Authority as a requirement of the *Water Act 2007*, is establishing an environmentally sustainable level of take for water resources across the Murray-Darling Basin by identifying key environmental assets and ecosystems functions and environmental watering requirements across the Basin including for the CLLMM region. The Authority is working to produce the first Basin Plan in 2011.

Coupled with this Long-Term Plan, other methods of delivering freshwater flows to the CLLMM region will be pursued by South Australia through the Commonwealth Environmental Water Holder, the River Murray Environmental Manager and its environmental watering plan, The Living Murray initiative, through the South Australian Government's development of an environmental water reserve and the finalisation of water allocation planning for the Eastern Mount Lofty Ranges. All of these, however, complement rather than replace the need for the Murray-Darling Basin Plan to ensure that diversions of water are set at sustainable limits.

The development of this plan has been supported financially by the Australian Government as part of its $200 million contribution to addressing the problems facing the site. Cost sharing arrangements are on the basis of funding to a maximum proportion of 90:10 (Commonwealth : state/other). Additional funding has been made available to the CLLMM site through projects such as the $10 million Lower Lakes Bioremediation and Revegetation Project, funded by the Australian Government, and the existing Murray Mouth dredging strategy, funded by the Murray-Darling Basin Authority.

The plan has called on the expertise of scientists, academics and research establishments. A considerable amount of research has been conducted in the preparation of this plan to extend understanding of the CLLMM site and the factors affecting it. Furthermore, feasibility assessments have been undertaken on the range of management actions proposed in this plan, as referenced in Section 10 of this document.

Consultation with the community has been an essential component. This has occurred through a Long-Term Plan Reference Group (including Australian Government representatives), extensive discussions with the Ngarrindjeri Regional Authority, and meetings with interested people, especially within the communities surrounding the Lower Lakes. Many individuals and organisations have provided helpful comments and suggestions through the feedback processes employed.

Action has also been taken to prevent irreversible ecological damage to the region before the plan's long-term strategies are ready to be fully implemented. Research into mitigating the impacts of low flows has been undertaken, including a major acid sulfate soil research project involving key universities and national research bodies. Bioremediation trials to mitigate acid, involving seeding more than 10,000 ha and planting more than one million wetland plants on exposed soil has also been undertaken, along with acid sulfate mitigation experiments and using more than 3,000 tonnes of limestone to dose the Goolwa Channel. The extensive science already undertaken at the site has also helped the immediate management of acid sulfate soils.

The potential effect of using seawater to avert lake acidification is also the subject of research (and is the subject of a complementary Environment Impact Statement). The initial findings of this research indicate that the introduction of seawater should be avoided and only be adopted as a last resort short-term response, with likely serious longer-term management implications. Furthermore, investigations are underway to confirm the amount of freshwater required at the site to avoid large-scale catastrophic acidification events in the immediate future, as well as the longer-term ecosystem water requirements at the site.

Summary of the plan

The environmental issues facing the Coorong, Lower Lakes and Murray Mouth (CLLMM) represent a basin-wide problem, and therefore a basin-wide solution is required.

The wetlands in the CLLMM region were declared a Ramsar site in 1985. The current crisis in the CLLMM region threatens the key values of the site and it is suggested by various academics that this process may have been underway at the time of listing.

Emerging from this work is the requirement to maintain adequate supplies of fresh water to this site. No other strategy provides a long-term future that preserves the current values of the site and avoids potentially catastrophic change to the environment. The CSIRO Murray-Darling Basin Sustainable Yields Project, which emphasises the probability of a freshwater future for the site, shows that the approach is realistic.

Freshwater inflows may take some time to return to the CLLMM site, and will depend on unpredictable climatic conditions. Thus, the management challenge is to find ways to use the freshwater available in the interim to best effect, while mitigating the worst effects of the crisis on the site and preparing the site so it may adapt to an uncertain future under changing climatic conditions.

The plan proposes an adaptive approach to managing the site. The aim of this adaptive approach is to develop strategies that can respond to changing conditions, as well as building ecological resilience into the site so it can cope with whatever climatic conditions prevail in the future. The best available science will develop management actions, and the effects of the actions will be closely monitored.

This plan's ultimate goal is to secure a future for the CLLMM site as a healthy, productive and resilient wetland system that maintains its international importance. Whilst the full array of historic ecological values may not be practical, restoring ecological function will be the principle driver to achieving the plan's goal, and a new suite of significant ecological values the likely outcome. Achieving this will directly support the economic, cultural and social wellbeing of the regional communities. The return of adequate freshwater end-of-system flows (flows through the Murray Mouth) is essential for any improvement in the health of the site, as any solution other than fresh water would not preserve the current values of the site to the same extent.

The plan recognises that large flows down the River Murray will maintain an open mouth and transport salt and other pollutants to the ocean via natural processes.

When flows are adequate to maintain the Lower Lakes at or near an optimal operating range, minimal intervention is required and **adaptation** actions that aim to build and maintain a resilient ecology at the site are possible. These include:

- The management of the lakes at variable levels to achieve ecological improvement (developed in consultation with users of the lakes)
- The enhanced diversion of water from the south-east of South Australia to the South Lagoon of the Coorong (via wetlands and water courses where possible)
- Vegetation plantings to restore ecological processes
- The operation of fishways.

However, whenever flows are not sufficient to maintain an open Murray Mouth, it will be necessary to implement **mitigation** actions. Mitigation actions aim to reduce the rate of ecological degradation, remediate damaged areas, prevent immediate and permanent ecological collapse, and maintain the ecosystem until conditions improve. These include:

- As a first step, the dredging of the Murray Mouth to allow tidal interchange between the ocean and the Coorong, to reduce salinity levels in the Coorong (as has been the situation since 2006).

Additional measures will be required within the Coorong lagoons, including:

- Pumping hypersaline water from the South Lagoon of the Coorong to the sea to reduce salinity in the South Lagoon and reset salinity gradients as a short-term measure
- Translocation of key aquatic plant species *Ruppia tuberosa* and *Ruppia megacarpa*, once salinity within the Coorong is appropriate (if salinity and water level issues in the South Lagoon are addressed, *Ruppia* may also naturally recolonise).

The current flow scenario, brought about by water-sharing arrangements and drought, has meant water levels in the lakes have continued to fall. This situation calls for additional **mitigation** measures such as:

- Securing water to manage water levels, keeping acid sulfate soils saturated and preventing acidification
- Limestone dosing for acid sulfate soil management
- Vegetation plantings to increase soil carbon to reduce acidification
- The construction of a Meningie lakefront habitat restoration
- The protection of critical environmental assets (for example the off-site conservation of fish species).

Such activities will need to continue until freshwater flows improve.

In order to maintain maximum flexibility to respond to events similar to those being experienced now, it is proposed that over the next five years:

- The future management of the Narrung Narrows will be assessed, in conjunction with the community and other government agencies, when there is a greater understanding of future Lake Albert freshwater flows and water levels. This assessment will need to consider issues such as the water flow between the lakes and fishways.
- Careful management is required to protect the high-value ecological assets at Currency Creek and Finniss River, as well as the tourism and recreational activities associated with Goolwa.
- Negotiations will be undertaken to continue to deliver freshwater flows to the site through the Commonwealth Environmental Water Holder, The Living Murray initiative and through the South Australian Government's development of an environmental water reserve.
- Appropriate governance arrangements involving the community, all three levels of government and the Ngarrindjeri (the site's Traditional Owners) will be introduced to ensure clear and transparent accountability.
- An 'adaptive management' approach will be adopted, promoting understanding of the effect of management decisions and providing flexibility to revise management decisions in response to new information. This will also involve the development and continual assessment of targets that outline the proposed start and end triggers for management actions directly associated with ecological conditions at the site.

Ideally, the improved inflows of 2009 will continue in 2010 and gradually restore water levels in the site. As this occurs the various management actions can take effect. However, if inflows are not sufficient for improvement in the water levels, the South Australian Government will continue to implement actions to build resilience in the site ready for recovery.

Further information

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 the detail that may be found elsewhere.

However, some people may wish to extend their knowledge or interest beyond this plan, and the reference list at the end of this document includes source reports and articles that may be useful.

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
CLLAMMecology	Coorong, Lower Lakes and Murray Mouth ecology – CSIRO research cluster
CLLMM	Coorong, Lower Lakes and Murray Mouth
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEH	Department for Environment and Heritage (South Australian Government)
DEWHA	Department of the Environment, Water, Heritage and the Arts (Australian Government)
DWLBC	Department of Water, Land and Biodiversity Conservation (South Australian Government)
EC	Electrical Conductivity
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth Government)
GL	Gigalitre (1 billion litres)
GRP	Gross regional product
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
IUCN	The International Union for Conservation of Nature
km	Kilometres
NRM	Natural Resource Management
NWQMS	National Water Quality Management Strategy
TBD	To be determined
µS/cm	Microsiemens per centimetre

The Coorong with Lake Albert in the background.

Introduction to the site

1.1 Site description

In 1985 the Coorong, Lower Lakes and Murray Mouth (CLLMM) site was designated as a Wetland of International Importance, commonly known as a 'Ramsar wetland'. 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. It is regarded as an important site for biodiversity in southern Australia.

The Coorong, Lakes Alexandrina and Albert 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 (**Figure 1**). Rainfall also has 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 seiching and supplemented by local rainfall and groundwater discharges. Lake Albert has no through-flow connection to the Coorong or Murray Mouth.

Introduction to the site

- *Site description*
- *Marine incursions*

Volumes of the Ramsar site components

Before the recent extremely low flows, Lake Alexandrina, Lake Albert and the tributaries (including Currency Creek and Finniss River) operated at a level of approximately 0.75 metres AHD. The volume of water held in these water bodies at this water level was a total of about 1,900 GL.

Of this, Lake Alexandrina held approximately 1,570 GL, Lake Albert held approximately 280 and the volume of the tributaries was 50 GL.

There is a large variation in water levels in the Coorong and the estuary, depending on factors such as the season. The volumes of these components are given between water levels of 0 metres AHD and 1 metre AHD, representing the highest and lowest levels of these Ramsar site components.

The volume of the North Lagoon ranges from just under 80 GL to approximately 160 GL. The South Lagoon varies from just under 100 GL to approximately 190 GL.

The estuary varies between approximately 20 GL and 40 GL.

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. They were built to prevent seawater entering the Lower Lakes and to maintain freshwater conditions during times of low flows, ensuring productivity in the surrounding areas. 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 for parts of the barrages.

Historically, surface flows of fresh water 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, averaging about 6 GL per year, have been released under regulated conditions via the Upper South-East Drainage Scheme.[1]

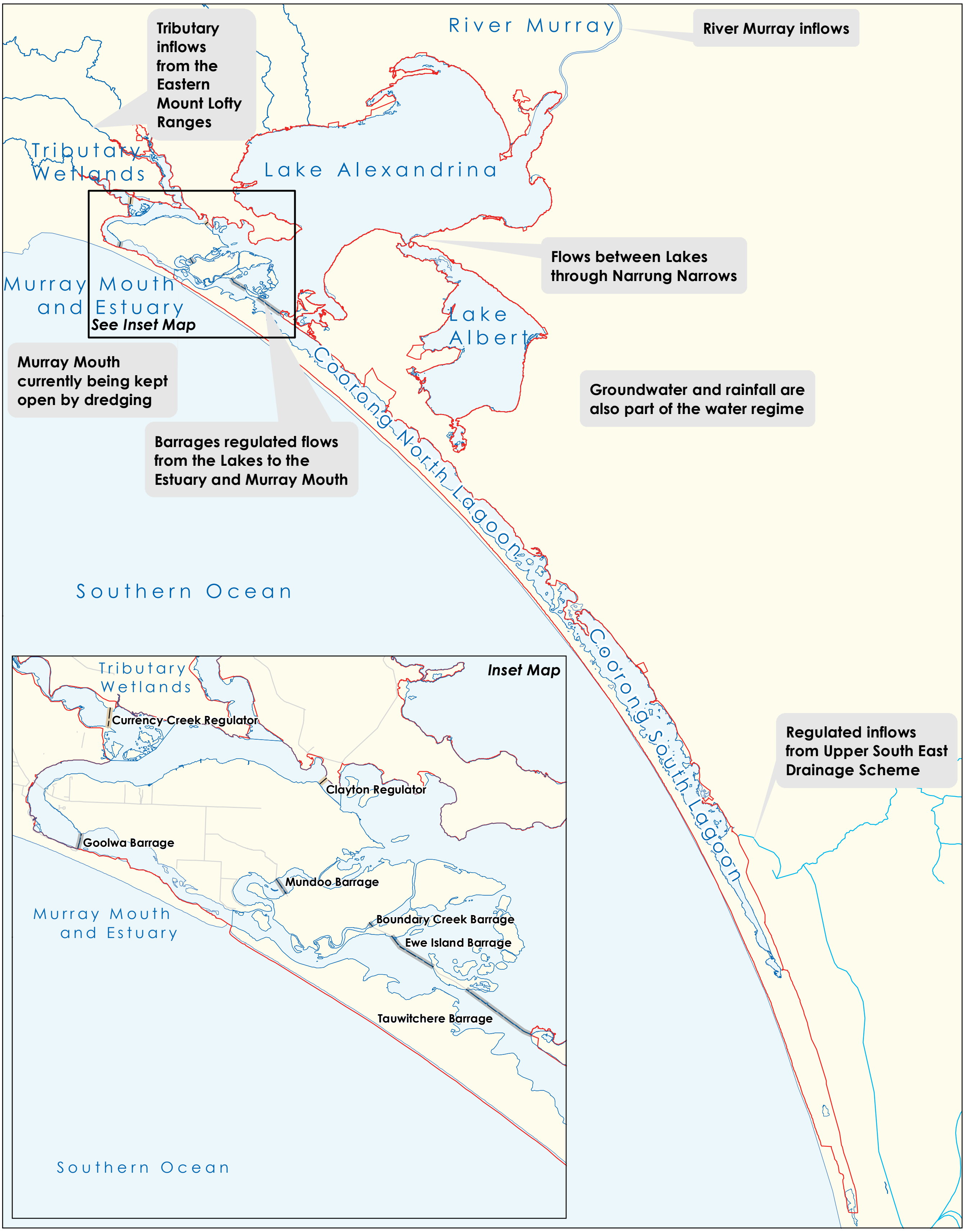
The Murray Mouth is the only site where water contaminants such as silt, salt and nutrients can be discharged from the Murray-Darling Basin to the ocean. Through-flow depends on coordinated barrage releases and dredging in times of low flow, so as to maintain an open Murray Mouth to the Southern Ocean.

To assist in describing the ecological character of the site, six geographic components are recognised: [2]

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 to describe in this plan the actions required to address key threats to the site.



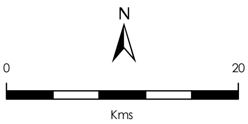


Figure 1. Coorong and Lakes Alexandrina and Albert Ramsar site: overview of primary water sources and flow pathways.

Produced by Coorong, Lower Lakes and Murray Mouth Projects
Department for Environment and Heritage (DEH)
GPO Box 1047 Adelaide SA 5001
www.environment.sa.gov.au/cllmm
Telephone: 1800 226 709
Data Source DEH - topographic data
Compiled 26 March 2010
Projection Lambert Conformal Conic
Datum Geocentric Datum of Australia, 1994

1.1.1 How the ecosystem functions

A detailed description of the functioning of the CLLMM ecosystem is provided in the *Ecological Character Description of the Coorong, Lakes Alexandrina and Albert Wetland of International Importance (2006)*[2] 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 South Australia, which affect the amount of fresh water flowing into the system
- Local weather conditions, which influence:
  - the rate of evaporation from the surface of the water bodies
  - water levels via wind seiching
  - the extent and timing of local direct rainfall
- Sea level, which changes:
  - 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)

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 site
- Regulated inflows to the Coorong from the Upper South-East Drainage Scheme (see *Technical Feasibility Assessment: South-East Flows Restoration* [3])
- Operation of the barrages and their associated fishways, which influence:
  - water levels in the Lower Lakes (see *Technical Feasibility Assessment: Managing Variable Lake Levels* [4])
  - 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* [5]).

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 by up to 50 cm daily due to wind seiching.

Wind seiching is important for keeping the CLLMM site healthy, increasing oxygen levels in the water and distributing nutrients used by plants and animals for food.

It also could transport pollutants in the Lower Lakes into the River Murray. Wind could transport poor-quality water upstream, threatening the quality of South Australia's public water supply.

Wind seiching also plays a part in flood irrigating the foreshore of the Lower Lakes, encouraging plant growth though late summer.

While all ecosystem components and processes are important to the overall healthy functioning of the system, some are central to maintaining ecological character, or can be considered primary determinants. For the Coorong, Lakes Alexandrina and Albert Ramsar wetland, the following have been identified as the primary determinants of ecological character and are most directly influenced by the amount of water that flows through the Murray Mouth:[2]

- 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, the expectation, based on scientific and local knowledge, is that the system will operate as expected and ecological character will be maintained.

'Limits of acceptable change' are the amount of change to a measure or a feature of the wetland's ecological character that can take place, without a loss or reduction of values for which the site was Ramsar listed. The limits of acceptable change for each of the primary determinants differ within each of the geographic units of the site, e.g. the Coorong's South Lagoon is naturally much more saline than Lake Alexandrina.

1.2 Marine incursions

1.2.1 Ancient sea level rise

Lakes Alexandrina and Albert were formed when the valley of the ancestral River Murray was partially filled by rising post-glacial seas between 20,000 to 7,000 years ago.[6] The southern edges of the lakes are defined by sandy ridges that were swept up by the rising sea and by on-shore winds. The same process formed the Coorong, where rising seas swept up the sands.[7]

1.2.2 Historic extent of marine incursions

It is estimated that the historic end-of-system flows averaged 12,200 GL per annum prior to development in the Murray-Darling Basin for irrigation and urban use.[8] Geomorphological studies show that sea level stabilised about 7,000 years ago and the Murray Mouth formed some time after this. In post-European times it had never closed completely until 1981.[2]

Before the barrages were constructed there were occasions during severe droughts when there was reverse flow at the Murray Mouth, so that seawater entered the Lower Lakes, but these were infrequent and the quantities of seawater were generally not large.[2]

This assessment is supported by the record of diatoms, microscopic single-celled algae with a hard outer shell, which were deposited in the sediments of the Lower Lakes. Different species of diatoms have adapted to different salinities. The diatom record in lakebed sediments provides strong evidence that the Lower Lakes have been predominantly fresh water for the last 7,000 years and that seawater ingressions, when they did occur, did not extend north of Point Sturt.[9] On the rare occasion of seawater intrusion into Lake Alexandrina, the area of the lake south of Point Sturt would have been subject to estuarine conditions.

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 diatom research.

There are many anecdotal accounts of marine creatures such as sharks being seen as far upstream as Morgan, about 320 km upstream of the Murray Mouth, 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.

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.[10] These studies suggest that prior to European colonisation, salinity levels in both lagoons were generally at, or below, those of seawater (approximately 60,000 EC). Periodic estuarine episodes (between 8,000 EC and 60,000 EC) 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.[10] Without freshwater inputs, the lagoons of the Coorong would have become hypersaline (i.e. saltier than the sea) due to evaporative concentrations of salt.

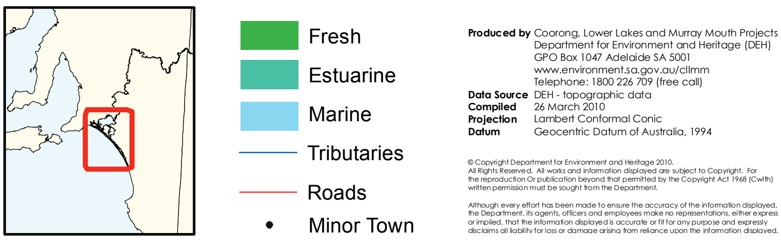


Figure 2. Summary diagram showing the typical salinity of the CLLMM region before large-scale consumptive water use in the Murray Darling Basin and barrage construction. Adapted from Fluin et al 2009.

The pelican is a 'Ngartji (totem or special friend) of Ngarrindjeri people, who have special responsibility to care for their Ngartji. To care for Ngartji is to care for country.'[12]

A history of human use of the site

2.1 The Ngarrindjeri story

The CLLMM site and surrounding areas represent the central homelands of the Traditional Owners, the Ngarrindjeri people, and thus is key to Ngarrindjeri culture and spiritual beliefs. This association is expressed through Creation stories (cultural and spiritual histories) about Yarluwar-Ruwe (Sea Country) that 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.'* [12]

> *'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.'* [12]

A history of human use of the site

- *The Ngarrindjeri story*
- *The European story*

By the late 1840s the lake shore land had become highly valued and towns such as Goolwa were settled on the shores from the early 1850's.

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*, prepared by Ngarrindjeri people in 2006,[12] 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) [13].

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 ngartji (totems) decline or disappear, the clearing of the land and the rapid degradation of their Ruwe (country).

2.2 The European story

2.2.1 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. 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's ready supply of fresh water, ability to be easily cleared and provision of late summer grazing pastures due to wind seiching led to it being considered for settlement. By the 1840s settlers were grazing cattle and sheep along the lakeshore, with stock drinking fresh lake water. [7]

By the late 1840s the lakeshore land was being surveyed and it became highly valued. Towns such as Clayton, Goolwa, Meningie and Milang were settled on the shore from the early 1850s. The River 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 interval from Milang to Meningie was one stage of the journey from Adelaide to Melbourne.

2.2.2 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 River 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. Irrigation pioneers such as the Chaffey Brothers established irrigation in the semi-arid mid-reaches of the river, but the Federation Drought soon began, and lasted 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 caused by drought and large-scale extractions for irrigation upstream depleted the head of fresh water, 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 help regulate the rivers for navigation and irrigation.

The River Murray Waters Agreement confirmed the rights to the water of Victoria and New South Wales 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 in South Australia. No provision was made 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 freshwater, 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.'* [14]

This history indicates that while drought has been an intermittent problem, the current environmental crisis is one caused by historical over-allocation of water resources as well as by drought.

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 1842 Charles Sturt had suggested harnessing the flow down the River Murray by directing it through the Goolwa Channel, to make it safer for boats to pass through.

2.2.3 River regulation

Later, when the river flow lessened, plans were devised to retain fresh water in the Lower 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. This resulted in the building of the five barrages at Goolwa, Mundoo, Boundary Creek, Ewe Island and Tauwitchere. These were completed in 1940 and remain in place today.[7] Other infrastructure developed to regulate the southern Murray-Darling Basin system included a system of four shared storages, 16 weirs and numerous other smaller structures.

The first 10 weirs, and their accompanying locks to facilitate navigation, were constructed between 1922 and 1935. Their primary purposes were 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, with a capacity of 3,000 GL, began in 1919 and was 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.

The Narrung Narrows causeway, which extends approximately halfway across the Narrows, was constructed in 1967. It is recognised that the causeway may have changed natural water flows into Lake Albert and created silting in the Narrows and in Lake Albert.

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 that usually occurred in spring.

2.2.4 More recent Murray-Darling Basin management arrangements

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 coordinate effective planning and management for the equitable efficient and sustainable use of the water, land and other environmental resources of the Murray-Darling Basin'.[15] During the time of the former Murray-Darling Basin Commission, indigenous interests, knowledge and culture were recognised.

In December 2008 the Murray-Darling Basin Authority assumed responsibility for the functions of the Murray-Darling Basin Commission, which ceased to exist. One of the major functions of the Authority is preparing the Murray-Darling 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 how much water can be taken from Basin waters on an environmentally sustainable basis. It will include an environmental watering plan outlining 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, progressively from 2012.

2.2.5 Recent water allocation history in South Australia

In recognition of the stressed condition of the River Murray, South Australia ceased issuing any additional irrigation entitlements after the 1967-68 drought. However, other states did not follow the lead set by South Australia and continued to increase irrigation entitlements for another 30 years, resulting in over-allocation of Murray-Darling Basin water resources and in particular the southern connected system.

The Murray-Darling Basin Agreement provisions for meeting the River Murray system dilution and loss requirements differ upstream and downstream of the South Australian border. Upstream they are met on a real-time basis from the shared resource and a small amount of New South Wales and Victorian tributary water. Downstream of the border, a set dilution and loss volume (696 GL) is included in the flow allocated to South Australia. The set dilution and loss volume enables a flow past Wellington of approximately 350 GL.[16] This volume is not adjusted, and does not meet real-time dilution and loss requirements to the Murray 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 between the 696 GL dilution and loss allocation and the real-time dilution and losses from the South Australian border to the Murray Mouth. 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 cannot be met.

Over use of water in the Eastern Mount Lofty Ranges has also reduced inflows to the CLLMM site from Finniss River, Currency Creek, Tookayerta Creek and other tributaries. Inflows to the CLLMM site from the Eastern Mount Lofty Ranges are variable and currently range between approximately 35 GL to 110 GL per year with a median inflow ranging between about 50 GL to 60 GL.

The South Australian Murray-Darling Basin Natural Resource Management (NRM) Board is preparing a water allocation plan for the Eastern Mount Lofty Ranges for surface, water course and ground water. It will guide granting licences to take water as well as transferring licences and water allocations. The plan is anticipated to be completed by late 2010/early 2011.

For the last three years South Australia has received barely enough water to meet its critical human water needs and those of irrigators looking to prevent the loss of permanent plantings. Some of the water that has been received has been achieved through significant purchases from the water market.

In line with its River Murray Drought Water Allocation Framework, where possible the state has provided water for environmental outcomes through:

- allocations to environmental entitlement holders
- use of the 696 GL dilution and loss water
- water-use reductions achieved within South Australia
- water allocation purchase.

During 2008-09 the South Australian Government made significant purchases for both critical human needs and the environment, including 50 GL for the Lower Lakes. This water was carried over for delivery during 2009-10. Some was 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 October 2009 the South Australian Government agreed to allocate at least 120 GL towards a Lower Lakes environmental reserve (in addition to 50 GL purchased during 2008-09), subject to inflows during 2009-10. Delivery is underway according to an optimised delivery pattern. This environmental reserve reduces 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.

A recent agreement between New South Wales and South Australian Governments has ensured that at least 238 GL of environmental water from New South Wales floods in early 2010, including 48 GL from The Living Murray initiative, will reach the Lower Lakes in 2010. A further 20 GL will be made available for the Lower Lakes following a decision by the independent Commonwealth Environmental Water Holder. South Australia is also set to receive an additional 257 GL of water from the Queensland floods in early 2010, thereby increasing the total water to be received by South Australia as a result of the Queensland and New South Wales floods to approximately 495 GL.

How this water entering South Australia is shared between consumptive users and the environment is a state responsibility, according to the *Natural Resources Management Act 2004*. The aims are to use the water that becomes available to South Australia, in excess of critical human needs, in the best way to support the long-term sustainability and viability of the South Australian 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 reviewed monthly 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, which include critical human needs as well as needs for agriculture.


Sharp-tailed sandpiper.

Values of the site

3.1 Ecological values

The listing of the Coorong, Lakes Alexandrina and Albert site as a Ramsar wetland recognises the site's diverse range of wetland ecosystems, habitats and bird, fish and plant species, a number of which are threatened with extinction. 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 designated as a Wetland of International Importance a wetland must meet at least one of the Ramsar criteria. In 1985 the site met three of the four criteria applicable at that time. Since the 1985 listing, the criteria have been revised a number of times.

The strength of the argument that the CLLMM site is indeed internationally important is illustrated by the fact that in 2006 it met eight of the nine criteria. It has not yet been assessed against criterion nine. The *Ecological Character Description (2006)*[2] documents in detail how the site qualifies against each of the eight criteria. These 'Ramsar-significant biological components' are summarised in **Table 1**.

A formal assessment of the site's present condition against the listing criteria did not occur as part of the process of developing this plan. However, examination of the information suggests that the site would continue to meet many, if not all, of these listing criteria. A formal assessment against the criteria will occur following detailed monitoring and data analysis. It is anticipated that the formal assessment will take place in 2012 and will draw on ecological information collected as part of the $10 million feasibility study (see Purpose and Context Section).

Values of the site

- *Ecological values*
- *Ecosystem services*
- *Social values*
- *Indigenous cultural values*
- *Economic values*

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 fish, 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. In 2006 the Coorong and Lakes site qualified against criteria 1 to 8 (shaded).

3.1.1 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.[2]

3.1.2 Criterion 2

Threatened flora

Six plant species listed as threatened at the state or national level occur at the site. They are the silver daisy-bush, dune fanflower, yellow swainson-pea, sandhill greenhood, metallic sun-orchid and scarlet grevillea. Many of these occur in terrestrial vegetation adjacent to the waterbodies.[2] Further surveys are expected to reveal more plants of note in this context.

Threatened fish

The site is known to support five species listed as vulnerable at global or national levels. These are the Murray cod, Murray hardyhead, Yarra pygmy perch, silver perch and big-bellied seahorse.[2]

Mount Lofty Ranges southern emu-wren

The Swamps of the Fleurieu Peninsula, which are listed as a critically endangered ecological community under the *Environment Protection and Biodiversity Conservation Act 1999* (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. About 150 individuals remain in the wild.[17] The species breeds in south-west Tasmania and migrates to the mainland in winter, using 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 region. Vegetation dominated by species including beaded glasswort, sea heath, Austral seablite and shrubby glasswort is favoured feeding habitat. In the CLLMM region this vegetation is most abundant around the margins of the Coorong although its predicted distribution includes almost the entire Ramsar site, except areas of open water.[2]

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.[18] 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. Only three frogs were identified in the region during the census, two at Clayton Bay and one on Mundoo Island, highlighting the rarity of the species in the region.

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. Areas defined as Fleurieu Peninsula Swamp occur at the confluence of Lake Alexandrina, Tookayerta and Currency Creeks and the Finniss River. The health of these swamps is strongly influenced by water levels in the Lower Lakes and inflows from these tributary streams.

The southern pygmy perch is one of the 20 native fish species listed as either protected or of conservation concern at the state level.

3.1.3 Criterion 3

Wetland-dependent or related ecological communities and species that qualify the site under criterion 2 also automatically qualify the site under this criterion.

Additionally, the criterion includes:

- Wetland-dependent/related plant species that are at least one of the following:
  - listed as vulnerable or endangered (but not rare) under South Australian legislation
  - 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 one of the following:
  - P – protected under the *Fisheries Act 1982*
  - C – provisional state conservation concern under the draft Threatened Species Schedule *National Parks and Wildlife Act 1972*.

Using these decision rules there are 20 fish species, five bird species, one vegetation association and one plant species that contribute to the site qualifying against this criterion.[2]

3.1.4 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 (i.e. those that require access to both marine and freshwater environments to complete their lifecycle)
- 49 species of birds including 25 migratory waterbird birds listed under the apan-Australia and China-Australia Migratory Bird Agreements and many resident species that breed within the site or rely on it for refuge during times of drought.

3.1.5 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 49 species listed under criterion 4 and 16 listed under criterion 6. There is a total of 78 species that meet this criteria,[2] including:

- Three species listed as endangered or critically endangered at either global or national levels – the Mount Lofty Ranges southern emu-wren, orange-bellied parrot and the Australasian bittern
- Five species classified as vulnerable within South Australia – 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 listed under Australia's migratory bird agreements with Japan, China, the Republic of Korea, or the Convention on the Conservation of Migratory Species of Wild Animals.

The Murray-Darling Basin Authority *Annual survey of waterbird communities of The Living Murray Icon Sites, November 2008* [85], found that waterbird abundance and breeding were concentrated in the CLLMM Icon Site, which supported an average of 134,635 waterbirds, comprising of 46 species (96 per cent of the survey total), including Cape Barren geese, banded stilt, Australian shelduck, great cormorant and migratory shorebirds.

Within the CLLMM Icon Site, most waterbirds were distributed in the Coorong (59,645) and Murray Mouth (54,620). Lakes Albert (9,397) and Alexandrina (10,983) supported lower numbers of waterbirds. No waterbird breeding was recorded, a considerable decrease from 2007 (3,951 mean breeding index).

3.1.6 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 site 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 another three species.

Some 16 species of birds have been regularly recorded in numbers exceeding 1 per cent of their global population. 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.

3.1.7 Criterion 7

The CLLMM site is considered significant for 49 fish species.[2] Taken collectively they qualify the site under this criterion because of their biodiversity. The transitional environment from fresh to marine waters makes it a unique habitat for fish species.

3.1.8 Criterion 8

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.[2] The native fish community includes:

- Five species 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*[19])
- 20 species classified as protected or provisionally listed as of conservation concern within South Australia
- 20 species that use the site at critical stages of their life cycles, 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 that randomly enter and leave inlets and estuaries.

3.1.9 Criterion 9

At Ramsar's ninth Conference of the Parties in November 2005, an additional criterion was added to the eight existing criteria – that a wetland should be considered internationally important if it regularly supports 1 per cent of the individuals in a population of one species, or subspecies, of wetland dependent non-avian animal species. When the site was assessed against the Ramsar criteria in 2006 it was not possible to confirm that it met this criterion, due to a lack of population data for relevant species.

3.2 Ecosystem services

Ecosystem services are the benefits provided by an ecosystem to its users. Ecosystem services can be categorised into: [20]

- 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 recognised for the range of ecosystem services they offer. The preceding section highlighted those attributes of the site of greatest interest from the perspective of biodiversity conservation; however, the CLLMM site is also important for the range of other services it provides, these being a product of a 'healthy' wetland ecosystem.

The description of ecological character for the CLLMM site [2] includes a comprehensive list of its ecosystem services as outlined in **Table 2**.

Table 2 is based on the definition of ecosystem services promoted by the Millennium Ecosystem Assessment and endorsed for use under the Ramsar Convention through Resolution IX.1 of the 9th Conference of the Contracting Parties in November 2005.

3.2.1 Biosequestration and greenhouse gas emissions

Carbon biosequestration is an important function of ecosystems that involves living organisms such as plants capturing and storing carbon. Many of the proposed actions in this plan seek to improve ecological function and so provide long-term biosequestration benefits. These will be in the form of improved carbon storage and capacity as ecosystem health is restored.

Ecosystem service	Details
Provisioning services	
Wetland products	Water source for irrigators (horticulture, viticultre) 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
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 (capturing and storing carbon)
Biological control of pests and diseases	Support of predators of agricultural pests (e.g. 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 Agreement, China-Australia Migratory Bird Agreement and Republic of Korea-Australia Migratory Bird Agreement. Supports significant numbers and diversity of native fish, including migratory species.

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

3.3 Social values

The CLLMM region is of national significance and 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 nationally and overseas.

Today the CLLMM region 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 four-wheel driving. The South Australian Tourism Commission estimated the number of visitors to the Coorong National Park in 2008 at about 138,000. The Murray Mouth and Sir Richard Peninsula are also key areas of interest.

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 CLLMM site is highly valued by birdwatchers, with their wetlands attracting at least 85 species of birds in total.

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.'* [21]

The region is one of the most popular tourism and recreational locations in South Australia, offering activities such as sightseeing, bird-watching, camping and boating.

3.4 Indigenous cultural values

The wellbeing of the Ngarrindjeri people is linked to the health of the CLLMM site. 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.'* [12]
>
> *'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*.' [12]

The crisis that has engulfed the region constitutes a new threat to the 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 CLLMM site (particularly the Coorong National Park) is acknowledged as culturally vital to the Ngarrindjeri people, with nationally important middens, burial sites and other sacred places providing evidence of Ngarrindjeri customs over many thousands of years.

3.5 Economic values

The CLLMM region has a mix of primary industry that 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 site. The River Murray and Lower Lakes, from Lock 1 at Blanchetown downstream to the barrages, form 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 river banks 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, currently underway.

The gross regional product (GRP) of the Lower Murray, Lower Lakes and Coorong regional economy was estimated to be around $700 million in 2006-07.[22] Primary industries directly contributed about $145 million and directly employed about 2,000 people. Irrigated agriculture employed 1,000 people, contributing more than $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 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.

Water security for irrigation and wine industries has been provided by the recently completed Lower Lakes irrigation pipeline in 2009. Pipelines have also been completed to communities in the CLLMM region for stock and domestic purposes to reduce dependence on the Lower Lakes as a water supply.

The region supports a mix of primary industries including dairy and cattle farming.

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.[23] The problems caused by over-allocation have been exacerbated by severe drought and the early impacts of climate change.[23] 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[8] found that in the absence of flow regulation and consumptive water use in the Murray-Darling Basin, an average 12,200 GL a year would reach the Murray Mouth, based on historical climate data. Current surface water use in the Murray-Darling Basin is 48 per cent of the available surface water resource, which is a very high relative level of use.[8] This level of use combined with natural losses has reduced average annual outflows through the Murray Mouth by 61 per cent, to 4,700 GL.[8]

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 below-average flows that cause concern.

The frequency of no water passing over the barrages has increased from 1 per cent to 40 per cent of the time due to consumptive water use across the entire Murray-Darling Basin.[8] As a result, sand pumping to maintain an open Murray Mouth has been needed, as well as activities to manage acid sulfate soils such as bund construction, pumping water, seeding exposed soils and limestone dosing of acidic water bodies.

Threats

- *Over-allocation*
- *South-East drainage*
- *Drought*
- *Climate change*
- *Sea level rise*
- *Maintenance of stable water levels*

Additionally, severe drought inflows to the Lower Lakes (which CSIRO [8] defines as annual inflow less than 1,500 GL) are predicted to occur in 9 per cent of years, with current levels of water resource development and current water allocation policies.[8]

Before water resource development, severe drought inflows to the Lower Lakes never occurred. Under these conditions, the minimum annual inflow to the Lower Lakes was 2,250 GL.[8]

These hydrologic changes due to water resource development are linked to the significant levels of environmental degradation observed at numerous floodplains and wetlands across the Murray-Darling Basin, including the CLLMM site [8].

In summary, over-allocation of the water resources of the entire Murray-Daring Basin has been implicated in the ecological degradation of the CLLMM site. Climate change may exacerbate this situation. Reform of water-sharing in the Murray-Darling Basin needs to be undertaken so the impact of severe drought inflows to the Lower Lakes can be reduced, or preferably avoided.

Over-use of water in the Eastern Mount Lofty Ranges has also reduced inflows to the CLLMM region from Finniss River, Currency Creek and other tributaries. The South Australian Murray-Darling Basin NRM Board is preparing a water allocation plan for the Eastern Mount Lofty Ranges for surface, water course and ground water. It will guide granting licences to take water as well as the transfer of licences and water allocations.

Management challenges and approaches

While the over-allocation of water resources across the entire Murray-Darling Basin will take considerable time and cost to resolve, the development of the Murray-Darlinga Basin Plan will establish sustainable diversion limits and, with The Living Murray initiative and other Australian Government initiatives, help address this issue. The exceptionally dry conditions being experienced across most of the Murray-Darling Basin mean that, even if large volumes of fresh water were to be secured immediately, remedial works would also be required at the CLLMM site over an extended period to minimise ecological damage.

The longer-term management strategy is to secure adequate fresh water for the site and ensure monitoring is in place so the flow is sufficient to support the desired ecological character. Adaptive management would effectively manage and build resilience in the system, as flows vary with changing climatic conditions (Section 11).

The current exceptionally dry conditions mean that, even if large volumes of fresh water were secured immediately, remedial works would also be required to minimise ecological damage.

4.2 South-East drainage

Before 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.'*[24]

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

- Former flow paths still observable today[24]
- Ngarrindjeri oral history and culture[12]
- Historical accounts[24]
- 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.[10]

During periods of high historic surface flows, wetlands in the South-East naturally stored and filtered water on its way to the Coorong. Long after surface flows ceased, these wetlands continued to hold water, providing a valuable ecological buffer and landscape benefit for species and habitats of the Coorong, and contributed to the same groundwater system that the Coorong is part of.

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.[25] Major drains diverted 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's South Lagoon corresponds with the completion of key components of the South-East drainage network.[24] The record of diatoms preserved in Coorong sediments appears to support this view[10] 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.[26] Discharge is 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.[26] Without the drainage network in place, a considerable proportion of this water would have flowed into the Coorong's South Lagoon. To put these volumes in context, the total volume of the South Lagoon varies from approximately 140 GL when full in winter, to 90 GL in late summer.[2]

Historical records suggest inflows to the Coorong from the South-East were greatly diminished after the construction of stop banks in 1912 and 1913 prevented the Bakers Range watercourse from contributing surface flows into the South Lagoon via Salt Creek.[24]

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 most recent few years being particularly severe.[27] 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 in **Figure 3** and **Figure 4** respectively.

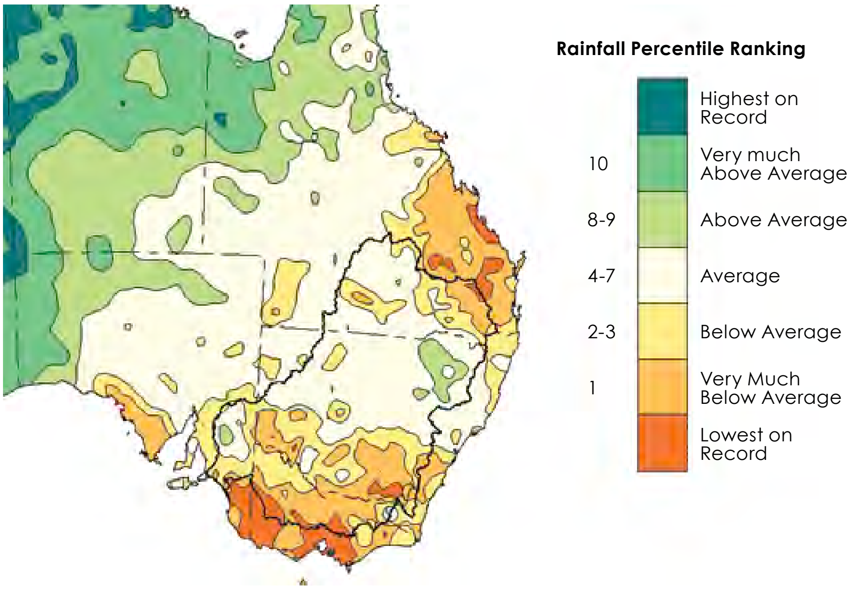


Figure 3. Rainfall deciles in the Murray-Darling Basin between November 1996 and October 2007.[28]

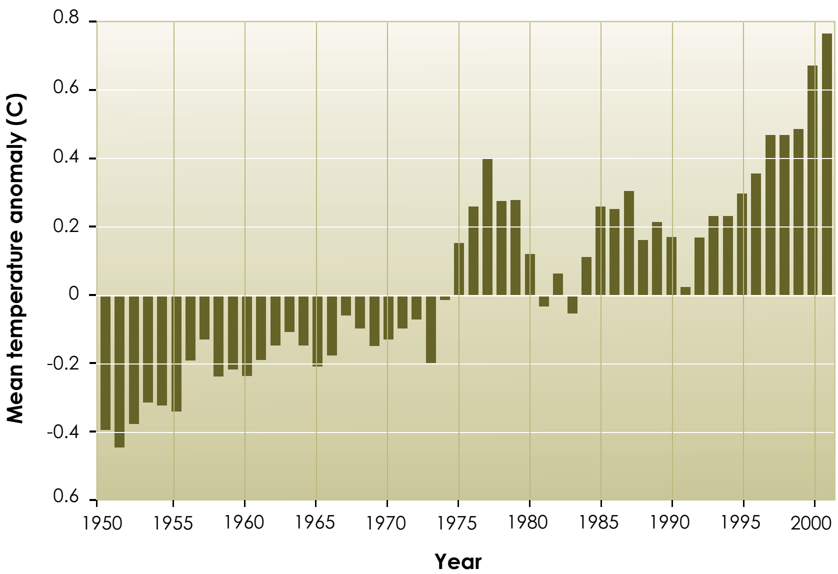


Figure 4. Murray-Darling Basin mean temperature difference. Differences are relative to the long-term average (1961-90).[28]

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

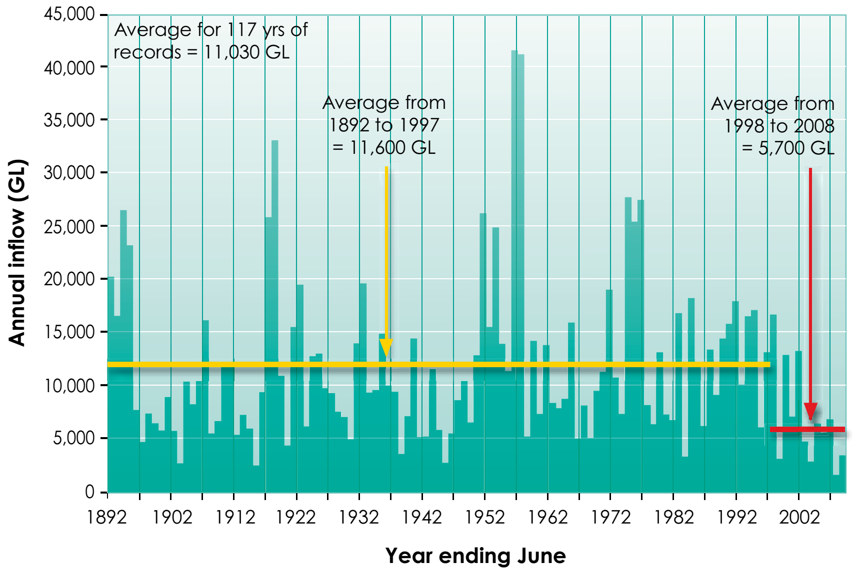


Figure 5. Murray-Darling Basin inflows [29]

It is estimated that when groundwater losses are included, 200 GL of water have been lost from the Murray-Darling Basin during this drought.[30] 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. However, because the CLLMM region relies almost exclusively on flows from upstream in the Murray-Darling system, it is directly affected by the quality and quantity of water that is delivered from upstream. The longevity of the drought has compounded the effects of over-allocation and lack of available water to cause severe detrimental impacts on the CLLMM region.

4.4 Climate change

Climate science predicts that south-eastern Australia, which includes the southern Murray-Darling Basin, is likely to become drier and hotter in the future. Climate change may 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'.[27] The intensity of the current drought may lie outside the limits of natural variability and may be explained – at least in part – by reference to anthropogenic climate change.

The CSIRO Murray-Darling Basin Sustainable Yields Project[8] examined rainfall and runoff in the Murray-Darling Basin under five climate scenarios (Section 6.4): historical (1895–2006), 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[31] and are all potentially representative of the year 2030.

Despite this, the CSIRO Murray-Darling Basin Sustainable Yields Project forecasts 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 a year in comparison with the current 0 GL end-of-system flows.[8] 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.[8]

The CSIRO Murray-Darling Basin Sustainable Yields Project median 2030 climate scenario 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 1,500 GL per year could occur in 13 per cent of years.

The situation is considerably worse under the extreme dry future climate scenario, which predicts flow at the Murray Mouth ceasing 70 per cent of the time and severe drought inflows to the Lower Lakes occurring in 33 percent of years.

There are some indications that the current drought may be influenced by anthropogenic climate change.[32] 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 metre by 2100. However, modelling indicates the dune barrier will not be breached by 2109.[33] 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 by the end of the century. A gradual or staged transition is required over large time periods.

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'.[34] In extreme circumstances such as these, islands that are important nesting grounds for birds are likely to be submerged, and mudflat habitats supporting many species of waterbirds, 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 100 years and neither, therefore, is the Coorong.[33]

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 existing ecological character. In the very long-term, however, the impact of sea level rise may be a more estuarine environment. Planning for the site aims to maintain a healthy environment that adapts successfully to changing conditions.

A component of the management response will be best-practice adaptive management to strengthen the resilience of the system to the predicted impacts of climate change. Adaptation measures will allow the site to function under stable but altered conditions and aim to build resilience in the system (Section 8.2).

It is predicted that if the barrages were to be permanently opened during periods of low freshwater flow, it would lead to hypersaline conditions in Lake Alexandrina and loss of ecological character.

4.6 Maintenance of stable water levels

Before the current water level crisis in the Lower Lakes, the primary objective of water-level management was human utility, although some ecological factors were given consideration. River regulation and diversions upstream have had an influence on maintaining static water levels. However, barrage operation has been the main management action used to control water levels in the Lower Lakes. Since their completion in 1940, the barrages have been operated to:[35]

- Prevent the ingress of seawater during periods of low flow, to maintain salinity levels in the Lower Lakes and the River Murray downstream of Lock 1
- 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 saline groundwater discharge into the Lower 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 fresh water, by direct extraction from the Lower Lakes, to towns and agricultural enterprises located around the lake margins
- Prevent flooding of surrounding land
- Permit fish passage between the Lower Lakes and the sea, with the recent inclusion of fishways.

To achieve the above objectives the Lower Lakes water levels are kept at:[35]

- 0.40 metres 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 flow over the spillways associated with the barrages as surcharge level is achieved)
- More than 0.85 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 understood that before the barrages were built, the lake levels generally remained above sea level due to the near continual flow of water from the River Murray.

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, flushing 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 CLLMM ecosystem has been compromised as a consequence.[2, 21] For example, excessively static water levels have resulted in:[36]

- A simplification of the aquatic and fringing plant communities, making them a less suitable habitat and restricting growth to a narrow band of emergent reeds
- Increased lakeshore erosion when lake levels are held at 0.6 metres AHD and above
- Loss of connectivity between the estuary and Lower Lakes, needed for diadromous fish.

Excessively static water levels have also contributed to:

- Reduced exchanges between Lakes Alexandrina and Albert through wind seiching
- Loss of spawning triggers for flood-dependent fish species.

Extremely low water levels (i.e. less than 0 metres AHD) have serious ecological impacts; keeping the level above these extremes is crucial in maintaining the ecological integrity of the site.

Episodic rapid falls in water level, which have been a feature of water-level management, are not ecologically ideal, as they result in:[36]

- '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 fresh water and estuarine-saline components of the aquatic habitat at critical times in fish life histories.

Management challenges and approaches

A lake water level management regime needs to be developed in consultation with all stakeholders, that better reflects ecological objectives and recognises the implications for other users.

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.

In 2006-07 there was a minor barrage discharge of 63 GL, due to unseasonal, localised (but major) rainfall in the Eastern Mount Lofty Ranges. There has been no discharge since then, as shown in **Figure 6**. Between 1975-76 and 1996-97 average annual barrage discharges were 6,023 GL. However, since then, the average annual barrage discharge has been only 890 GL.

Impacts and consequences

- *Reduced freshwater inflows*
- *Low water levels*
- *Ecosystem degradation*
- *Lack of connectivity between the Lower Lakes and the sea*
- *Social impacts*
- *Ngarrindjeri culture*
- *Economic impacts*

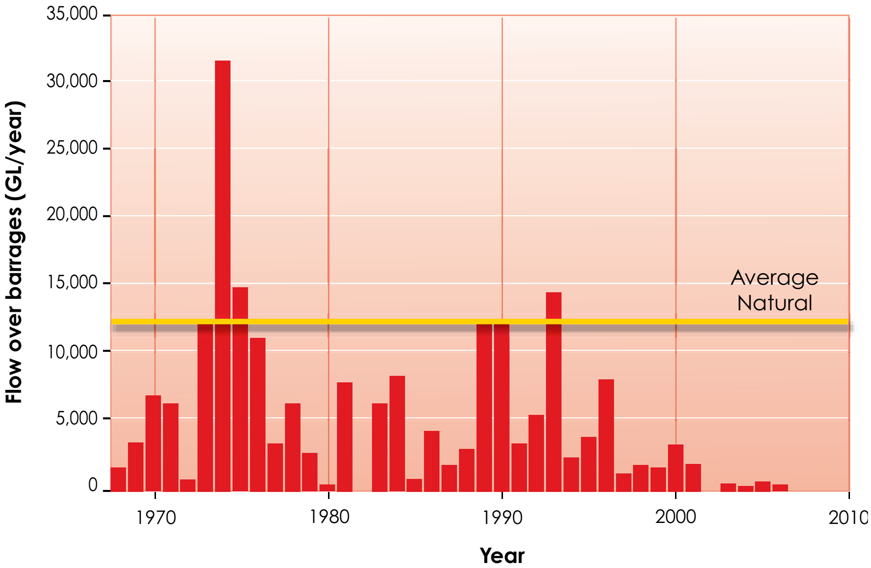


Figure 6. River Murray discharge at the barrages from 1968 to 2009. [37]

In an average year about 40 to 50 per cent of the public water supplies for metropolitan Adelaide and associated country areas including the Fleurieu Peninsula, Yorke Peninsula and the Mid-North are extracted from the River Murray. Reservoirs in the Eastern Mount Lofty Ranges that depend on local rainfall provide most of the remaining water supply. However, in 2007 and 2008 the River Murray provided a much greater proportion than this, due to drought and overuse reducing inflows to the Mount Lofty Ranges reservoirs. To ensure sustainable water use in the Eastern Mount Lofty Ranges, the South Australian Murray-Darling Basin NRM Board is finalising a draft water allocation plan.

In 2009, improved rainfall in the Eastern Mount Lofty Ranges provided water to a majority of the reservoirs and therefore less water was pumped from the River Murray in South Australia than the previous two years.

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. Levels 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. Unless water is provided, Lake Albert is likely to experience fish kills due to factors including increased salinity, low dissolved oxygen levels and poor water quality. Both lakes are also 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 refreshed by river 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 now reach about five times the salinity of seawater.

Due to the barrages holding back seawater, water levels in Lakes Alexandrina and Albert have fallen to unprecedented lows, disconnecting the two lakes. A bund was built between the lakes at the Narrung Narrows so they could be independently managed while the current crisis continues (Section 8.1). During 2009, the water level in Lake Alexandrina dropped to -1.0 metre AHD, and in Lake Albert -0.5 metres AHD. This resulted in the exposure of acid sulfate soils.

5.2.1 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, alteration of soil structures, 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.

Acid sulfate soils are a concern both during the ‘drying’ of soils when water levels are falling, and in the ‘rewetting’ phase, as water returns (e.g. during rain). Mobilisation of acid and metals is of particular concern during rewetting. If Lake Alexandrina were to acidify, 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 the now dry shore of 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.[38] In some parts of the site, it was noted that there was the potential for acid sulfate soils to develop if water levels continue to drop, although the risk 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, when acidity and metal mobilisation may occur.

Acid sulfate soils

Sulfidic soils naturally occur in coastal and freshwater areas where there are large amounts of sulfur 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 acid sulfate soils that contain sulfuric acid.

The acid can also cause toxic metals such as manganese, aluminium, arsenic and heavy metals to be released. When the soils are wet again, through rainfall or increased river flow, the acid and metals can spread and affect large areas.

Acid sulfate soils also have the potential to cause rapid deoxygenation of the water.

Based on water levels at March 2009, more than 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.

Maintaining an open Murray Mouth is crucial.

A significant new finding occurred in May 2009 with 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 [38]. If ponded acidic water reconnects with the lakes, it can rapidly transport acid and high concentrations of metals into the lakes and increase the rate of acidification.

The risk of wind-blown dust containing acid and high concentrations of toxic metals is also of concern. However, under current conditions the presence of acid sulfate soils is not considered to significantly increase the risk to public health from dust in the region.

Research indicates there is no other site in the world that has such diversity or concentration of acid sulfate soil sub-types or has experienced their exposure on a scale of this magnitude.

Management challenges and approaches

The best management approach is to prevent acidification by inundating soils with fresh water. However, due to low inflows and the recent drought, actions such as bioremediation (promoting naturally occurring bacteria that reverse the acidification process) and limestone dosing can be used. The Goolwa Channel Water Level Management Project and Narrung Narrows regulator are also needed to manage acidification that 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. It is recognised this would have significant implications for the ecological character of the site, as well as economic and social impacts.

5.2.2 Elevated salinity

Many of the wetlands in the CLLMM region now have salinity levels well above their historical ranges.

Salinity levels in Lake Alexandrina generally used to be less than 1,000 EC units (which was suitable for stock, domestic supplies and irrigation). However, current readings are more than five times that level. In Lake Albert, salinity levels are more than 10,000 EC units, and are likely to increase unless freshwater can be made available. For comparison, the salinity of seawater is approximately 60,000 EC units.

In the Coorong, salinity has increased with time (**Figure 7**). Parts of the Coorong now experience salinities approximately five times the salinity of seawater, far higher than at any other time in the 7,000 years it has existed.

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

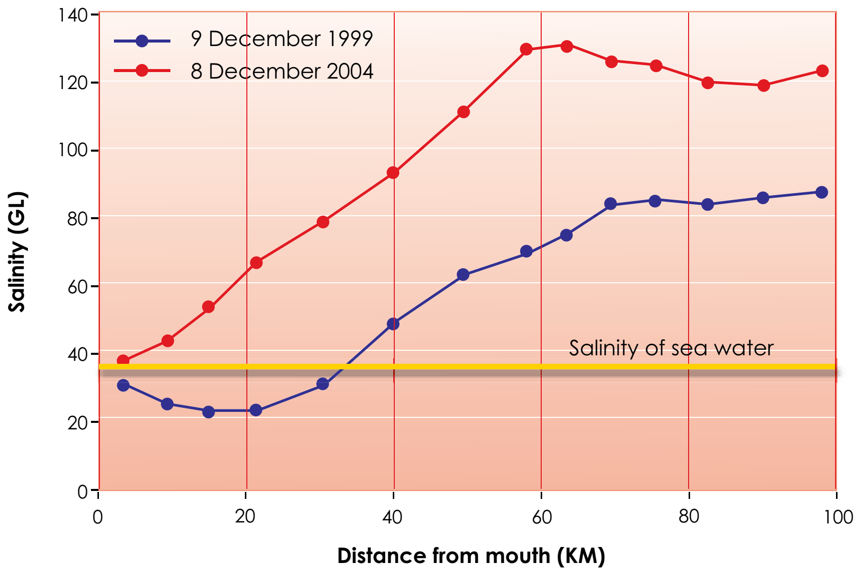


Figure 7. Longitudinal profiles of salinity (salinity gradient) measured along the Coorong on 9 December 1999 and 8 December 2004. Data provided by the South Australian Departments for Environment and Heritage, and of Water, Land and Biodiversity Conservation. [37]

Management challenges and approaches

The only effective management approach is to discharge the salt, silt and other pollutants through the Murray Mouth. This is not possible under current circumstances of extremely 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 this is possible in the future.


MILANG
GENERAL STORE

5.3 Ecosystem degradation

The current crisis has had, and is continuing to have, a profound impact on the ecosystem of the CLLMM region. 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.

5.3.1 Low water levels in the Lower Lakes

Before the current crisis, much of the biodiversity of the Lower Lakes depended, either directly or indirectly, on 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.[2]

This band of vegetation is generally located between 0.85 metres and 0.30 metres AHD. But since water levels have dropped below sea level for the first time since barrage construction, have remained below this level and continue to decline, the fringing band of aquatic vegetation is no longer connected to the water body 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.[39, 40] A fall in numbers of a range of waterbirds including ducks, darters, shorebirds, terns, coots, cormorants and ibis have been documented.[41] 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 naturally been colonised by terrestrial plants. This is beneficial in managing acid sulfate soils and wind erosion, but does not support aquatic species threatened by the current conditions.

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 also expected to decline, with salinity likely to increase and dissolved oxygen concentration 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. Compared to native species, introduced fish (with the exception of eastern gambusia) are usually not highly tolerant of elevated salinities. Redfin perch are intolerant of salinities above about 12,500 EC[1] and as a result raised salinities will have a drastic impact on this species. In comparison, common carp have a higher salinity tolerance of about 20,000 EC.[42]

Given current trends, fish kills in Lake Albert are anticipated unless high salinity and dissolved oxygen thresholds can be prevented. A fish kill at Lake Alexandrina is more difficult to predict, but it could occur in the next few years unless River Murray inflows increase or some other management intervention prevents it.

Eastern Fleurieu School Milang Campus students have played an important role in rescuing and caring for tortoises encrusted by tubeworms.

5.3.2 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 have been reduced) and from the air through sea spray. 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.[2] In autumn 2009 (prior to winter rains) salinity in central Lake Alexandrina had reached 6,430 EC and was 35,100 EC near Goolwa.[43] In Lake Albert salinity near Meningie was 12,200 EC. Seawater has a salinity of approximately 60,000 EC.

Salinity has a strong influence upon aquatic ecosystems including the Lower Lakes.[2] All aquatic organisms can tolerate a range of salinity but will not persist at salinities outside that range. Therefore, the salinity of a water body 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 over abundance of other species.

The abundance of salinity tolerant tubeworms in the Goolwa Channel has increased dramatically. Tubeworms are common in the Coorong and Murray Mouth region, with indications that they have inhabited the Coorong for hundreds of years and may therefore be native to the area. However, they have only recently colonised the Goolwa Channel in summer 2007-2008.

Tubeworms have encrusted the shells 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 also live longer, and theoretically can 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 present in the Lower Lakes before the current crisis, and the salinity tolerances of their most salinity-sensitive life stages (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).[42]

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 water body created in late 2009 between the new Clayton temporary flow regulator and the Goolwa barrage. The salinity in the Goolwa pool was about 13,000 EC in January 2010.

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.

Fairy turns are now listed as vulnerable because their numbers have greatly reduced.

Volunteers help rescue tortoises

Local volunteers continue to provide life-saving support for the tortoises of the Lower Lakes by rescuing them, cleaning their shells of 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, Eastern Fleurieu School Milang Campus and Investigator College have played important roles in rescuing and caring for tortoises.

5.3.3 Elevated salinity in the Coorong

Before European settlement, fresh water 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.[37] Freshwater flows from the south-east of South Australia helped keep the southern end of the Coorong relatively fresh.[10, 24] Pre-European salinities in the Coorong's South Lagoon were typically 8,300 EC to 58, 333 EC (i.e. less than seawater).[10]

European settlement of South Australia and the Murray-Darling Basin has led to greatly reduced freshwater inflows to both ends of the Coorong. Construction of the South-East drainage network, which commenced in the 1860s,[25] significantly limited 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.[44] When the CLLMM site was listed as a Wetland of International Importance in 1985, the typical salinity range in the South Lagoon had risen to between 90,000 EC and 230,000 EC.[45]

Despite this increase, a healthy ecosystem existed in the South Lagoon and was maintained largely by barrage flows.[45] 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 an invertebrate species (a chironomid or non-biting midge).[45] In recent years there has been substantial decline in the availability of these food resources and this has led to a decline in the number of waterbird species in the South Lagoon. [46]

An important feature of this system was the highly productive seasonal mudflats, inundated in winter/spring and exposed in summer/autumn, which provided feeding habitat for vast numbers of endemic and migratory shorebirds.[47] This ecosystem persisted in the South Lagoon until as recently as 1999.[37] The decline of these important mudflats has resulted in a decline in habitat and breeding areas for the endemic and migratory shorebirds.

The current crisis has resulted in freshwater flows through the barrages into the northern Coorong – already greatly reduced from historical levels – completely stopping. Flows through the barrages introduce fresh water, potentially replacing water lost through evaporation, in the North Lagoon. When the barrages are closed the water replacing evaporative losses in the system are of marine origin, and salinity in the South Lagoon has increased rapidly as a consequence. The ecological consequences of the current crisis have been severe for the Coorong. The tassel/hardyhead/chironomid ecosystem, and the shorebirds it supported, has largely disappeared from the South Lagoon.[37] It has been replaced by a simplified system featuring high numbers of highly salt-tolerant brine shrimp, banded stilt and chestnut teal.[37] A vestige of the tassel/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.

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.[49] Significant decline of saltmarsh vegetation has been observed. It has been estimated that up to 75 per cent of the saltmarsh vegetation of the CLLMM site has been lost or degraded due to excessive salinity and/or inappropriate water levels.[50]

Case study: Fairy Terns

Fairy terns are now listed as vulnerable on the IUCN Red List because their abundances have fallen quickly, particularly in the Coorong. Their ability to breed successfully in the Coorong has been curtailed because of the absence of small-mouthed hardyhead fish near secure breeding locations in the South Lagoon. The global population of fairy turns is now less than 4,000. In the 1980s, more than 1,350 fairy terns used the Coorong, making the region a stronghold for the species. In 2000, the number counted in the Coorong had fallen to nearly 700, and the total has now dropped to around 300. If they continue to fail to breed successfully (as is likely under the current conditions) the fairy tern will face local extinction.[48]

Despite increased survey effort, preliminary analysis of May 2009 surveys (a peak period for orange-bellied parrots in the Coorong) revealed that the mean number in the Coorong has declined markedly, from 23 in 2006 to 19 in 2007, five in 2008 and three in 2009.[51]

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.[45] 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.[37] Changes to and loss of the aquatic vegetation throughout the Coorong are strongly linked to increased salinity[37] and changes in seasonal water level patterns.

Management challenges and approaches

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 only in limited areas of the North Lagoon.

Limestone dosing has been implemented to manage acidification.

5.3.4 Localised acidification of surface waters

The exposure and subsequent rewetting 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.[43] It is much easier to measure the pH of water than it is to measure the response of the aquatic ecosystem to acidification.

About 200 hectares of acidic water was discovered at Loveday Bay in August 2009. Separated from Lake Alexandrina by a narrow sand barrier, the water had become so acidic that mussel shells had been completely or partially dissolved along the shoreline. Sampling in the acidified waters revealed a complete absence of invertebrates. This indicates the potential for biodiversity loss if there is a large-scale acidification event.

Risks to the Lower Lakes ecosystem posed by acidification and associated mobilisation of metals have been investigated.[52] Most research on the issue has been carried out through laboratory studies and is therefore difficult to apply at the whole-of-ecosystem scale. The risk assessment concluded that acidification could have devastating effects upon the aquatic ecosystem and that avoiding acidification is extremely important.[52]

Management challenges and approaches

Although saturating soils with fresh water is the best method of preventing acidification, 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 but will be explored, with the understanding that this would have serious implications for the ecological character of the site and economic and social impacts.

Congolli fish.

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 fish and other aquatic biota to migrate between the marine and freshwater environments of the Lower Lakes has been curtailed. Such migration is critical for a number of species, particularly diadromous fish species. The CLLMM region is a critical pathway between habitats and the site supports seven diadromous fish species.[42]

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 region historically included congolli, common galaxias and estuary perch, while anadromous species included pouched lamprey, short-headed lamprey and short-finned eel.[42] While estuary perch may historically have been common,[53] in the last 20 years they have been recorded in the CLLMM region just twice[54] and may be locally extinct. This is probably due to a lack of connectivity and the 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.

Case study: congolli

Congolli is a small native fish that lives in the Coorong and Lower Lakes but 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 fresh water to estuarine and marine waters for spawning. In spring and summer both adults and young migrate back to fresh water. A loss of connectivity between these habitats due to the current crisis has led to a significant decline in the population of congolli. At the Goolwa barrage, adult congolli have been observed congregating in an attempt 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 to teach them about the ecology of their Yarluwar-Ruwe.

5.5 Social impacts

The combined population in the three local government areas of the CLLMM region (Alexandrina Council, The Coorong District Council and Murray Bridge Council) was estimated in the 2006 Census to be about 44,000. The Murray Bridge Council area has the largest population with more than 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 the presence of families who have lived in the area for generations. The residents have a strong sense of community. The area is provided with adequate essential services and assets such as service clubs, sporting clubs, community groups, local government and environmental groups.

However, the economic status, 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 shrunk as skilled workers, especially young people, seek employment away from home. This has had an impact on family and community life, and has affected volunteering and community service.[22]

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

Many people have expressed a sense of loss as a consequence of the condition of the CLLMM site. This is not restricted to a loss of amenity, but extends to feelings of emotional or spiritual loss. 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 with the potential to become entrenched in and fracture communities.

The loss of 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 that are under threat.

5.6 Ngarrindjeri culture

The links between the CLLMM site and surrounding areas are central for the Ngarrindjeri. More than 4,000 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 stated how significantly they are being affected by the loss of ecological character of the CLLMM region.[55, 56]

The following quotes, written years before the current crisis, 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?'* [12]

> *'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 ngartji [friend] is no longer thriving in its own ruwi [country]. The stress on the ngartji echoes the stressed ruwi and stressed people.'* [57]

The Ngarrindjeri leadership, in accordance with Ngarrindjeri traditions and responsibilities, is committed to minimising 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.'* [12]

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.

The Regional Partnership Agreement between the Ngarrindjeri Regional Authority, the Australian Government and the State Government of South Australia was signed in July 2008. It supports the development of the Ngarrindjeri Caring for Country program, with a focus on sustainable economic development, and 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 will help ensure a diversity of healthy wetland habitats, as well as help restore and maintain 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

Anecdotal evidence suggests 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.[58]

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 bankruptcy if current conditions continue. The value of dryland grazing has been affected by the reduction of flood irrigation through wind seiching and the additional costs associated with alternative feed and water sources.

The gross value of output from the Lakes and Coorong Fishery has not been affected by the reduced water level in Lake Alexandrina. This is primarily attributed to the fisheries licence holder's ability to shift effort between environments and species and therefore contribute to the long-term viability and sustainability of the resource. However, the low lake levels are causing difficulties for boat access and manoeuvrability.[61] Anecdotal information suggests that lack of manoeuvrability has resulted in smaller catches.[58]

The number of dairy cattle reliant on the Lower Lakes has been in decline.

Although there have been no dramatic changes in the grape and wine industry, the security of future production has been threatened by low water levels. The construction of irrigation pipelines through the Australian Government-funded Lower Lakes Pipelines project has helped reduce the impact on these industries, particularly in the Currency Creek and Langhorne Creek areas, by providing an alternative water source.[61]

Businesses directly connected to water and tourism have experienced a decline in business of up to 80 per cent. This has resulted in the loss of employment, some businesses being sold and others being placed on the 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. Anecdotal evidence suggests houseboat hiring 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.[58 61]

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.[58]

Case study: the dairy industry

Between 2002 and 2007, the number of dairy cows reliant on the Lower Murray lakes and swamps declined from 37,360 to 24,481 with the value of production dropping from $73 million to $51 million.[59] Between 2007 and 2009, the number of cows in the Lower Murray lakes and swamps fell from 24,481 to 19,884, while the value of production increased by 10 per cent to around $56 million as milk prices rose from $0.33 a litre to $0.45 a litre.[60] Over the same period the number of cows in Meningie Lakes dropped from 10,933 to 9,746 and in the Lower Murray swamps area from 13,548 to 10,138.

Acid sulfate soil laboratory trials.

BACKGROUND

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 Importance 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 resembles the historical character of the site can be maintained, and the chance of establishing any type of complex ecosystem will become increasingly unlikely.

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.

What is the latest science telling us?

- *Consequences of doing nothing more*
- *Consequences of introducing seawater*
- *How much freshwater is required for longer-term management?*
- *What future climatic scenarios should we plan for?*
- *Is a freshwater future possible?*

If current low flows continue, 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 (depending on the timing and volume of future freshwater flows 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
- Higher levels of salinity in the Lower Lakes to beyond tolerance thresholds for freshwater species
- Higher levels of salinity in the Coorong to beyond tolerance thresholds for extant species
- Higher 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
- Higher 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 tubeworms 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.

Research into the impact of introducing seawater to address acid sulfate soils, compared to using freshwater.

6.2 Consequences of introducing seawater

6.2.1 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, and 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 and neutralised during transport through the soil?
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 being formed?
6. What were the air quality impacts of acid sulfate soil exposure?

What we now know

Approximately 85 per cent of the sediments of the Lower Lakes have the ability to generate 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.

In field and laboratory experiments, the introduction of seawater onto already oxidised acid sulfate soils enhanced contaminant (acid, metal, metalloid, nutrient) release compared to fresh water.

Introducing seawater to soils already covered by fresh water through a 'shandying' effect could prevent further exposure of potential acid sulfate soils and so prevent further acid from forming. However, if contaminants such as salt cannot be flushed from the system, evaporation could lead to hypersaline conditions in the lakes.

The impacts on groundwater of introducing seawater to keep acid sulfate soils submerged is currently being investigated.

Studies indicate that freshwater aquatic species are progressively affected as salinity levels increase above 1,820 EC.[76] Lake Alexandrina's salinity historically has been below 1,000 EC and is currently above 5,500 EC. Above 1,820 EC, species are progressively lost and ecological communities become less diverse.[62, 63]

Salinities of 60,000 EC (seawater) or greater are excessively above the tolerance limits for freshwater ecosystems. **Figure 8** illustrates the tolerance limits for key freshwater, estuarine and marine species, showing that once levels reach 10,000 EC, many of the freshwater ecological functions are affected, resulting in a simplified ecological system within the water column, benthic habitats (at the bottom of the lakes) and lake edges.

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

The results of the research project in March 2010 indicate that the best management strategy to avoid acidification is to ensure sufficient freshwater flows are delivered to the CLLMM region 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 e.g. with limestone treatment and vegetation plantings. The vegetation plantings will also alleviate potential dust problems.

The conclusions of the research project reinforce the position that introduction of seawater is a last resort, short-term response to avert acidification of the water. Indications from geochemical modelling are that seawater may result in increased acidification relative to fresh water, although seawater could be useful in the absence of sufficient fresh water to prevent high-risk sediments (e.g. in the middle of the lakes) from becoming exposed. These findings are based on laboratory and field experiments on exposed lake sediments, which demonstrated that seawater inundation can increase acidity and release greater levels of contaminants from the soils compared with River Murray (fresh water) inundation.[64]

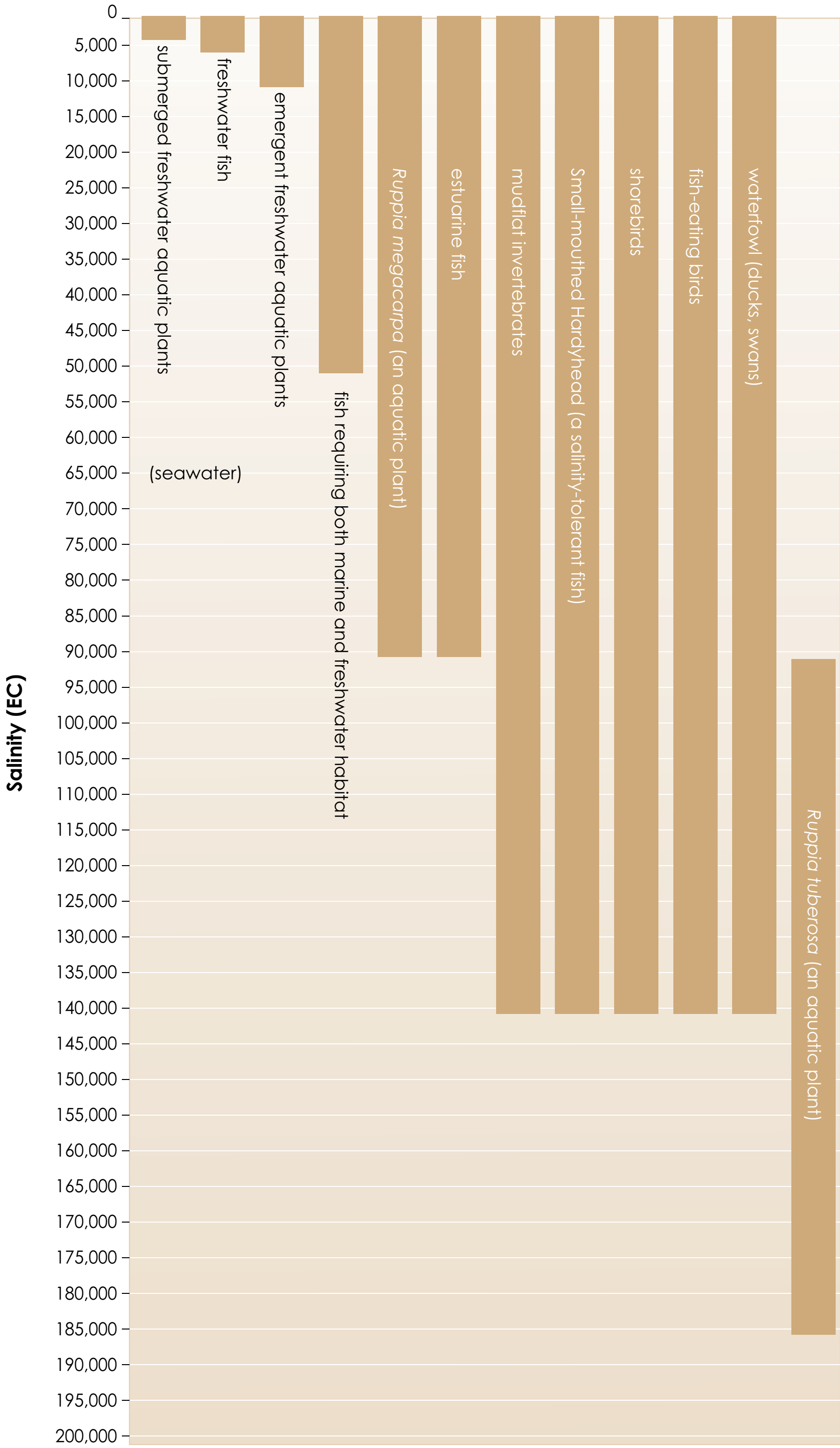


Figure 8. Indicative salinity tolerances for key CLLMM species.

Acidification trigger levels

Investigations into the trigger levels for acidification are nearing completion. The latest 3-D modelling in February 2010 indicated that water levels of -0.75 metres AHD in Lake Albert and -1.75 metres AHD in Lake Alexandrina are the levels below which broad-scale waterbody acidification is likely to occur.

These water levels are based on the hydrology and geochemistry of the lakes but do not take into account ecological considerations, e.g. the use of seawater to maintain the lakes at or above these water levels could avert irreparable acidification, but could create irreparable ecosystem-scale changes. Also, these water levels do not reflect the fact that localised acid sulfate soil 'hot spots' are likely to exist (i.e. between 0 metres AHD and -0.75 metres AHD in Lake Albert or 0 metres AHD and -1.75 m AHD in Lake Alexandrina), which could have significant adverse impacts.

Apart from modelling, real-time monitoring of the lakes and acid sulfate soils hotspot areas (especially monitoring alkalinity, pH and salinity) is continuing to inform management decisions.

Management challenges and approaches

In November 2008, the Murray-Darling Basin Ministerial Council approved the Real-time Management Strategy that aims to avoid acidification of Lakes Alexandrina and Albert by maintaining the lakes above alkalinity and water level management triggers. The strategy involves real-time monitoring of key water quality parameters, reviewing lake level predictions and acidification thresholds, assessing fresh water availability and responding by securing additional water to avoid acidification. The strategy enables managers to predict when management triggers will be reached and assess how much additional water is required. If there is insufficient fresh water available to maintain the lakes above management triggers, minimum quantities of seawater would be introduced through the barrages. Approval must be gained under the EPBC Act before seawater can be introduced.

6.2.2 What if the barrages were removed and seawater was introduced as a long-term measure?

The opening of the barrages on a permanent basis is not seen as a desirable long-term approach. 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 in less than two years, rather than a healthy marine environment.

Analysis of current tidal regimes and River Murray flows indicate that the barrages should not be opened and remain open indefinitely, and seawater should not be introduced as a long-term measure under the current lake conditions. Until Lake Alexandrina returns to a water level at which the River Murray water can discharge over the barrages into the Coorong, there would be insufficient fresh water to flush the system. It would lead to constriction of tidal flows into the Coorong, which would require increased dredging to prevent serious impacts. Opening the barrages is only likely when a positive freshwater 'head' of River Murray water is re-established.

Although investigations are still to be completed, initial risk assessments indicate that under current lake conditions, opening the barrage gates on more than a temporary basis is likely to have a number of negative impacts, including:

- Acidity mobilisation
- Release of metal contaminants
- Hypersalinity
- Eutrophication
- Impacts on freshwater ecological functions
- Threats to water security for Adelaide and country towns.

Without adequate freshwater flows, letting seawater enter Lake Alexandrina on a long-term basis is likely to create an increasingly degraded hypersaline ecosystem. The introduction of seawater may also increase the risk of acid sulfate soils.

The introduction of large amounts of seawater into Lake Alexandrina could 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 as part of a long-term response would adversely affect Ngarrindjeri culture and so consultation would be required before that occurred.

6.3 How much freshwater is required for longer-term management?

A project to determine how much water is required to secure a healthy future for the CLLMM Ramsar site is currently underway. Attempts have been made in the past to determine a water target for the site. Although based on the best available knowledge, each suggested target has 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 trade-offs have not been fully articulated.

Knowledge arising from recent research within the region,[37] and the availability of tools such as hydrological and ecological response models, mean 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 species and processes indicative of the historical character of the region.

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

Step 4. Investigating the impact on the region's ecological character 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.

The results of each step will 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.

6.3.1 Step 1 findings

The following ecological objectives have been identified for the CLLMM Ramsar site:[65]

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.

6.3.2 Step 2 initial findings (currently a work in progress)

Many species and ecological processes are being considered for selection as indicators of what an appropriate water regime might be. These include:[65]

1. Vegetation species or species assemblages (e.g. tassel species, samphire communities and paperbark woodlands)
2. Fish species (e.g. Murray cod and Murray hardyhead)
3. Macroinvertebrate species (e.g. the freshwater mussel, yabbies and tubeworms)
4. Ecological processes (e.g. photosynthesis, decomposition, acidification and salinisation).

Species and ecological processes are being selected as indicators if they are directly affected by such factors as water levels and water quality, are key species within the region, are threatened or considered to be a matter of national environmental significance under the EPBC Act and are sensitive to environmental change. Invasive species are also being considered as they can identify changes in environmental conditions.

6.3.3 Steps 3, 4 and 5 (underway)

Step 4 will identify the trade-offs between ecological values that may be required in the event of a longer-term drying climate occurring (Section 6.3).

The methodology for determining an appropriate flow regime focuses on water level and salinity thresholds for the indicator species and processes. In this way, it has been specifically designed to remain applicable in the event of large-scale environmental changes arising from climate change, for example, and is relevant to the diverse range of different habitat types and flow regimes existing across the CLLMM site.

What we know

South Australian modelling has indicated that for the 10-year period between 1997 and 2006, the average annual end-of-system flow was around 2,400 GL. During that time, average salinity in the South Lagoon of the Coorong nearly doubled. This led to a rapid decline in the ecosystem – aquatic plants, fish and bird life declined dramatically. [37]

There is ample documented evidence that many other species were profoundly affected and/or lost by flows reduced to this level.[2, 37] Average end-of-system flows of only 2,400 GL per year have been shown to lead to increasingly hypersaline conditions in the Coorong and detrimental impacts to the ecology of the site. Salinity has continued to increase and has reached a maximum of approximately 310,000 EC, which is approximately five times the salinity of seawater.

Preliminary modelling results

To flush the salt and other pollutants from the entire Murray-Darling Basin from the system, there needs to be an adequate head of water above the prevailing sea level to drive a flow through the barrages. South Australian preliminary modelling work has indicated that an average annual barrage discharge of at least 2,000 GL is required to maintain salinity in Lake Alexandrina below 1,000 EC (these figures are subject to peer review).

The discharge target would need to be provided as a rolling average over two and three-year cycles, not as a long-term average, and within a regime that includes higher flows to maintain a healthy South Lagoon.

What we know

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

6.4 What future climatic scenarios should we plan for?

For the CLLMM region, the primary driver of a healthy and functioning environment is the supply of fresh water. Therefore, knowing the likely availability of fresh water is central to establishing a realistic goal in which environmental values can be maintained.

In a report to the Murray-Darling Basin Authority,[32] the CSIRO recommends that the range of climates planned for should be based on *both* the recent dry climate conditions and future climate scenarios, using the findings of the *Water availability in the Murray-Darling Basin* CSIRO Sustainable Yields Project report.[8]

The use of the CSIRO Murray-Darling Basin Sustainable Yields Project in planning for future climate scenarios is recommended because its findings 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 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 may be part of a global warming trend (Section 11.5).

Table 3 provides an outline of the three key scenarios modelled by CSIRO and the likely implications for water flows to the CLLMM region. The baseline scenario (for comparison with other scenarios) is the historical climate from mid 1895 to mid 2006 and the current level of water resource development. The average annual end-of-system flows for this baseline scenario is 4,733 GL.

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 predicted 'dry' climate to 2030. The succession of dry years currently being experienced is therefore expected to be highly abnormal, even under dry future climate scenarios.

Climatic scenario	Overview	Implications for the CLLMM region	Possible implications for the ecological character of the CLLMM region
Wet 2030 model scenario	Mean total end-of-system flow = 5,550 GL/yr	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 most years. In some years water levels may be higher due to volumes 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.
Median 2030 model scenario	Mean total end-of-system flow = 3,482 GL/yr	73.6 percent of mean flow under current development and historic climate at Murray Mouth. Sever drought inflows to the Lower Lakes (ie. 1,500 GL) increase to 13 percent of years. Slight increase in the average period between flood events that flush the Murray Mouth. Maximum period between flood events that flus the Murray Mouth increased to nearly one in eight 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 percent of the time. Wetland systems (including Laxes Alexandrina and Albert, the Coorong, the Murray Mouth and estuary, the Goolwa Channel and the tributaties) connected during these periods. At other times, the Coorong, Murray Mouth and estuary could experience disconnection. Dredging required occasionally for an open Murray Mouth. 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 percent of mean flow under current development and historic climate at Murray Mouth. Increase in periods when Murray Mouth ceasing to flow to 70 percent of time. Severe drought inflows the Lower Lakes (i.e. < 15,00 GL) increase to 33 percent of years. Increase in the average period between flood events that flush the Murray Mouth to one in three years. Maximum period between flood events that flush the Murray Mouth to one in three years. Maximum period between flood events that flush the Murray Mouth increased to over one in 16 years.	Water level in Lake Albert drops too low and water would be pumped from Lake Alexandrina into Lake Albert to avert acidification of the latter. (i.e. these wetland systems would be artifically connected) Water levels in the Lake Alexandrina dropping. Flows over the barrages would occur approximately every three years in ten. Dredging would be required to maintain and 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.

Table 3. Future climate scenarios and their implications for the CLLMM region 8.

However, in addition to these scenarios, there is also described an extreme dry climatic scenario (**Table 4)**. While this scenario goes beyond that which the science predicts will be common, it does describe the extraordinary situation currently faced by the CLLMM region and may occur within any climate scenario, given the climatic variability that is a feature of the Murray-Darling Basin region. In other words, periods of below-average flows can and almost certainly will occur in the future and should be planned for. This includes continuation of the current extreme dry sequence.

Climatic scenario	Overview	Implications for the CLLMM region	Possible implications to ecological character of the CLLMM region
CLLMM region 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.

Table 4. The extreme-dry climate scenario and its implications for the CLLMM region.

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 **Table 3** and **Table 4** are based on the current water-sharing agreements, and do not incorporate water recovery targets being achieved by South Australia through The Living Murray initiative, other mechanisms such as the Commonwealth Environmental Water Holder, or new water-sharing arrangements that will arise as a result of the Murray-Darling Basin Plan.

The CSIRO Sustainable Yields report assumes the continuation of water-sharing agreements in place at that time. However, the Basin Plan to be developed under the *Water Act 2007* will set new sustainable diversion limits. Therefore, revised water-management arrangements could reduce the periods 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-sharing arrangements for the dry and/or median scenarios.

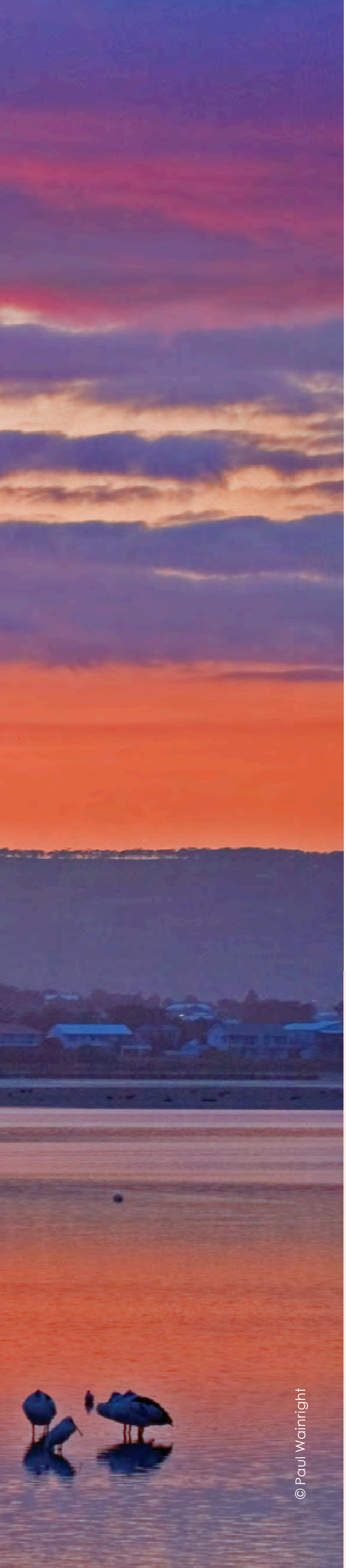
In periods of low flow, costly interventions such as acid sulfate soil treatment, including limestone addition, could be required.

6.5 Is a freshwater future possible?

Drawing from the best available CSIRO information, it is reasonable to base the plan for the Lower Lakes around fresh water. The development of the Basin Plan is a most significant initiative contributing to delivering an adequate end-of-system freshwater flow.

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.[8] It is not possible to return end-of-system flows to this level, and it is likely that this area will recover to a state that differs from the historical state, 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 fresh water 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.[37]

Given these positive predictions for fresh water, the option of admitting seawater into the Lower Lakes by permanently opening the barrages is not seen as a necessary, or desirable, long-term approach.



BACKGROUND

How do we manage for a healthy future?

7.1 A goal for the site, primarily focused on conservation

The South Australian Government suggests all Australians have a shared responsibility to conserve the ecological character of the CLLMM region – a wetland site recognised for its international importance. In addition to the site's exceptional environmental significance, the South Australian Government is mindful of its cultural, social, recreational and economic value, and the obligation to promote conservation of the site through 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 to conserve the species, ecological communities and ecosystems of the site, ensuring long-term regional and economic wellbeing.

How do we manage for a healthy future?

- *A goal for the site, primarily focused on conservation*
- *What is our approach?*

The Goal

The South Australian Government's goal is to secure a future for the CLLMM site 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 Living Murray Icon Site Management Plan (the key operational plan) and will be supported by other operational plans as they are developed.

7.1.1 Ecological objectives

In order to utilise the goal for the site, eight specific ecological objectives that focus on the ecological process and attributes that should occur at the site have been developed. By focusing on these objectives it will be possible to manage the site through the current crisis, as well as into the future.

The ecological objectives for the CLLMM region are:

- The region supports biological populations that persist without management intervention
- No barriers exist that would interrupt the recruitment of biological populations
- Water links the various habitats and management units of the site
- A range of habitats exist within the region
- A suitable salinity gradient is maintained across the site
- Both flows and water levels vary through time
- A variety of ecological functions are supported at appropriate levels
- Links exist between aquatic and terrestrial ecosystems.

Measurable ecological outcomes have been identified for these objectives. [66]

Sixth generation Milang farmer Ben Wilson and his son Samuel.

Indicatively achieving the goal for the site will lead to:

- 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 1,000 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.
- The return of captive southern and Yarra pygmy perch 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 (Section 8.1).
- 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 lakebeds. A target salinity of 1,500 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.
- The Murray Mouth kept open, mostly by river discharges that maintain the connection.
- Enhanced connectivity within the region with the removal of all temporary flow regulators and enhanced bio-passage through the barrages.
- 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.
- 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.
- A salinity and water level gradient along the Coorong, with average annual salinities closer to the long-term average of around approximately 62,000 EC across the system.
- No additional channels in the system e.g. no connection between Lake Albert and the Coorong, or new connections between the Coorong and the ocean. 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.
- The return of amenity for local residents and their communities.
- Adequate flows of water of a suitable quality to promote a living Ngarrindjeri cultural life.
- 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.
- The continuation of agricultural industries, albeit in a modified form and not reliant on the Lower Lakes for water supply, through the Lower Lakes Pipelines project.
- Protection of biological and ecological features that give these wetlands their international significance.

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. The key threats 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 the impacts and consequences of these threats are interrelated and so cannot be addressed in isolation. Many appropriate actions also address multiple threats, impacts and consequences.

To comprehensively address these threats, impacts and consequences, and to achieve the goal, the site will be managed according to the following approaches:

- Implement **mitigation** actions that:
  - Reduce the rate of ecological degradation
  - Remediate damaged areas
  - Prevent immediate and permanent ecological collapse
  - Maintain the ecosystem until conditions improve.
- Implement **adaptation** actions that:
  - Build and maintain a resilient ecology at the site that 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 are undertaken concurrently. These approaches are therefore not considered to represent stages in the implementation of management actions for the site; rather, short-term mitigation measures must be undertaken in tandem with longer-term adaptation measures and are dependent on the conditions and water available at the site.

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

This management method recognises that the ecological character of the site is changing, and will continue to change. However, it is possible to maintain a Wetland of International Importance, albeit a changed and changing wetland.

This method will also ensure that short-term remedies do not limit future management options for long-term positive ecological outcomes in an uncertain 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 in Section 11 and Appendix 8.

The information arising from the project to determine how much fresh water is required for the longer-term site management (Section 6.3) should assist in determining how decisions will be made in the event of a longer-term dry climate.

Aerial limestone dosing in Currency Creek was undertaken in autumn 2009 to manage exposed acid sulfate soils.

What has 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 responses to the challenges at the site. These measures can be classified as 'mitigation', 'adaptation', 'enabling', 'complementary' and 'last resort', to address the issues that have occurred or are expected to occur.

8.1 Mitigation measures

These measures are designed to reduce the impacts of continued 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.

What has been done?

- *Mitigation measures*
- *Adaptation measures*
- *Enabling actions*
- *Complementary actions*
- *Last resort measures*

8.1.1 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 the Goolwa Channel
- Recovering the target of 35 GL, South Australia's share from The Living Murray initiative. As one of the six Icon Sites, the Coorong and Lower Lakes is entitled to a portion of the 500 GL water-recovery initiative.

Vegetation works in the Lower Lakes

A trial involving seeding large areas of the Lower Lakes has been conducted on exposed lakebeds, to stabilise soils and prevent soil erosion. In addition to addressing soil erosion, the trial will test the technique's effectiveness in managing acid sulfate soils on this scale.

In 2009, the project included aerial seeding of about 4,500 hectares around the Lake Alexandrina, barrage islands and exposed areas in the Goolwa Channel, machine seeding of 500 hectares in Lake Albert and the northern shorelines of Lake Alexandrina, and applying more than 300 tonnes of shallow rooted ground-cover seed.

Autumn vegetation works in 2010 include aerial seeding of over 300 tonnes of seed to around 5,000 hectares of exposed lakebed, over 1.1 million native seedlings being planted on over 2,300 hectares of exposed lakebed and approximately 120,000 seedlings being planted on higher ground around the lakes by the community.

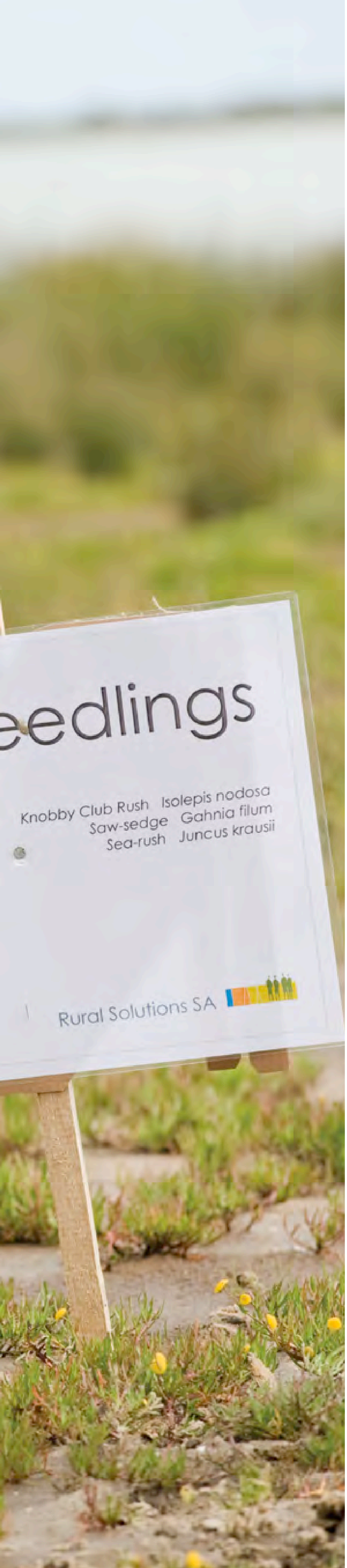
Initial results show seeding has covered the exposed shoreline. Monitoring will show how well the trial addresses soil erosion and acid sulfate soils.

This was funded through the Australian Government $10 million Lower Lakes Bioremediation and Revegetation Project.

8.1.2 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 to prevent and control soil acidification have been put in place, including:

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



- 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 began in January 2010 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.

8.1.3 Increased salinity

In response to increasing salinity levels in Lake Albert, a 'fish down' has been implemented to remove as many European carp as possible before a predicted fish kill takes place, to reduce the effect of strong odours on the community.

8.1.4 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 initiative
- 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 those that historically 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. Some of these measures are still at a developmental stage and may be 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 $120 million 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. This would occur in cooperation with the Australian Government's Upper South-East Drainage Scheme and the REFLOWS program (which aims to link the drainage system in the Lower South-East to the Upper South-East wetlands and Coorong), which are under construction and include implementing an adaptive flow management strategy and decision support system, 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 volume, 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.

Community volunteers are taking an active role in propagating seedlings to be planted in the Lower Lakes through the $10million Lower Lakes Bioremediation and Revegetation Project, funded by the Australian Government with support from the South Australian Department for Environment and Heritage.

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. This project builds on the Coorong and Lower Lakes Community-Eco-Action Project, a Goolwa to Wellington Local Action Planning Group initiative 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 determine sustainable water allocation.

8.4 Complementary actions

These are actions put forward by the South Australian Government and 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 aim to improve water-sharing equity within the Basin.

These actions include:

- The Water for Good plan[67] 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[67]
- The South Australian Government's constitutional challenge to upstream states to protect South Australia's rights to water
- Development of an Irrigated Agriculture Strategy to consider options for sustainable irrigated industries into the future.

8.5 Last resort measures

Last resort measures are those that the South Australian Government would prefer not to take but must consider in the event that critically low end-of-system flows continue. There are two such 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
- The introduction of a minimal amount of seawater to Lake Alexandrina to maintain its level above the trigger level for acidification.

Environmental Impact Statements involving a range of technical investigations are underway for these last resort measures, to ensure all the impacts on matters of National Environmental Significance can be carefully considered and appropriate action can be taken quickly if a critical point is reached.


Emerica.

PROPOSED ACTIONS

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 assessments of likely actions. This process was undertaken methodically through a series of steps.

9.1 The first step

The first step in this process was to identify and collate the many proposals and ideas for addressing the management challenges facing the site. These were drawn from a recent Senate inquiry[68] and extensive community consultation undertaken in April–June 2009 and August–September 2009.

Identifying mitigation and adaptation measures for the longer-term

- *The first step*
- *The second step*
- *The third step*
- *The fourth step*
- *The benefits of this selection process*

9.2 The second step

The second step was to assess the list of proposals using the decision framework depicted in **Figure 9**.

For an explanation of the climate scenarios used for the assessment process see Section 6.4.

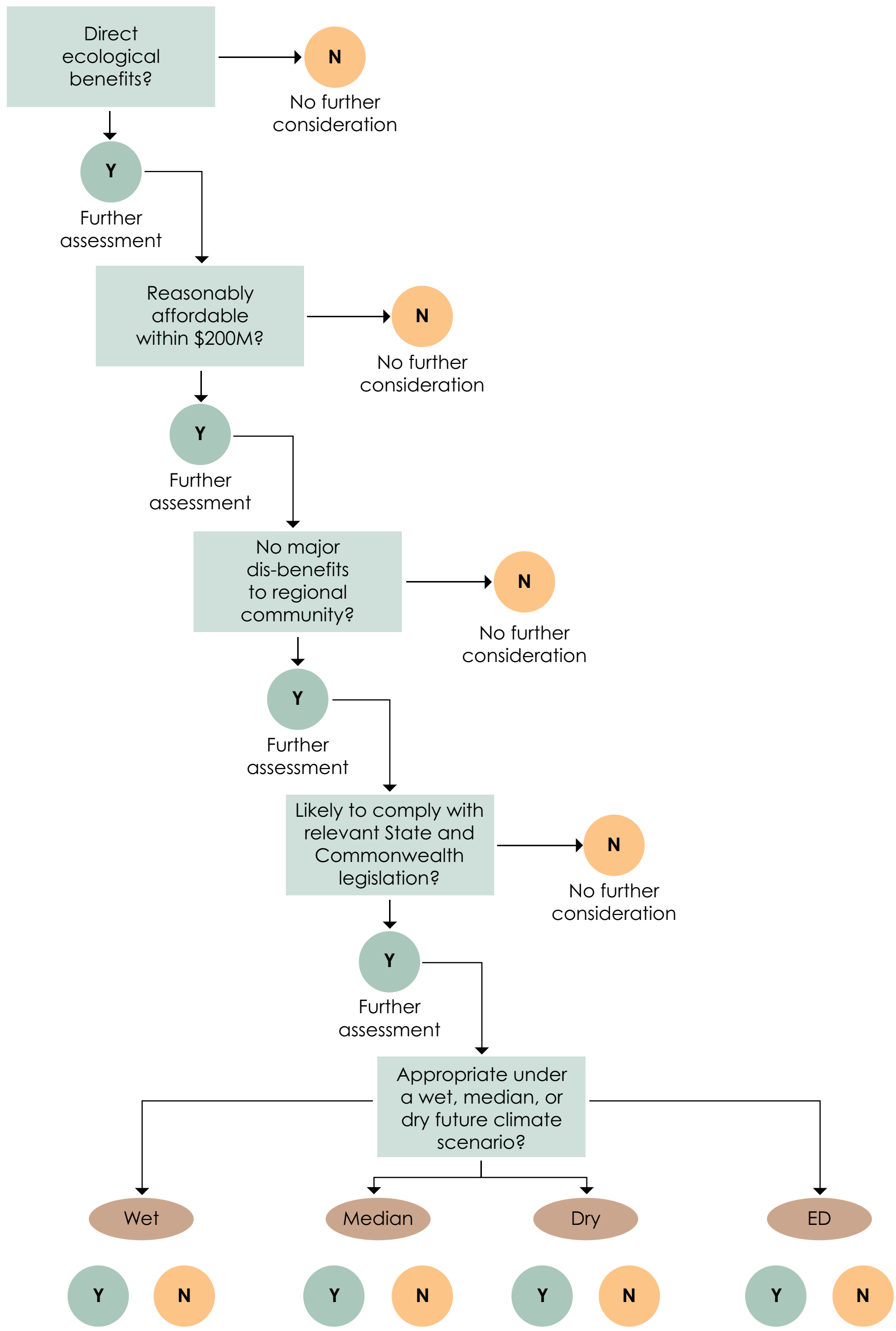


Figure 9. Decision framework for selecting proposals for detailed technical feasibility assessment.

9.3 The third step

The proposals were prioritised using three hierarchical criteria (i.e. criterion 1 was considered the most important, with criterion 3 the least important). The criteria are outlined in **Table 5**.

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.

Table 5. Criteria used to prioritise proposals.

9.4 The fourth step

Proposals prioritised during the third step underwent detailed technical feasibility assessments. These 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 in Section 10.

9.5 The benefits of the selection process

This process has identified management actions that:

- Provide ecological benefits to the site under a range of possible future climatic scenarios, in particular during dry or extremely dry periods
- Are reasonably affordable within the available budget of about $200 million
- 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 because it does not rely on the development of multiple plans to cover the various climatic scenarios, and recognises the limited capacity to predict climatic conditions. The process outlined includes actions that can be adapted and responsive to prevailing climatic conditions. This is outlined in more detail in Section 11.

Other management actions considered

Some of the management actions considered were found to be unsuitable for ecological or economic reasons (i.e. they exceeded the budget of about $200 million currently available for the site). A description of the key actions in this category can be found in Appendix 4.

PROPOSED ACTIONS

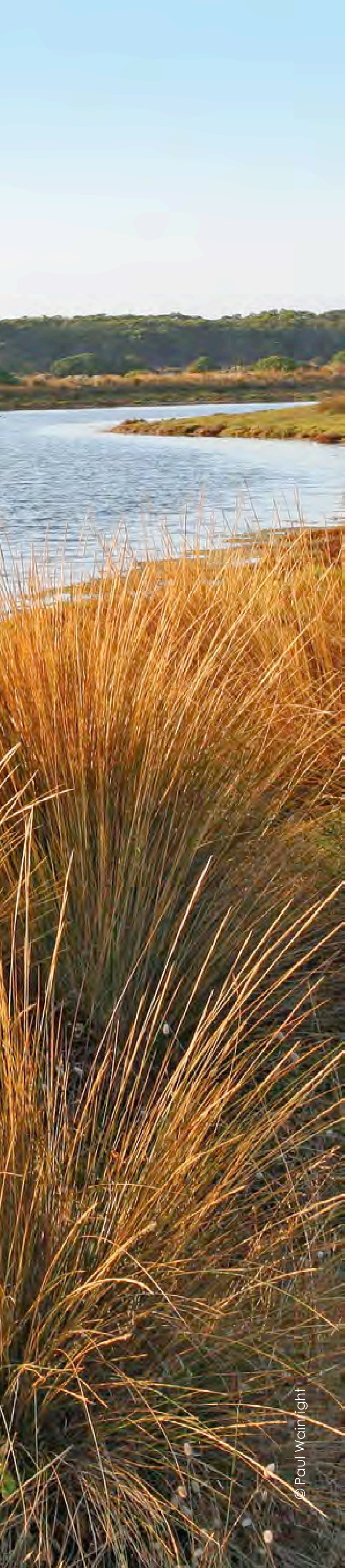
Priority management actions (2010 – 2014)

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 started with a worst-case climate scenario for the next five years.

The success of planned actions in ensuring a healthy, productive and resilient wetland system relies on improved freshwater flows into the Lower Lakes. As indicated earlier, there is no substitute for adequate volumes of freshwater to ensure the site's healthy future. Implementation of the Basin Plan, with its emphasis on environmental outcomes, from about 2012, is the most significant initiative that can contribute to a sustainable future.

Priority management actions (2010 – 2014)

- *Environmental water management actions*
- *Priority mitigation measures*
- *Priority mitigation and adaptation measures*
- *Priority adaptation measures*
- *Enabling measures*



10.1 Environmental water-management actions

The health of the CLLMM site 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 throughout the entire Murray-Darling Basin has been a factor in the ecological degradation of the Lower Lakes and Coorong under historical climate. Current water-sharing agreements 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 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 long-term future of the site as a Wetland of International Importance is at risk. The proposed management actions aim to maintain the ecosystem in a state from which recovery to a healthy, productive and resilient wetland is possible. Without the return of freshwater flows the success of the proposed actions 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 initiatives, and better management of unregulated flow events for environmental outcomes.

The Basin Plan, under the *Water Act 2007,* must incorporate provisions that return the Basin to sustainable levels of extraction. The *Water Act 2007* provides for setting environmentally sustainable limits on the amount of water that can be taken in the future from Basin water resources. It also identifies key environmental water assets and functions, and environmental water requirements across the Basin, including the CLLMM site.

An environmental watering plan that sets environmental objectives for Murray-Darling Basin wetlands, including the CLLMM site, is being developed as part of the Basin Plan.

The environmental watering plan must specify:

- The overall environmental objectives for the water dependent ecosystems of the Murray-Darling Basin
- Targets by which to measure progress towards achieving the environmental objectives specified above
- An environmental management framework for planned environmental water and held environmental water
- The methods to identify environmental assets in the Murray-Darling Basin that will require environmental watering
- The principles to be applied and methods to be used to determine the priorities for applying environmental water
- The principles to be applied in environmental watering.

Under the Water for the Future program, the Australian Government is purchasing water entitlements that will become available for Murray-Darling Basin ecological assets. Water availability is currently limited but the Commonwealth's environmental water holdings are expected to increase significantly in coming years.

The Commonwealth Environmental Water Holder makes decisions on the use of the Commonwealth's environmental water holdings. A whole-of-basin approach is taken in deciding where to use water. The priority assigned to watering actions is based on an assessment against publicly available criteria and on advice from a committee of scientific experts, the Environmental Water Scientific Advisory Committee. In the summer of 2010, Lake Albert was selected by the Commonwealth Environmental Water Holder to receive 20 GL of Commonwealth water.

As an Icon Site, the CLLMM site has been identified as a priority wetland in the Murray-Darling Basin and may receive environmental water through The Living Murray initiative. The Living Murray first step aimed to recover 500 GL of water for the Icon Sites by 2009, but the actual volume of water available through the initiative depends on water allocations. With the current suite of water recovery measures, up to 485 GL of water will be available to share between the six Icon Sites. The CLLMM site was allocated 48 GL from The Living Murray initiative in the summer of 2010 and received some water over the last 12 months for several refuge sites around the lakes.

Use of The Living Murray water is determined by New South Wales, Victorian, South Australian, Australian Capital Territory and Australian Governments (parties to The Living Murray Intergovernmental Agreement), through the Murray-Darling Basin Authority Environmental Watering Group. They develop an annual environmental watering plan to prioritise use of The Living Murray water each year and allocate through agreed decisions in response to water bids.

The South Australian River Murray Environmental Manager is the primary decision maker on environmental water within South Australia and has the responsibility for managing, allocating and delivering environmental water for 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 it to enhance environmental water delivery to ecological assets including the CLLMM site. Subject to inflows during 2009-10, the South Australian Government agreed to allocate at least 120 GL to a Lower Lakes environmental reserve (in addition to 50 GL purchased during 2008-09). Delivery is underway, according to an optimised delivery pattern.

South Australia will continue to actively bid for environmental water from both the Commonwealth Environmental Water Holder and The Living Murray. While the water potentially available from The Living Murray and Commonwealth Environmental Water Holder is not sufficient to provide all the CLLMM site's environmental requirements, 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.

To achieve a management strategy that will help the site 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 site.

In addition, South Australia is working with the Murray-Darling Basin Authority and other Basin States to develop the Murray-Darling Basin Plan, which will identify environmentally sustainable levels of take across the Basin. Further negotiation will also occur in relation to the Murray-Darling Basin Agreement that will deliver better environmental outcomes for the site.

Until environmental water needs and sustainable diversion limits are met, there are other 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 site. For this reason, it is unlikely that one action alone 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 actions that follow adopt the ***mitigation***, ***adaptation*** and ***enabling*** terminology of Section 8.

Figure 10 indicates that the further lake levels decline, the more management actions need to be implemented, thereby increasing management costs. Therefore, the key long-term management action is to secure adequate freshwater and prevent further decline in lake levels.

Lake level (metres AHD)	Environmental water allocation	Diverting freshwater from the South-East to the Coorong	Manage variable lake levels	Construction/installation of fishways	Vegetation plantings (& associated activities)	Maintenance of an open Murray Mouth	Coorong salinity reduction program	Protecting Critical Environmental Assets	Translocation of *Ruppia*	Acid sulfate soil treatments	Lake Albert water level management	Construction of artificial wetlands at Meningie	Temporary weir near Pomanda Island	Introduction of seawater
0.8	•	•	•	•	•									
0.75	•	•	•	•	•									
0.7	•	•	•	•	•									
0.6	•	•	•	•	•									
0.5	•	•	•	•	•									
0.4	•	•	•	•	•									
0.3	•	•	•	•	•									
0.2	•	•		•	•	•	•	•	•					
0.1	•	•		•	•	•	•	•	•					
0	•	•		•	•	•	•	•	•	•				
-0.1	•	•			•	•	•	•	•	•				
-0.2	•	•			•	•	•	•	•	•	•	•		
-0.3	•	•			•	•	•	•	•	•	•	•		
-0.4	•	•			•	•	•	•	•	•	•	•		
-0.5	•	•			•	•	•	•	•	•	•	•		
-0.6	•	•			•	•	•	•	•	•	•	•		
-0.7	•	•			•	•	•	•	•	•	•	•		
-0.8	•	•			•	•	•	•	•	•	•	•		
-0.9	•	•			•	•	•	•	•	•	•	•		
-1	•	•			•	•	•	•	•	•	•	•		
-1.1	•	•			•	•	•	•	•	•	•	•		
-1.2	•	•			•	•	•	•	•	•	•	•		
-1.3	•	•			•	•	•	•	•	•	•	•		
-1.4	•	•			•	•	•	•	•	•	•	•		
-1.5	•	•			•	•	•	•	•	•	•	•		
-1.6	•	•			•	•	•	•	•	•	•	•	•	•
-1.7	•	•			•	•	•	•	•	•	•	•	•	•
-1.8	•	•			•	•	•	•	•	•	•	•	•	•
-1.9	•	•			•	•	•	•	•	•	•	•	•	•
-2	•	•			•	•	•	•	•	•	•	•	•	•
-2.1	•	•			•	•	•	•	•	•	•	•	•	•
-2.2	•	•			•	•	•	•	•	•	•	•	•	•
-2.3	•	•			•	•	•	•	•	•	•	•	•	•
-2.4	•	•			•	•	•	•	•	•	•	•	•	•
-2.5	•	•			•	•	•	•	•	•	•	•	•	•
-2.6	•	•			•	•	•	•	•	•	•	•	•	•
-2.7	•	•			•	•	•	•	•	•	•	•	•	•
-2.8	•	•			•	•	•	•	•	•	•	•	•	•
-2.9	•	•			•	•	•	•	•	•	•	•	•	•
-3	•	•			•	•	•	•	•	•	•	•	•	•

Figure 10. As lake levels decline more management actions will be necessary, thereby increasing costs.

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 seawater through the Murray Mouth. Since 2002, barrage flows have been inadequate for an open Murray Mouth without management intervention.

Mitigation measures to keep the Murray Mouth open will maintain the ecosystem in a state from which a return to a healthy, productive and resilient wetland future is still possible.

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 10.2.2 and 10.4.1.

The benefits of an open Murray Mouth include that it:

- Maintains tidal variation and salinity levels 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 at the site
- Discharges salt and other pollutants accumulated from the entire Murray-Darling Basin to the sea.

The current dredging program has been in place at the Murray Mouth since 2002 and is currently operated and funded 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 effective option, 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
- When there are insufficient flows through the barrages to maintain an open Murray Mouth, dredging is the least expensive solution to achieving an open Murray Mouth
- The current dredging effort cost significantly less over the previous three years and investigations into how to further reduce and refine spending continue
- 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.

In a snapshot

Location of activity: Murray Mouth.

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

For more information, see: *Managing salinity in the Coorong – maintaining an open Murray Mouth Technical Feasibility Assessment.*[5]

10.2.2 Managing salinity in the Coorong – pumping hypersaline water out of the Southern Lagoon

This action is one of three complementary actions designed to improve the health of the Coorong and is required whenever River Murray flows are not sufficient to maintain an open Murray Mouth. Salinity levels in parts of the Coorong are currently about five times higher than seawater. This action, together with the maintenance of the Murray Mouth and the diversion of South-East 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 South Lagoon are so high that in the absence of other intervention, a major flood in the River Murray with barrage flows in excess of 10,000 GL would be required to restore target salinities. This action is a one-off intervention 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
- Promoting the ecological recovery of the South Lagoon by reducing salinities to within target levels for the tassel/chrinomid/hardyhead ecosystem
- Increased ability of seagrasses to populate (and allowing for the transplanting of native aquatic plants)
- Return of waterbirds 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 Murray 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, freshwater flows over the barrages, combined with increased freshwater flows from the South-East, are the only permanent solution.

The benefits of pumping hypersaline water from the South Lagoon could be increased by dredging the sills at Parnka Point, between the Coorong's North and South Lagoons. This area acts as a natural constriction 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 that supports improved ecological character.

Greater connectivity and water mixing are important to help manage the salinity gradient. To understand the benefits and risks for dredging the sills at Parnka Point, further feasibility assessment is needed and detailed flow measurements are required once pumping commences. This data can then be used to further assess the need for dredging the sills at Parnka Point and the installation of temporary regulators to maintain water levels, including heritage, technical and ecological implications.

In a snapshot

Location of activity: South Lagoon of the Coorong.

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

For more information see: Managing salinity in the *Coorong – pumping hypersaline water out of the Southern Lagoon.*[3]

10.2.3 Limestone dosing

Limestone dosing is expected to play a critical role in the continuing management of acid sulfate soils. Limestone dosing is one of three complementary measures aimed at managing acid sulfate soils. The other actions include those described in 10.2.4 and 10.2.5.

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 limestone slurry or aerial dosing.

Limestone dosing trials have been conducted at Currency Creek and Finniss River. 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 limestone dosing have included:

- Identification of a variety of limestone application methods
- Indications that the action provides flexibility and suits an adaptive management approach
- Proof that limestone addition is 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 soil hotspots as required
- Refining the techniques for large-scale delivery of limestone.

There are some ecological risks from the proposed action including potential negative effects on water bodies as well as aquatic plants and animals, but these need to be considered in the context of the much greater risk of not treating or trying to prevent acidification. The negative impacts of limestone application are considered less significant than the effects of untreated acidification; not treating acidity is likely to result in complete ecosystem collapse. These potential effects will be monitored and managed as part of an emergency response monitoring program that will form part of a wider monitoring program that is being developed for the entire CLLMM site. Monitoring includes ambient water quality monitoring at set locations to identify water quality trends and areas of concern, and event water quality monitoring which is used to inform the type and suitability of management actions necessary to mitigate acidification risks.

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: *Treating Acid Sulfate Soils Technical Feasibility Assessment.*[69]

Limestone can be applied quickly through the construction of limestone barriers.

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 at the CLLMM site have been identified as possibly benefiting from this action. Trials are underway to ascertain the feasibility of this approach.

Construction of sub-surface barriers typically includes the excavation of trenches that are then filled with a control material that helps retain sub-surface groundwater. Trials are determining 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 and the tributaries.

Activity addresses: acid sulfate soils arising from low inflows.

For more information see: *Treating Acid Sulfate Soils Technical Feasibility Assessment.*[69]

10.2.5 Lake Albert water level management

With Lake Albert water levels at critically low levels, this management action proposes the pumping of up to 90 GL of water from Lake Alexandrina to Lake Albert between January and June 2010. Initially the project proposed to pump 35 GL of water from Lake Alexandrina to Lake Albert, however the New South Wales floods in early 2010 increased the volume pumped to 56 GL. Pumping is not expected to impact on water levels in Lake Alexandrina due to the large volume of the lake. 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 future management of the Narrung Narrows will be assessed in conjunction with the Ngarrindjeri, the community and all three levels of government, when there is a greater understanding of future Lake Albert freshwater flows and water levels. This assessment will consider the water flow between the lakes and fish passageway.

The lake level will be maintained to ensure that the highest-risk acid sulfate soils are kept inundated.

Exposed lakebed will be managed by alternative methods such as limestone dosing (Section 10.2.3) and vegetation plantings (Section 10.3.1) to minimise the potential for large-scale acidification of the lake.

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

- The perceived urgency for the summer of 2009-2010, demonstrated by water level modelling
- The very high risk of large-scale acidification in Lake Albert if water levels drop too low.

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

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: *Managing Water Levels in Lake Albert to Prevent Acidification Technical Feasibility Assessment.* [70]

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 lakebeds.

This action proposes the large-scale vegetation of exposed sediments 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 native and non-native 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 Australian Government will initially fund the vegetation works as part of a $10 million Bioremediation and Revegetation Project.

The benefits of vegetation plantings include:

- Binding surface soils together to reduce erosion
- Encouraging the growth of soil-based bacteria that can inhibit and reverse the mobilisation of acid sulfates in the soils, and keep the soils in an inert state
- Contributing to the prevention of mobilisation of heavy metals and keeping those metals inert in the soils
- Providing a more positive environment for other native flora and fauna.

The necessary fencing, weed and vermin control measures undertaken as part of this activity will increase the likelihood of remediation success. **Table 6** shows proposed fencing works in 2010.

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 6. Proposed fencing works 2010.

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.*[71]

10.3.2 Meningie lakefront habitat restoration

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 and ecological values 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.

Detailed feasibility assessments of the Meningie foreshore and trials of local vegetation indicate that the area is suitable for this management action, which aims to generate 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 aims to achieve 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, amenity issues.

For more information see: *Treating Acid Sulfate Soils Technical Feasibility Assessment.*[69]

Southern purple spotted gudgeon.

10.3.3 Protecting Critical Environmental Assets Program

This management action aims to protect critical environmental assets through the active management of threatened species populations, unique to the CLLMM region. In the first instance, it involves captive breeding and/or translocation of fish between captivity and the wild, depending upon the site conditions within the CLLMM region. Other threatened species will be considered as required.

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 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, decreased levels of dissolved oxygen and high salinity, this action will ensure compliance with the national implementation of recovery plans.

Fish species initially included are:

- 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, acid sulfate soils, and artificial structures.

For more information see: *Protecting Critical Environmental Assets Program – Critical Fish Habitat and Refuge.*[72]

10.3.4 Translocation of large-fruit tassel *(Ruppia megacarpa)* and tuberous tassel *(Ruppia tuberosa)*

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

Increased salinity and altered water levels have reduced numbers of this plant at the site. Transplanting tassel successfully is heavily reliant on appropriate hydrology and salinity levels. Combined with separate management actions 10.2.1 and 10.4.1, successful transplanting of tassel will help:

- 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, Coorong and the sea, elevated salinity and ecosystem degradation arising from low inflows.

For more information see: *Ruppia Translocation in the Coorong Technical Feasibility Assessment.*[73]

10.4 Priority adaptation measures

10.4.1 Diverting freshwater from the South-East to the Coorong

Historically, flows from the South-East have played an important role in the maintenance of ecologically appropriate salinities within the Coorong's 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 (including regulators at diversion points along the flow paths) and existing drains, to divert water from the lower South-East towards the Coorong's South Lagoon.

This action will reduce rising salinity levels in the Coorong's South Lagoon and is one of three complementary measures to manage Coorong salinity levels. The related actions are management actions 10.2.1 and 10.2.2. The benefits of this measure are:

- Reduced salinity by the supply of median of 32 GL per year of freshwater from the South-East to the Coorong
- Enhanced ecosystem resilience
- Greater flexibility for Coorong management 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 long-term health of the tassel/chironomid/hardyhead system
- Restoring flows to the wetlands of the upper south-east of South Australia.

Feasibility studies funded by the Murray-Darling Basin Authority in 2007/08 and 2008/09 have shown the action to be technically feasible. Further detailed studies are underway, including feasibility studies funded by Murray Futures, to determine the viability of the project, but further investigations are required before implementation.

The action is complementary to the Restoring Flows to the Wetlands of the Upper South-East of South Australia program, funded by the Australian Government's Water for the Future program and the Upper South-East Flood Management and Dryland Salinity Program.

The action is one of few options that delivers 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: *Managing Salinity in the Coorong-restoring freshwater flows from the South-East Technical Feasibility Assessment.*[3]

10.4.2 Construction/installation of fishways

Fishways help to re-establish connectivity between the individual parts of the site by allowing greater water mixing and movement of biota. 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 they rely on throughout their lifecycles.

Construction of fishways 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. While the role of fishways may be restricted during low water levels, this is the best time for their installation as they are cheaper and easier to construct.

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 to maintain their effectiveness.

Different fishway options are available and selection will take into account the specific requirements of each site. The proposed fishway program is building on the existing Hume to the Sea native fish program, implemented by the former Murray-Darling Basin Commission. Proposed works include constructing rock ramps, new fish locks, fish culverts, vertical slots 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: *Restoring Fish Passage Technical Feasibility Assessment.*[74]

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 in most instances from the new pipeline projects funded by the Australian Government through the Murray Futures program, it is possible to consider operating the Lower Lakes at more variable levels for enhanced environmental outcomes.

The benefits of managing the Lakes at variable levels include:

- Increased and greater diversity of aquatic vegetation in the Lower Lakes
- Wetlands fringing the Lower Lakes that can cope with greater variability in future water availability
- Reduced system water requirements through reduced evaporative losses.

However, Lower Lakes water level management must be considered within the wider context of water level management downstream of Lock 1. As the River Murray and Lower Lakes from Lock 1 to Blanchetown downstream to the barrages comprise one weir pool, it follows that when Lake levels are lowered, levels in the River Murray channel recede. Experience has shown that when Lake levels are too low, upstream effects may include the partial drying of wetlands, and, at very low levels, the stranding (or partial stranding) of irrigation infrastructure.

Work is underway to identify the site's ecosystem water requirements. This work builds on the operational principles and guidelines developed for the Living Murray Icon Site Program and will ascertain the best minimum and maximum water level management 'envelopes' for the Lakes from an environmental perspective.

These issues are yet to be fully explored, with implementation only possible when lake and water flows return to suitable levels.

In a snapshot

Location of activity: entire system.

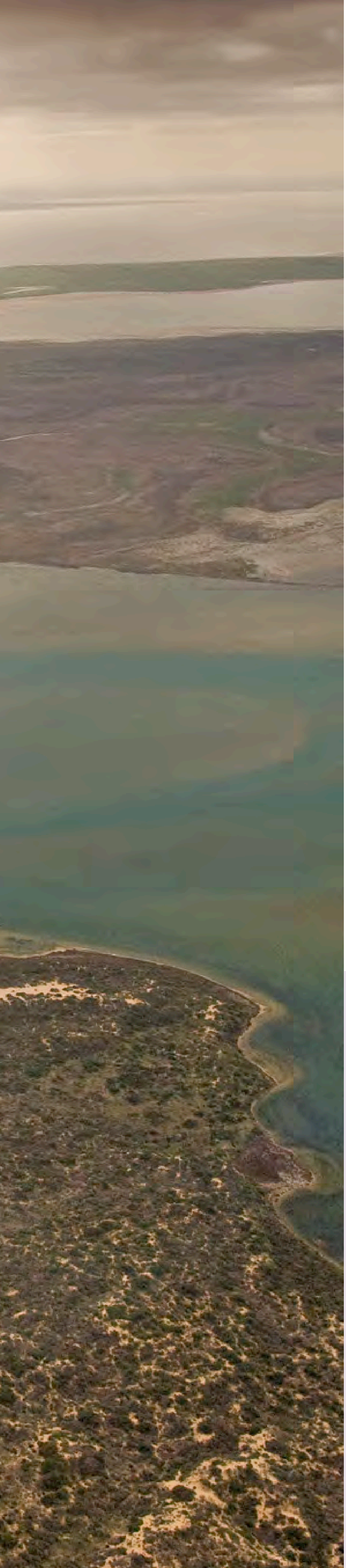
Activity addresses: ecosystem degradation resulting from uniform water levels.

For more information see: *Managing Water Levels in the Lakes to Improve Ecological Health Technical Feasibility Assessment.*[4]

10.5 Enabling measures

Enabling actions are those taken to support mitigation and adaptation actions. Without these enabling actions, other measures would not be possible. They include:

- Implementing an adaptive management regime (Section 11)
- Ensuring appropriate governance arrangements involving the community, and continuing to develop partnerships with the Ngarrindjeri (Section 12).



PROPOSED ACTIONS

Managing the site as one complex, interconnected ecosystem

Effective management of the CLLMM site begins with an understanding that the ecological components of the site are interconnected. None can be managed in isolation. Therefore, while any particular management action may appear to target only one area of the site, the action must 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[75] have been developed for each of the water bodies. These diagrams depict how a particular management action may affect an ecosystem (see Appendix 5 for an example). Such models form the basis for the appropriate application of adaptive management.

Managing the site as one complex, interconnected ecosystem

- *How to deal with uncertainty*
- *Reviewing the appropriateness of our management response*
- *Adjusting our management response to changing climatic conditions*
- *Applying adaptive management in the CLLMM region*
- *What can be expected in the next five years?*

11.1 How to deal with uncertainty

The size and complexity of the site and the natural seasonal fluctuations that it faces mean 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 the site must contain a mechanism for dealing with a high degree of uncertainty about the future and ways to improve the understanding of the effect of any management decisions, and have the flexibility for change 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.[76] Learning is then fully incorporated into decision-making and management decisions are improved over time.

Adaptive management is not a trial-and-error approach. Instead, monitoring is 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 improves the understanding of how the system operates and changes over time.

There are six steps in the adaptive management process:

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 11 shows how the steps use knowledge gained during implementation to improve site management and focus research on the priority knowledge gaps.

By applying the adaptive management framework presented in **Figure 11**, positive ecological, cultural, social and economic outcomes can be achieved – despite the complexity of the CLLMM site and anticipated challenges.

For the CLLMM site, learning will occur through 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.

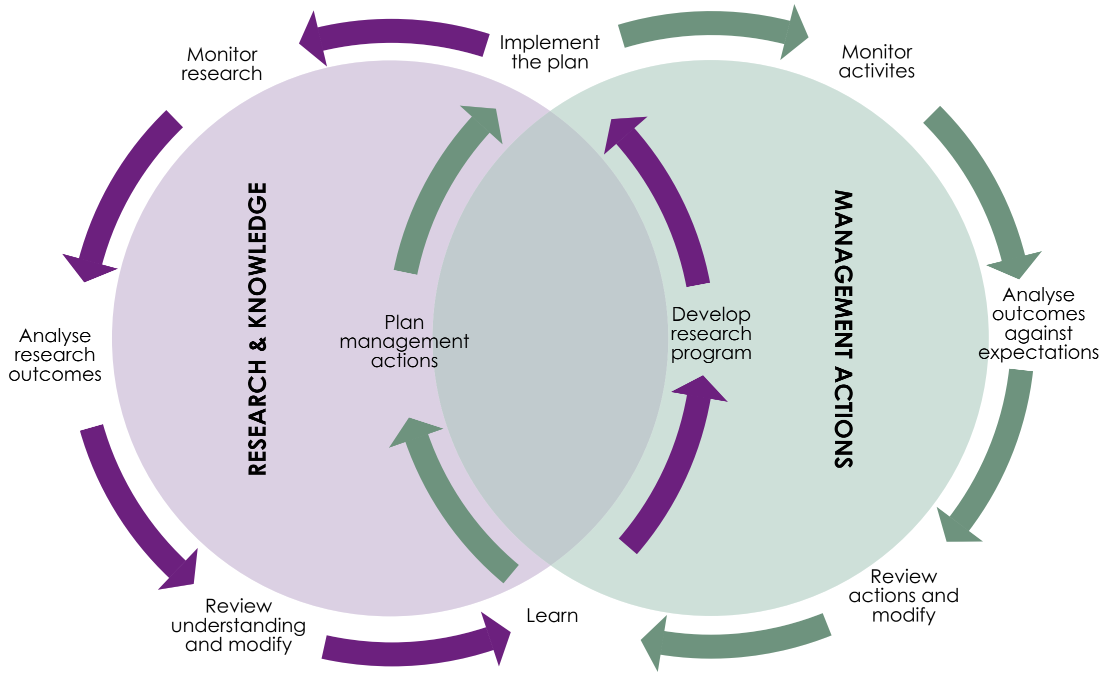


Figure 11. The six steps involved in the adaptive management process and how they are integrated with the research and knowledge, and management sectors.

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 that 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:

- Management goals for the site
- Strategies for achieving these goals
- 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 the management response to changing climatic conditions

The priority management actions for 2010-2014 were chosen (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 scenario, 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 including the proposed start and end triggers directly associated with ecological site conditions.

How long the 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, if river inflows improve at some future time, it will be possible to scale back some of the acid sulfate soil treatment measures (as the acidification risk will have reduced). Equally, with improved water levels, it will be possible to scale back some of the vegetation plantings as there will be fewer 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 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.

By defining when each measure should be undertaken and when it should cease, including any measures upon which it depends, 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. Three specific elements of the framework are also under development:

- A monitoring and evaluation plan linking condition monitoring and management.
- A research plan outlining the key areas for targeted research. Documentation standards will be based on the International Organization for Standardization framework for environmental management (ISO: 14000) to enable standardisation of recording 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 site governance (Section 12) to ensure that decisions are based on the best available technical and scientific advice.

An example of adaptive management in the CLLMM 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 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 2009-10

In the past three years we have seen unprecedented lows in water inflow to the Lower Lakes. Lake Alexandrina has dropped steadily each summer reaching approximately -1.0 metre AHD in 2009 and again in 2010. In mid 2009, lake levels of -1.0 metre AHD were predicted to be a worst case scenario. Winter 2009 had *better than worst case* direct rainfall, and *better than worst case* inflows from the River Murray were received over the summer months due to the provision of additional water.

The first priority for the extra water was to prevent high risk soils from drying out and acidifying. The greatest risk was identified in Lake Albert with its central core of clayey soils. The pumping of extra water into Lake Albert commenced in early 2010.

At least 150-200 km² of soils were exposed to air over summer. Most of these generated acidity in the soils, but had a limited impact only on the alkalinity levels in the lake bodies. There was wind-blown sand from these exposed areas, however wide-scale plantings on exposed soil conducted in 2009 assisted in stabilising these soils throughout the summer.

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 Lower 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, encouraging 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 temporary flow 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.

Fish kills are predicted in Lake Albert as the lake's salinity rises due to evaporation. Other contributing factors to a possible fish kill include low dissolved oxygen levels, blue-green algae and poor water quality.

11.5.3 Winter 2010 onwards

The extent of inflows from the Murray-Darling Basin will determine how conditions develop in the latter part of 2010 and during 2011. If inflows are sufficient to hold the lakes at levels no lower than those for summer 2009-2010 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.

However, if low inflows lead to further lowering in lake levels, the scientific investigations currently underway will be particularly relevant. These will provide valuable information on 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 that 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 for the life forms in the lake and for the nature of its eventual recovery.

In the event no other suitable option can be identified there may be no choice but to dry the lakes 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 approach will be to try and 'buy another winter' each year with freshwater, and supplement with bioremediation, limestone and other complementary actions as appropriate, depending on local rainfall events and inflows upstream on a year-by-year basis.

Ideally, however, the improved inflows of 2009 will continue in 2010 and gradually restore the site. As this occurs, the various management actions can take effect. Flows through the barrages will start to flush the salt load in the Lower Lakes and refresh the Coorong. Fish can be restored to the site from their ex-situ storages. The pumping of hypersaline water out of the South Lagoon to the sea will have assisted the translocation of tassel to the South Lagoon, and fish and bird life will return to the Coorong.

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


PUBLIC JETTY

PROPOSED ACTIONS

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; Australian, state and local governments; business and community members.

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

The project governance arrangements for the CLLMM site will ensure:

- Accountability for project delivery rests with a single organisation and is clear and transparent
- Strong, relevant and timely communication across the project between the Australian Government (primary funder), the South Australian Government, the Ngarrindjeri, key stakeholders and the community
- Alignment with Australian and South Australian Government objectives and priorities
- Sound and responsible financial management over the life of the project
- Identification and mitigation of risks throughout the life of the project
- Sound scientific and technical information is gathered and used.

Governance

- *Purpose of governance arrangements*
- *Context for governance arrangements*

12.2 Context for governance arrangements

The CLLMM Project forms part of the overall Murray Futures program, for which the Minister is 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 Australian Government officers. In order to meet the requirements of the Commonwealth-State funding deed, the delivery of the Murray Futures program in South Australia will be managed by the Commissioner for Water Security (and Executive Director Murray Futures, in the Office for Water Security).

The nature of the project means there are many links between agencies in all levels of government and their programs, in addition to key community bodies, for advice, endorsement of proposed decisions and 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 Management (NRM) Board.
- The need for adequate supplies of fresh water to sustain it means that the CLLMM site is a key topic 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 Traditional Owners with whom a Kungun Ngarrindjeri Yunnan 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 Coorong and Lakes Alexandrina and Albert Ramsar Management Plan.
- The large scale of the project involves policy and project decisions at many levels – Cabinet, Minister, Chief Executive, Director and project.

There are numerous other bodies (often community-based) with interests 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.

'The Australian Government's interests for CLLMM projects will be managed through the Intergovernmenal Project Board. The Murray Futures Steering Committee has general oversight of all Murray Futures programs.

Arrangements are in place for consultation with Ngarrindjeri through the Kungun Ngarrindjeri Yunnan agreement. A Community Advisory Board will provide community views on the implementation of management actions and their environmental, economic and social impact. In addition, community reference groups will be established when required, and vary in size, membership and character depending on the nature and timeframes associated with their issues or projects.

The key elements of the proposed governance structure are depicted in **Figure 12**. The governance arrangements can be classified into four components that encompass different roles and responsibilities as follows:

1. Strategic governance (SA Minister)
2. Decision-makers (Murray Futures, CLLMM Intergovernmental Project Board)
3. Options analysis and recommendations (CLLMM Intergovernmental Working Group, CLLMM Project Steering Committee)
4. Advisors and collaborators (Kungun Ngarrindjeri Yunnan Agreement, Water Security Council and Technical Group, Community Advisory Board).

Governance of the project and adaptive management will be strongly integrated. Governance will include strong links between the Australian and SA Governments to: monitor the overall progress of management actions that have been agreed for funding; monitor compliance with respective obligations between the Australian Government and the state; provide a forum for independent review of issues as they arise; and consider matters referred to it by proponents of management actions. Strong links will also be fostered between governance and the CLLMM Project teams who will undertake day-to-day management of the project, provide research, monitoring and reporting against management objectives, as well as undertake policy development and planning.

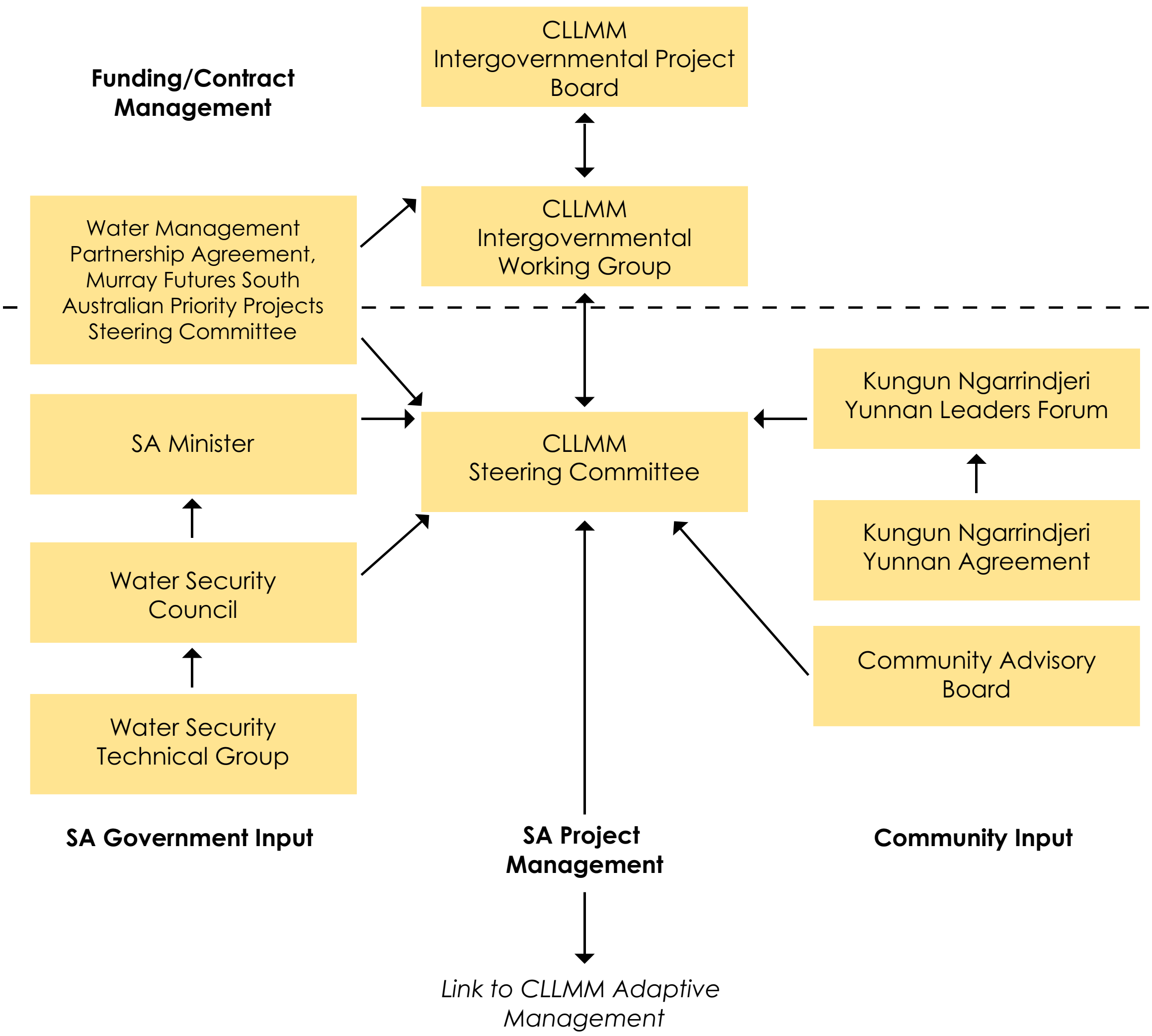


Figure 12. Proposed governance arrangements.

APPENDIX 1

Legislative and policy context

A range of international agreements and Commonwealth and state legislation and policies govern the management of the CLLMM site. An overview of these is presented in **Table 7**. A discussion of some of the most important of these follows.

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.* [77]

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.

Australia's commitment under Article 3.1 of the Ramsar Convention as a Contracting Party is to 'formulate and implement their planning so as to promote the conservation of the wetlands included in the List, and as far as possible the wise use of wetlands in their territory'. [78]

Three agreements on migratory birds 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'.[79]
- The China-Australia Migratory Bird Agreement states that each government will 'take appropriate measures to preserve and enhance the environment of migratory birds.'[80]
- 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.'[81]

International agreements	Ramsar 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, policies and programs	*Environment Protection and Biodiversity Conservation Act 1999* *Water Act 2007* *Native Title Act 1993* *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* Water for the Future (2008) National Water Quality Management Strategy
Multi-jurisdictional strategies and plans	Intergovernmental Agreement on Murray-Darling Basin Reform (2008) Water Management Partnership Agreement (2009) The Living Murray (2002) The Lower Lakes, Coorong, and Murray Mouth Icon Site Environmental Management Plan (2006-2007) The Murray-Darling Basin Plan Commonwealth Wetlands Policy (1997) 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) Act 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) Coorong National Park Management Plan (1990) Management Plan for the South Australian Lakes and Coorong Fishery (2005)

Table 7. International agreements and Commonwealth and state legislation governing the management of the CLLMM site.

Commonwealth legislation, policies and programs

The EPBC Act provides a legal framework for protecting the environment, in particular matters of National Environmental Significance, including Ramsar wetlands, listed migratory and threatened species, listed threatened communities and heritage sites. It outlines requirements for approval of activities that might have a significant impact on Ramsar wetlands, mechanisms for declaring and designating Ramsar wetlands, management planning obligations and principles, and allows for funding and other assistance to be provided by the Commonwealth for the protection and conservation of Ramsar sites.

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
- Rules about trading water rights in relation to Basin water resources.

The Basin Plan must give effect to relevant international agreements under the *Water Act 2007*. 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 agreements between New South Wales, South Australia and Victoria.

The Australian Government's Water for the Future strategy 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 10-year, $5.8 billion Sustainable Rural Water Use and Infrastructure program. State-priority Murray Futures projects will be funded from the program. South Australia will receive up to $610 million for 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 support an enduring response to the environmental problems facing the CLLMM site. This includes a $10 million feasibility study of the long-term options for the management of the site, which has produced this document. In addition, up to $120 million is being provided by the Australian Government for the Lower Lakes Integrated Pipeline Project.

The Australian Government 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 strategies and plans

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 by 30 June 2009 500 GL of water, 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 site 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.

The National Water Quality Management Strategy (NWQMS) is a national approach to improving water quality in Australia and New Zealand. The NWQMS is endorsed by the Environment Protection and Heritage Ministerial Council, the Natural Resource Management Ministerial Council and the National Health and Medical Research Council. The NWQMS aims to protect and enhance the nation's water resources by improving water quality and reducing pollution while supporting the businesses, industry, environment, and communities that depend on water for their continued development.

Closing the Gap is a strategy that aims to reduce indigenous disadvantage with respect to life expectancy, child mortality, access to early childhood education, educational achievement and employment outcomes.

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 to carry out any work (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)

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.

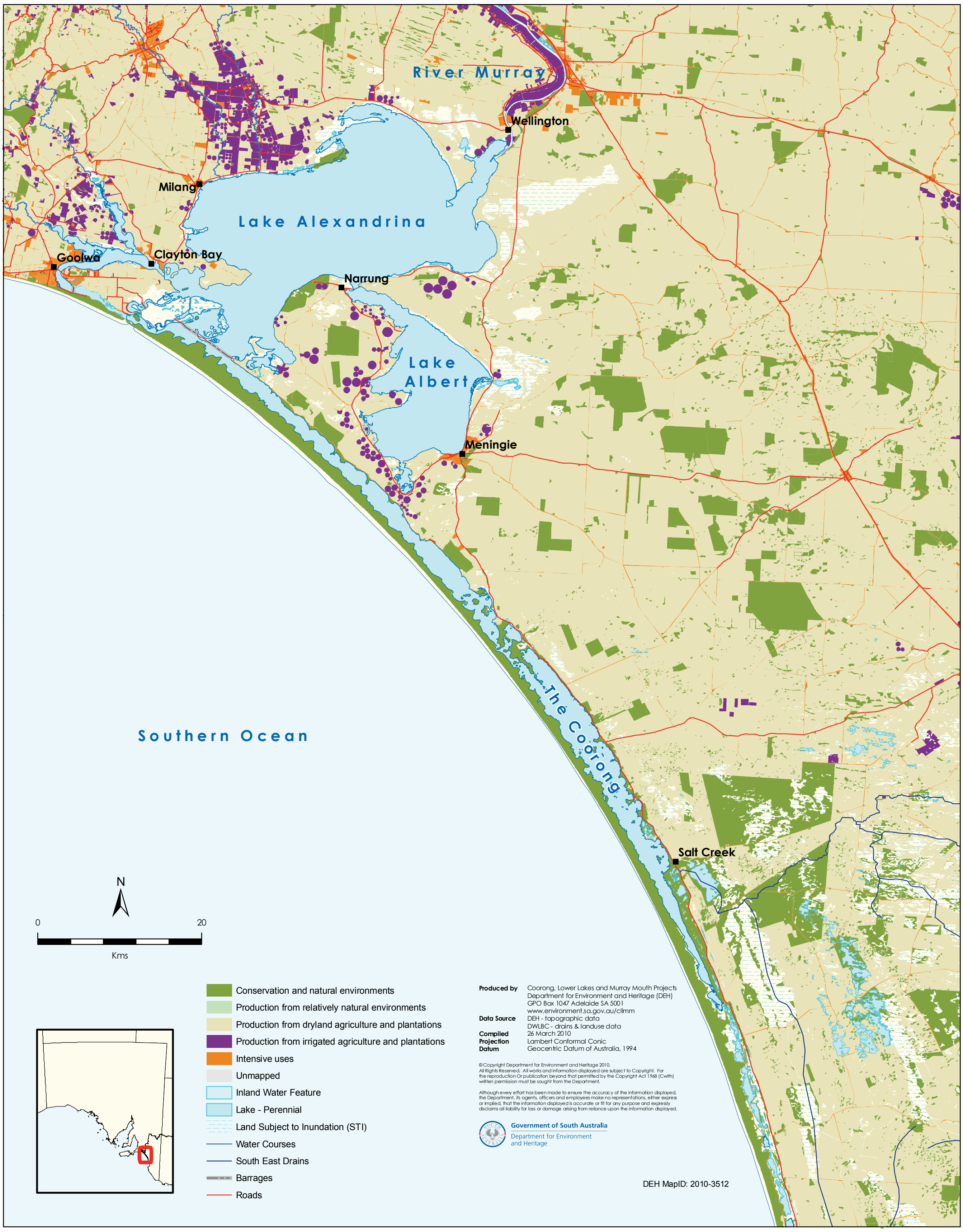
The 10-year integrated package aims to ensure that South Australia will respond proactively to climate change by adopting flexible, adaptive environmental management practices that foster long-term community, industry and environmental outcomes. It aims to maximise the use of existing environmental water and target water to key priority sites, while 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 through Water for the Future, 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 CLLMM region
- 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 2. Map showing land use in the CLLMM region before the current conditions.

APPENDIX 3

Indicative ecological response to declining water levels and quality

Lake level (metres AHD)	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 (fish ways allow flows and fish passage through at lower water levels) 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 impacted dredging required to maintain an open mouth. Murray 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	
-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	
-0.6	863	66 106	645		

(continued)

Lake level (metres AHD)	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
-0.7	797	64 278	627	4 500	Acidification of Lake Albert is predicted to occur at this level (-0.75 m AHD) 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.
-0.8	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	
-1.6	318	40 347	395	8 000	
-1.7	278	38 598	377	8 300	Acidification of Lake Alexandrina is predicted to occur at this level (-1.75 m AHD) and lower Therefore: all biota in Lake Alexandrina and tributary wetlands (estuarine fish, waterfowl, fish-eating birds) threatened.
-1.8	241	36 996	362	8 700	
-1.9	205	3 4830	341	8 900	
-2	171	32 676	320		
-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 recommended

The South Australian Government appreciates the many submissions and proposals received during the development of this plan. Some options were suggested by several contributors. However, not all have been included as recommended actions. This section provides a preliminary response as to why those proposals are not supported.

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. Calculated costs of these proposals demonstrate that moving large volumes of water long distances rapidly becomes very expensive. Depending on the source, the cost of water brought from northern Australia would range between $6 and $9 per kilolitre.[82] 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 CLLMM are of different orders of magnitude. The desalination plant being constructed at Port Stanvac for Adelaide's water supply will produce 100 GL per year. This is very significant in terms of urban water security (200 GL a year) and is affordable for that purpose. But it is not a significant amount of water in relation to the needs of the CLLMM region. While it is much cheaper than bringing water from northern Australia, it would still cost about $1 billion a year just to cover 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 River 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 before 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 without 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 would become hypersaline within two years.[42] Without adequate freshwater flows, letting seawater enter Lake Alexandrina will lead to an increasingly degraded hypersaline ecosystem, not a healthy estuarine or marine system.

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

These are components of urban water security, as described in the Water for Good plan. However, the quantities of water available through these methods 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 conduct 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 filling the Coorong with sand, while the rate of closure of the current Murray Mouth will accelerate.

Modeling has shown that the current dredging program that has been in place since 2002 is by far the most effective means of keeping the Coorong and estuary connected to the sea until end-of-system flows improve.[83] 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 refresh Lake Albert, but result in hypersaline conditions.

River Mouth training walls

River Mouth training walls were considered to prevent sand from being transported into the Murray Mouth and also to provide shelter to the inner parts of the entrance from wave action, creating a permanently open Murray Mouth. Due to the way that sand is transported in and around the Murray Mouth, it is expected that sand would still build up within the Murray Mouth during times of low river flows. Therefore dredging would still need to occur in the Murray Mouth and the inner mouth areas.

Assessments of the different options for maintaining an open Murray Mouth were made based on effectiveness, contribution to ecosystem health and cost. Dredging without construction of permanent training walls was considered a better option.

APPENDIX 5

Ecosystem process diagram for the CLLMM site

As shown in **Figure 13**, 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. 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) represent an alteration from the current degraded ecological character that 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 remain 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,[84] 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.

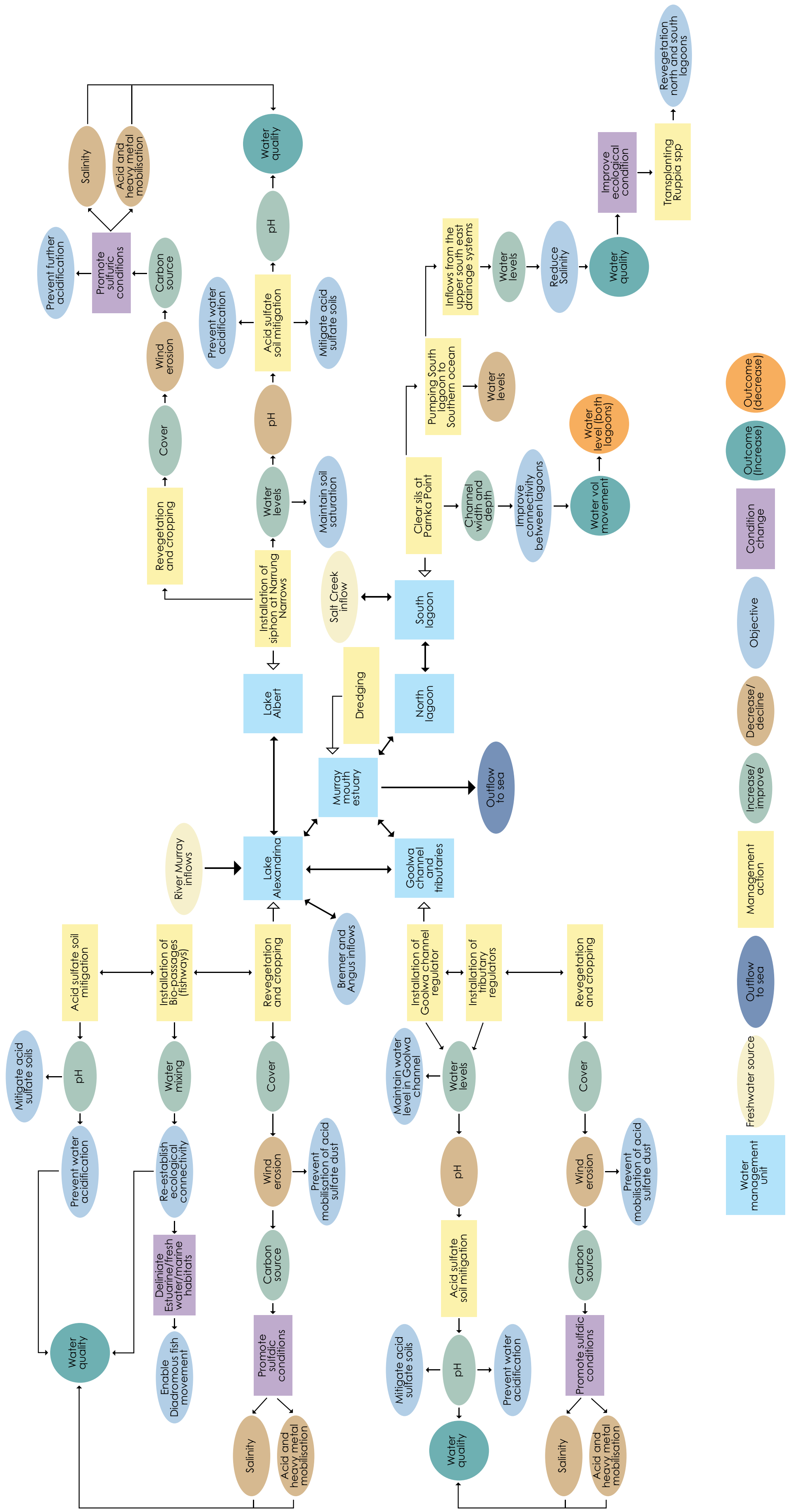


Figure 13. Ecosystem process diagram for the Coorong, Lower Lakes and Murray Mouth (current as at September 2009).

APPENDIX 6

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 reduced bird numbers in the South Lagoon.

Conceptual models of the ecology of the South Lagoon, and the species associated with the ecology, indicate that by reducing salinity and maintaining appropriate water levels, adaptive management of the South Lagoon should result in improved water quality. This would allow the recolonisation of tassel from the North Lagoon. This in turn would facilitate the future recovery of historical aquatic habitat by recolonisation of other food species.

Historically the maximum salinity in the South Lagoon was approximately 160,000 EC, but summer salinity in the South Lagoon is now higher than 280,000 EC and has at times exceeded 310,000 EC. Such high salinities place the South Lagoon beyond 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 is principally caused by reduced freshwater inflows, resulting in the loss of tuberous tassel as a food source for waterbirds, including 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.

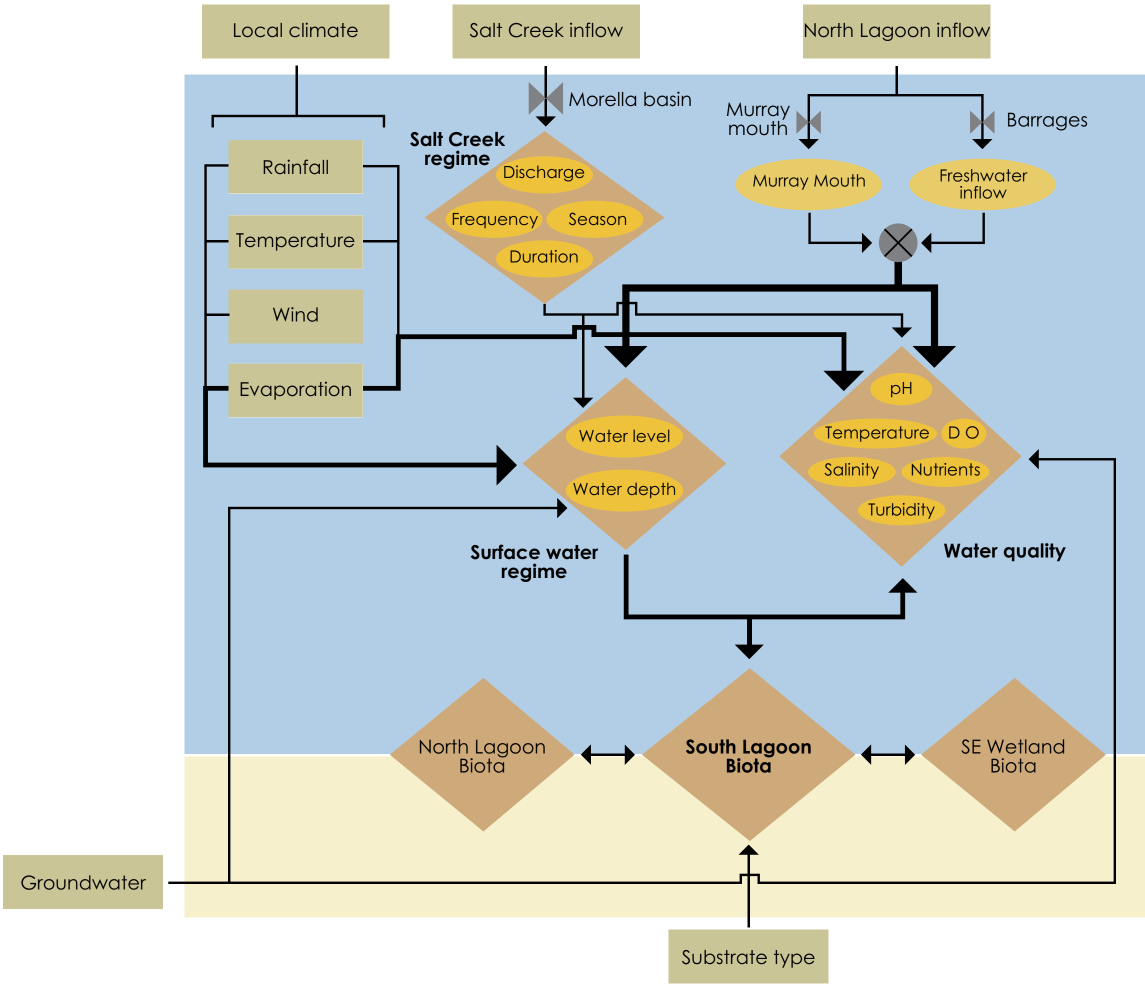


Figure 14. Conceptual model of the South Lagoon.[84]

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
- 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.

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
- 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.

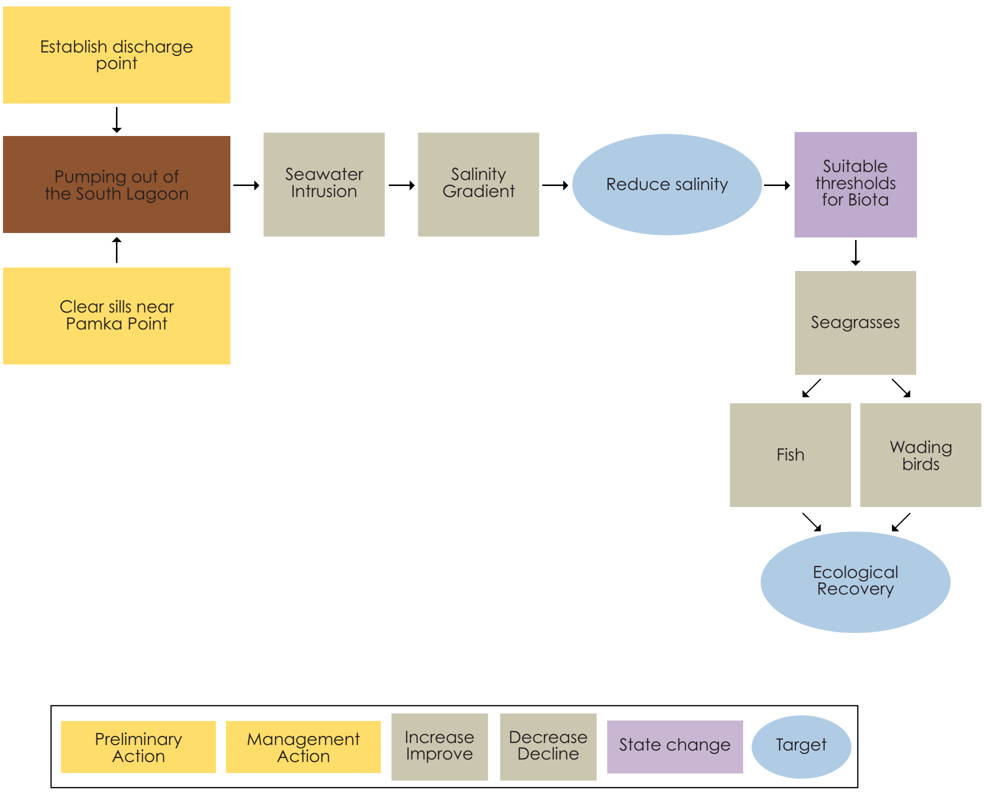


Figure 15. Process chain for pumping hypersaline water from the South Lagoon.

Develop implementation plan

The implementation plan outlines the logistics, necessary approvals, risk assessment and management responses. The plan also 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 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 shown in the following table.

Water Quality Targets	Ecological Targets
Maximum salinity of 160,000 EC for summer and 90,000 EC 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 birds occupy 80 per cent of available habitat 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 take at least 18 months to achieve the target salinities. Interim targets or trigger points are expected at the times shown.

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, and to gauge if the action is having 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. 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 will be required to determine if pumping is required in the future to keep salinity near target levels. This would require the setting of a trigger salinity level for re-starting pumping.

Specify triggers and limits of acceptable change

The tolerances of key species are:

- Tuberous tassel tolerates approximately 160,000 EC, plus needs adequate water levels, which are dropping
- Chironomids tolerate up to approximately 190,000 EC
- Small-mouthed hardyhead fish tolerate up to approximately 190,000 EC.

These salinity tolerances establish important benchmarks for management action to ensure the restoration of ecological character in this part of the CLLMM site.

Step 2: Implement the plan

Implementing the plan involves undertaking the action in the manner and timeframe specified in 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. The findings will be entered into a decision support system; a computer system that will help guide decisions in managing the site. 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 the expected timeframe (early or late), an investigation will be initiated to determine the reasons. If required, models used for water quality will be altered to reflect the changes.

Following achievement of the desired water quality objectives and ecological outcomes, the success of each action or decision will be evaluated. Questions 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 timeframe
- *Cease action*: if the targets for salinity and water levels have been achieved within an expected timeframe
- *Review causes:* if water quality is not within the range of expected results.

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

- Proceed with the action if the issues can be resolved. Models and targets will be reviewed and updated, and timelines will be extended
- Suspend the action until uncertainty or identified issues are addressed
- 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, so that knowledge gained from past actions improves future decision-making.

APPENDIX 7

Implementation schedule

			2010			
Location	Program	Activity	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 300 GL of hypersaline water from the South Lagoon	•	•	•	•
		Dredging of sills at Parnka Point				
	Vegetation	Revegetation – tubestock		•		
		Weed control		•		•
		Vermin control		•		•
	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	•	•	•	•

2011				2012				2013				2014			
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
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
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Location	Program	Activity	2010 Jan – Mar	2010 Apr – Jun	2010 Jul – Sept	2010 Oct – Dec
Lake Albert	Managing acid sulfate soils	Construction of artificial wetland		•	•	
		Limestone dosing		•	•	
		Installation of sub-surface barriers in the lakebed	•			•
	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 temporary flow regulators: Clayton and across Currency Creek	•	•	•	•
		Limestone dosing		•	•	
	Vegetation	Revegetation – tubestock		•		
		Revegetation – aerial seeding		•	•	
		Weed control	•			•
		Vermin control	•			•
		Fencing		•	•	•
	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	•	•	•	•

2011				2012				2013				2014			
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
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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 300 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 lakebed	✓	↑	X	X
	Studies on impacts of seawater	✓	↓	X	X
	Construction of artificial wetland	✓	✓	↓	X
Vegetation	Revegetation – tubestock on lake edge	✓	↑	↑	↑
	Revegetation – aerial seeding of exposed lakebed	✓	✓	✓	↓
	Cropping to stabilise soils	✓	✓	↓	X
	Weed control	✓	↑	↑	↑
	Vermin control	✓	✓	↑	↑
	Fencing	✓	✓	↓	X
Fishways	Construct/install fishways	✓	✓	↓	X
Protecting critical environmental assets	Conservation of threatened species	✓	✓	↑	↑

(continued)

Program	Activity	Climate Scenario			
		Extreme Dry	Dry	Median	Wet
	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

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*
Dune fanflower	*Scaevola calendulacea*
Dwarf grass-wrack	*Zostera muelleri var.*
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*
Eastern curlew	*Numenius madagascariensis*
Eastern gambusia	*Gambusia holbrooki*
Estuary perch	*Macquaria colonorum*
Fairy tern	*Sternula nereis*
Freshwater eel-tailed catfish	*Tandanus tandanus*
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*

Common name	Scientific name
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*
Redfin perch	*Perca fluviatilis*
Red-necked avocet	*Recurvirostra novaehollandiae*
Ribbon weed	*Vallisneria americana*
River blackfish	*Gadopsis mormoratus*
Rushes	*Juncus spp.*
Sandhill greenhood	*Pterostylis arenicola*
Scarlet grevillea	*Grevillea treueriana*
Sea heath	*Frankenia pauciflora*
Sharp-tailed sandpiper	*Calidris acuminata*
Short-finned eel	*Anguilla australis*
Short-headed lamprey	*Mordacia mordax*
Shrubby glasswort	*Tecticornia arbuscula*
Silver daisy-bush	*Olearia pannosa*
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*
Yellow swainson-pea	*Swainsona pyrophila*
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 have been exposed to oxygen (e.g. exposed to air through lowering of water levels) and produce sulfuric acid (the same acid as in a car battery).
Adaptation measures	Measures that allow the site to function under stable but altered conditions. The purpose of adaptation measures is to develop long-term sustainable solutions for the site.
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).
Anadromous	Living primarily at sea but migrating up rivers to spawn.
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 between the mainland and Hindmarsh, Mundoo, Ewe and Tauwitchere Islands. Work on the barrages began in 1935 and was completed in 1940.
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.
Benthic	The deepest part of a water body (e.g. the bottom of a lake).
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 (e.g. living organisms, such as plants, capturing and storing carbon, removing it from the atmosphere).
Biota	All living organisms of a region.
Calcareous	A sediment, sedimentary rock, or soil type which contains a high proportion of calcium carbonate.
Catadromous species	Fish species that spawn at sea but use freshwater environments during their juvenile and sub-adult life stages.
Colloidal	Very fine particles evenly dispersed in a substance (e.g. water) so they are not easily filtered or readily settle out of the substance.
Commonwealth Environmental Water Holder	Commonwealth Environmental Water Holder was established by the *Water Act 2007* to manage water entitlements acquired by the Commonwealth through water entitlement purchasing and water savings through investment in improved infrastructure.
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 studies and 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, including in the Lower Lakes and Coorong.
Dredging (Murray Mouth)	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 – microsiemens 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. Drinking water should be under approximately 1,000 EC units and seawater is approximately 60,000 EC units.
Ecological character	The combination of the ecosystem components, processes, and benefits and services that characterise the wetland at a given point in time. Within this context, ecosystem benefits are defined in accordance with the variety of benefits to people (ecosystem services).
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 EPBC Act 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 to people. They include provisioning services such as water for irrigation and drinking supply; regulating services such as water purification and climate regulation; cultural services such as tourism and recreation; and supporting services such as nutrient cycling and providing habitat. These services will generally have an indirect benefit to humans or a direct benefit in the long-term.
Emergent vegetation	Protruding from the water (e.g. 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 EPBCAct.
Environmental Impact Statement (EIS)	Outlines the potential impacts on matters of National Environmental Significance (including threatened species, Ramsar wetlands and national heritage sites) defined under EPBC Act.
Ephemeral (water course)	A watercourse or body (such as a river or lake) 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 such as wind and water movement; 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.
Eutrophication	Process by which an increase in the concentration of chemical nutrients in a water body result in negative environmental impacts including rapid growth of algae and cyanobacteria and the depletion of oxygen.
Evaporative losses	The amount of water that is lost to the atmosphere via evaporation.
Ex-situ	Not in its original location e.g. ex-situ conservation measures include captive breeding programs at a different site from an animal's natural habitat.
Fauna	Animal species, especially the animals of a particular region or period, considered as a group.
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	Plant species, especially the plants of a particular region or period, considered as a group.
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 sized 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 (including Finniss River and Currency Creek). The project has seen the construction of two temporary flow regulators – one in the Goolwa Channel and one in Currency Creek. Construction of a third temporary flow regulator for Finniss River has been put on hold.
Groundwater	Water that is below the 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.
Hydraulic head	Water level gradient. Water flows in a direction of high to low hydraulic head.
Heavy metals	A very dense metal such as lead, cadmium or mercury or metalloid (a non-metal that behaves like a metal) such as arsenic. Because they cannot be degraded or destroyed, heavy metals are persistent in all parts of the environment.
Hydrodynamic	Relating to forces in, or motions of water.
Hydrology	The science dealing with surface waters and ground waters; 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 agricultural 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/or limestone slurry (dry limestone mixed with water) to the lakebed and water to keep the water's pH high enough to neutralise acid released from the exposed acid sulfate soils in the region.
The Living Murray	Initiative 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 35 GL).
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 (animals without a backbone such as insects) visible to the naked eye.
Migratory species	Migratory species are those animals that travel to different regions each year. A number of migratory species travel to and within Australia and its external territories, or pass though or over Australian waters during their annual migrations. Examples of migratory species are birds (e.g. albatrosses and petrels), mammals (e.g. whales) and reptiles (e.g. leatherback turtles). Migratory species listed in the EPBC Act also include any native species identified in an international agreement approved by the Minister.
(The) Minister	Minister for Environment and Conservation, the River Murray, and Water.
Mitigation measures	Measures designed to reduce impacts resulting from continued low or non-existent end-of-system flows. They are implemented to prevent continued ecological degradation until conditions improve. Some are of a temporary nature to deal with immediate challenges and not suitable for long-term application.
Mono-sulfidic black ooze	Gelatinous soil that consists of iron sulfide; formed under anoxic and often increased saline conditions; once disturbed can rapidly remove oxygen from overlying waters and react with the oxygen to form sulfuric acid.

Murray Futures	Funded by the Australian Government's 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 to the ocean.
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	A chemical reaction where a substance combines with oxygen (e.g. iron reacts with oxygen to form rust and sulfidic soils react with oxygen to form sulfuric acid).
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.
Primary Determinants	Ecosystem components central to maintaining ecological character.
Pyritic	Relating to the common mineral pyrites (iron disulfide).
Ramsar	The Convention on Wetlands of International Importance Especially for Waterbird Habitat, commonly known as the Ramsar Convention, was initially adopted in Ramsar, Iran, in 1971. Australia is a signatory and currently has 65 Wetlands of International Importance, commonly known as Ramsar wetlands. The Coorong, Lakes Alexandrina and Albert, was designated a Wetland of International Importance in 1985.

Ramsar Management Plan	The Environment Protection and Biodiversity Conservation Regulations 2000 require that at least one management plan be prepared for each Australian declared Ramsar wetland, which outlines the principles for managing the site in accordance with the regulations.
Red List	The International Union for Conservation of Nature Red List aims to identify and document those species most in need of conservation attention to reduce global extinction rates and to provide a global index of the state of change of biodiversity.
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 Murray Environmental Manager	The primary decision maker on environmental water within South Australia. They have a key advocacy role in Murray-Darling Basin forums and coordinate all environmental watering activities within the South Australian River Murray, including the delivery, allocation and management of environmental water and Living Murray Icon Site management. They also facilitate environmental water donations and encourage community involvement in flow management.
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.
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 sub-surface 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 soils that contain sulfur in the absence of oxygen. They 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 they can become acidic (pH <4) through the oxidation of sulfides to form sulfuric acid. Sulfidic soils that oxidise to form sulfuric acid 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 junction of Lake Alexandrina and Tookayerta Creek, Currency Creek 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.
Terrestrial	Relating to living or growing on land (as distinct from aquatic).
Threatened species	Any species that is likely to become endangered 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 EPBC Act lists threatened native species in the following categories: extinct; extinct in the wild; critically endangered; endangered; vulnerable; conservation dependent.
Threatened ecological communities	The EPBC Act lists threatened ecological communities as: critically endangered; endangered; or vulnerable (also see 'ecological community').
Tributary	A stream or other body of water (surface or underground) that 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).

Turion	A young, scaly shoot budded off from underground stems or a detachable winter bud used for overwintering in many aquatic plants.
Vulnerable species	A threatened species. Native vulnerable species are listed in the EPBC Act. They are not critically endangered or endangered but face 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.

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