Government of South Australia

Australian Government

MURRAY**FUTURES**

Lower Lakes & Coorong Recovery

The Coorong, Lower Lakes and Murray Mouth

Directions for a healthy future

May 2009

Securing tomorrow's water today

Have your say

This document outlines a possible direction for the future management of the Coorong, Lower Lakes and Murray Mouth. It was released in May 2009 following the collation and analysis of relevant information from policy documents, historic and scientific research and preliminary consultation with a number of local stakeholders. The development of a long term management plan will be developed in three stages over the course of this year. The final plan will be completed in October. Community input is vital to ensure that the best possible plan is developed. Community members are now being invited to participate in the process.

While we have done our best to include existing information and the latest scientific research, we are keen to receive any information that improves our knowledge or corrects our understanding of the issues. The authors are aware that this document does not yet provide all of the necessary detail upon which management decisions can be made. This detail will be progressively incorporated following extensive community consultation, discussions with local government, discussion across South Australian Government agencies and with Australian Government departments. Furthermore, necessary technical investigations will be undertaken, the findings of which will be progressively incorporated into a revised version of this document.

A number of community events will be held throughout the region in May 2009, where people can contribute to possible solutions for the Coorong, Lower Lakes and Murray Mouth.

We would like any interested person or organisation to provide comment about any aspect of this document.

How to contact us

You can send us your comments and suggestions in a number of ways. Written feedback is preferred, either online or in the post. However, if you prefer to speak to one of the planning team, you can do so either at community information sessions planned for May, or call our free call number during normal business hours.

Email: cllmm@deh.sa.gov.au
Phone: 1800 226 709 (free call during normal business hours)

What are the next steps?

Community feedback and the latest scientific developments will help build a preliminary long term plan, which the public will be invited to comment on in July 2009.

The final version of the long-term plan for the region will be completed in October 2009, based on further community feedback, science, research and modelling. It will include details on how each of the environmental issues affecting the region will be addressed.

Further information

Murray Futures

www.murrayfutures.sa.gov.au

Department for Environment and Heritage
Coorong, Lower Lakes and Murray Mouth Projects

www.environment.sa.gov.au/cllmm

This project is part of the South Australian Government's $610 million *Murray Futures* program supported by funding from the Australian Government under the *Water for the Future* program.

Contents

1. Summary

Situated at the end of the Murray-Darling Basin System, the Coorong, Lower Lakes and Murray Mouth (CLLMM) are recognised internationally[1] as one of Australia's most significant wetlands.

The Murray-Darling Basin is experiencing the worst drought since records began in 1891. Because the Coorong, Lower Lakes and Murray Mouth rely on flows from upstream in the Murray-Darling system, they are directly affected by the quality and quantity of water that is delivered.

Years of basin over-allocation, and the current severe drought have led to significant impacts upon the Coorong, Lower Lakes and Murray Mouth. Due to the barrages holding back seawater, water levels in the Lakes have dropped to unprecedented lows – to more than 1 metre below sea level in Lake Alexandrina in April 2009. As the water levels have fallen, serious land and water management issues have progressively emerged with the drying of wetlands, exposure of previously submerged sulfidic soils, and the disconnection of different elements of the system. There have been insufficient freshwater flows through the barrages and as a result the water quality of the system has declined markedly.

As water levels have not previously, in recorded history, fallen to such extremely low levels, there is no precedent for dealing with environmental impacts on this scale. Unlike natural disasters, where a step by step plan can be prepared to recover from specific events, planning for this unfolding situation will by necessity be reactive.

The outlook under changing climatic conditions will see changes in freshwater availability and sea level rise. However, the precise timing and impacts are uncertain.

Many of the local enterprises and communities in the region rely heavily on a healthy environment to prosper.

Our goal is to secure a future for the Coorong, Lower Lakes and Murray Mouth as a healthy, productive and resilient wetland system that maintains its international importance. Achieving this will also support the local economy and communities.

Over the next 20 years, the long-term plan for the region will work towards keeping freshwater in the Coorong, Lower Lakes and Murray Mouth system.

However, given the likely constraints of reduced inflows to the Murray Darling Basin and sea level rise we cannot adopt a 'business as usual' approach.

To enable us to adapt to changing conditions ongoing monitoring, research and planning must be important components of our management response.

As future rainfall and impacts of sea level rise are uncertain, plans to manage the Coorong, Lower Lakes and Murray Mouth must be able to adapt to an environment in which there will be greater variability in salinity and availability of freshwater due to changing climatic conditions. Our approach to monitoring and management must be sufficiently responsive to each climatic circumstance over time. Six core elements must be put in place to ensure a healthy future. These are:

i. A responsive management approach based on robust research, adequate monitoring and extensive community involvement
ii. Engagement of the traditional owners – the Ngarrindjeri
iii. Freshwater provided to the lakes
iv. The Murray Mouth open and connecting the Coorong to the sea
v. Accepting variable lake levels yet maintaining system connectivity, and
vi. Managing localised threats and water qualities, especially acidification and hypersalinity.

There are a number of ways to achieve each of these elements. The final version of the long-term plan will present various actions addressing each element, factoring in climatic variables.

Ensuring that all of the core elements are in place will put the region in the best position to adapt to future climates and conserve, to the greatest extent possible, the plants, animals and habitats that make it a wetland of international importance.

1 The Coorong, Lower Lakes and Murray Mouth (CLLMM) was designated a Wetland of International Importance under the Ramsar Convention on Wetlands in 1985.

2. What is at stake?

A wetland of international environmental standing

The Coorong, Lower Lakes and Murray Mouth comprise a system of shallow lakes, lagoons and wetlands at the end of the Murray-Darling Basin system. This is where the River Murray flows into the sea through a narrow gap in the largest continuous coastal dune barrier system in the Southern hemisphere. An overview of the system is provided in Appendix One.

The Coorong, Lower Lakes and Murray Mouth site was designated as a Ramsar Wetland of International Importance in recognition of its diverse range of wetland ecosystems, habitats and bird, fish and plant species (many of which are threatened or endangered). It is regarded as a biodiversity 'hot spot' in southern Australia. The Ramsar criteria are presented in Appendix Two.

Its flora and fauna and their habitats are also protected by the Convention on Migratory Species, bilateral agreements with Japan (the Japan-Australia Migratory Bird Agreement, JAMBA), China (CAMBA), the Republic of Korea (ROKAMBA), and through the East Asian Australasian Flyway Partnership.

A compelling example of the area's ecological significance is that more than 30 per cent of the migratory wading birds that fly to Australia from far off lands such as Siberia, spend summer at the site.

It has regularly supported 77 bird species, mostly water birds, in numbers around 20,000. Waders include stilts, avocets, plovers, lapwings and oystercatchers. The site is home to at least seven endangered or vulnerable plant species, the endangered Orange-Bellied Parrot Species which migrates annually to and from Tasmania, the Southern Bell Frog, and critically endangered swamp communities which are a habitat for the Southern Emu-Wren. The Fairy Tern and Little Tern nest on islands in the Coorong, and pelicans, swans and ibis also nest in the area.

Sixty five different species of fish have been reported, and there are some 49 native fish species, including five species which are nationally listed as threatened species under the *Environment Protection and Biodiversity Act 1999*, and a further 20 species that are protected or have been listed as of conservation concern within South Australia. A futher 20 fish other species use the site at various stages of their life cycle. There are approximately ten species of frogs in the lakes and environs. Reptiles include the Eastern Tiger Snake, the Eastern Brown Snake, and Eastern long necked, Murray short necked and Broad shelled turtles.

The area is also one of six Icon Sites under the Murray-Darling Basin Authority's *Living Murray* initiative, which is Australia's most significant river restoration program and a partnership of the Australian, NSW, Victorian, South Australian and ACT governments. Ecological objectives of this initiative are aimed at restoring or improving the sites' ecosystems, habitats, and species of flora and fauna. More detailed information about the legislative and policy context for the Coorong, Lower Lakes and Murray Mouth is provided in Appendix Three.

The Coorong National Park is also acknowledged as an archaeological and cultural site of national importance, with middens and burial sites throughout the park giving evidence of long term Aboriginal occupation.

The unique ecology within the Coorong and Lakes Alexandrina and Albert has been in a slow and steady decline for some time. The speed of this decline has increased substantially since 2007 when it became evident that ecosystem processes were collapsing with the decreasing water levels within the Lakes. Several important ecological 'hot spots' have now become dry and are showing signs of soil acidification. Several species of native fish are now in captive maintenance programs because their habitats are now dry. Without active management the site will be greatly affected by soil acidification and increasing salt levels within the remaining water. This will lead to an environment which will not be able to support a diverse and healthy wetland system. One of the largest freshwater ecosystems in Australia is at risk of collapse.

A prized local environment

The Coorong, Lower Lakes and Murray Mouth are popular areas for recreational activities such as sightseeing, bird-watching, camping, walking, picnicking, fishing, swimming, boating, canoeing, water skiing and 4-wheel driving. In 2008 the South Australian Tourism Commission estimated the visitation rates to the Coorong National Park to be around 138,000.

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

There are also less tangible values associated with the area's natural beauty.

> 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. (*Icon Site Management Plan*, 2006-2007, p.14)

The region is one of the most popular tourism and recreational locations in South Australia. Local businesses such as cafes, restaurants and accommodation are significant employers in the region and reliant on tourism and recreational activities. These retail and service industries are affected by any downturn in tourism activities. In addition, the flow-on effects from any downturn would impact on employment in a range of industries in the community.

A rich and diverse culture

Cultural and spiritual significance for the Ngarrindjeri people

> At the request of the Ngarrindjeri, this section remains to be developed in consultation with Ngarrindjeri people. The South Australian Government is committed to working with Ngarrindjeri regarding the management of the area and is dedicated to dialogue with Ngarrindjeri about the future of their traditional lands.

A regional community and economy

The major towns associated with the Coorong, Lower Lakes and Murray Mouth region include Goolwa, Clayton, Milang, Langhorne Creek, Wellington, Meningie, Narrung, Raukkan and Salt Creek.

Many regional communities upstream of the Coorong, Lower Lakes and Murray Mouth are also affected by the current conditions and decisions about the future management of the site. The River Murray and Lower Lakes, from Lock 1 at Blanchetown downstream to the barrages, is one weir pool. When Lake levels recede it follows that levels in the River Murray channel recede. When salinity accumulates in the Lakes, it follows that salinity can progressively accumulate upstream in the River Murray channel. Problems that have arisen upstream of the Lower Lakes include the drying of swamps, the slumping of riverbanks and irrigation banks, disruption to the operation of ferries across the river, and the stranding of irrigation infrastructure. There is also the possibility of the stranding of off-take pumps which provide water for Adelaide and many country towns.

The major land uses in the region include conservation of natural environments (for example the Coorong National Park), dryland agriculture, irrigated agriculture and residential uses. The distribution of these land uses across the Coorong, Lower Lakes and Murray Mouth region is presented in Appendix Four.

The Coorong, Lower Lakes and Murray Mouth have a mix of primary industry (predominantly irrigated and dryland agriculture, viticulture and fishing), manufacturing (wine, machinery and equipment) and recreation and tourism activity. They also have a significant urban population, with associated housing and service sectors. It is estimated that nearly 28,000 people live in the broader region to Murray Bridge.

The gross regional product (GRP) of the regional economy was estimated to be around $700 million in 2006-7. Primary industries directly contributed about $145 million to this and directly employed around 2,000 people. Irrigated agriculture employed 1,000 people, contributing over $70 million to the GRP. Drought conditions over the last few years have substantially reduced these numbers.

The restructuring of regional industries which has occurred in recent years can be expected to continue. There will be changes impacting on all industries in the region. Changes have already occurred, with 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 effect this situation has on industry in the region.

3. What are the problems and management challenges?

Issue	Current situation	Management Challenges
Reduced freshwater inflows and levels as a result of drought, over-allocation and a changing climate	Low flows and unprecedented low water levels (below sea level) due to over-allocation upstream, drought and high evaporation rates.	The over-allocation of water resources will take considerable time and cost to resolve. There is limited opportunity to purchase water at the moment. Desalination of water is also extremely costly and would take time to implement.
Acid Sulfate Soils	Low water levels in the lakes and tributaries have uncovered large areas of previously waterlogged soils that, on exposure to air, are acidifying and producing Acid Sulfate Soils. Potential environmental, human and animal health and economic impacts.	Best management approach is to saturate with freshwater (which is clearly difficult under current circumstances). Other management responses are being trialled at this stage.
Salinity	Salinity levels increasing throughout the site, exceeding those suitable for human or livestock consumption, and for irrigation of horticultural crops.	Best management approach is to flush with freshwater (which is clearly difficult under current circumstances). Desalination of water is also extremely costly and would take time to implement.
Biodiversity loss	The combined impact of low flows past Wellington and reduced water quality is impacting upon the ecological character of the site.	Unless the critical water quantity and water quality needs of the site are addressed, it is expected that its ecological character will change dramatically.
Sea level rise	Current predictions are for a rise of at least 0.3 m by 2050 and 1.0 m by 2100. There will be impacts on biodiversity, peninsulas, and the barrage system. At some point, it is likely that the site will assume a more estuarine character.	Possible management responses to this issue could be to fortify the coastline (including the barrages and low-lying islands) in the short-term, and to transition to a more estuarine character in the longer term when tidal conditions permit.
Socio-economic impacts	Irrigation and fishing industries are being affected and there are concerns about health implications and the future of local industries and associated effects on employment and a financially viable future.	There are challenges for the community to remain energised and engaged in finding and implementing the best solutions to this difficult and complex situation.

Freshwater inflows and water levels

The Murray-Darling Basin is experiencing the longest period of low flows since river regulation. These low flows have been caused by over-allocation and more than ten years of drought due to reduced rainfall and increased evaporation resulting from record high temperatures across much of Australia, including the Murray-Darling Basin.

In South Australia, River Murray water levels below Lock 1 (at Blanchetown) have been decreasing considerably over the past few years, because evaporative and seepage losses downstream of Lock 1 have exceeded the flow past this point. As a consequence the river has not flowed through the barrages to the sea for over two years.

In an average year about 40-50% of the public water supplies for Metropolitan Adelaide and associated country areas including the Fleurieu Peninsula, Yorke Peninsula and the Mid-North is extracted from the Murray. However, in the past two years the Murray has provided a much greater proportion than this due to reduced inflows to the Mount Lofty reservoirs.

Due to the barrages holding back seawater, freshwater levels in Lakes Alexandrina and Albert have fallen to lows that are unprecedented, disconnecting the two lakes. Levels have fallen by approximately 0.6 metres in each of the last two years. In April 2009 the water level in Lake Alexandrina was approximately minus 1.0 metre, Australian Height Datum (AHD) (approximate height above sea level) and minus 0.5 metre AHD in Lake Albert (maintained by pumping water from Lake Alexandrina). A worst case scenario is that Lake Alexandrina will be at minus 1.5 metres by February 2010.

Why are freshwater inflows difficult to manage in times of low flow?

Key actions which address issues arising from the low current freshwater inflows include:

- Work being undertaken by the Murray-Darling Basin Authority for a new Basin Plan will set more sustainable policies for the use of water.
- Reducing the extractions from the River Murray e.g. establishment of desalination plants and re-using water.
- Changing trading rules which impact on the sale of water between jurisdictions.

These actions take considerable time, cost and/or will to implement. As a consequence, it is expected that remedial actions will be required to address the immediate problems being faced in the Coorong, Lower Lakes and Murray Mouth area.

The exceptionally dry conditions we are experiencing currently mean that even if large volumes of freshwater were to be secured immediately, remedial works will also be required as part of an integrated management response.

Acid Sulfate Soils

Unprecedented low water levels in Lake Alexandrina (and its tributaries) and Lake Albert have uncovered large areas of previously saturated Acid Sulfate Soils that, on exposure to air, are acidifying.

The potential impacts of exposed Acid Sulfate Soils are on the environment (poor water quality, aquatic ecosystem toxicity, polluted soils and vegetation toxicity); on the health of humans and animals (dermatitis, eye inflammation, asthma); and on the region's economy (impacts on infrastructure, agricultural productivity).

There is particular concern over the mobilisation of acid and heavy metals, both during the 'drying' of Acid Sulfate Soils when water levels are falling, and in the 're-wetting' phase.

The water supply for Adelaide and many country towns could be put at risk by the acidification of Lake Alexandrina. There is a risk that water of increasing acidity could accumulate and contaminate potable water at South Australian pumping locations in the River Murray below Lock 1.

Why is managing Acid Sulfate Soils difficult?

The primary management option is to prevent the acidification of soils by ensuring their saturation by freshwater, which is now in short supply.

The key secondary management option is to encourage a natural bio-remediation process in the lakebed where bacteria in the soils neutralise acidified compounds. This requires the right combination of carbon, carbonates and iron to be in place. These can be provided through application of acid neutralising materials such as limestone, revegetation, mulching and application of iron oxides.

The secondary management techniques are still the subject of experimentation to establish their effectiveness on the scale required. Revegetation plots were established in 2008 at two locations in Lake Albert, to trial potentially suitable plant species. The Government is currently working with the community to determine suitable target areas for revegetation.

While the key emphasis for the future of the site is on saturation of soils by freshwater, it is currently agreed by the Murray Darling Basin Ministerial Council that the minimum necessary quantities of saltwater for the Coorong be used should adequate quantities of freshwater not be available to prevent acidification. Given our present understanding of acidification and mitigation techniques, and the likely changes seawater would cause to the ecological character of the site, this is seen as a *last resort* option.

Processes of acid mitigation and positioning for recovery will need to form key elements of the interventions taken at the site. The level of uncertainty about the effectiveness of the acid mitigation process will diminish over the next year as further trials and tests are undertaken. The introduction of seawater to the site is a last resort to mitigate the effects of acidification. Nonetheless, the impacts of seawater introduction and recovery will be explored.

Salinity

The salinity levels recorded in the Mouth and Estuary and many parts of the Lakes now exceed those suitable for human or livestock consumption, or for irrigation of horticultural crops. This situation is severely affecting the agricultural productivity of the region. The World Health Organization's recommendation for safe drinking water is 800 EC units[2]. A projection is that by the end of April 2009 the average salinity for Lake Alexandrina will exceed 7,180 EC units. Some recent salinity readings in the Goolwa Channel have exceeded 20,000 EC units.

Prior to European settlement, the Lakes at the terminus of the River Murray were predominantly freshwater, with river water discharging to the sea and keeping the Mouth open.

The Murray Mouth is the only site where water contaminants such as silt, salt and nutrients can exit the Murray-Darling Basin. There has been no significant release of water from the Lower Lakes via the barrages since November 2005 and connection at the Murray Mouth has been dependent on dredging. Both Lakes and parts of the Murray Mouth and Estuary have become increasingly saline as a result of evaporation of salt-laden water.

The 23 different wetland types in the Coorong, Lower Lakes and Murray Mouth now range from freshwater to estuarine to saline, with hyper-saline wetlands now present in some parts of the South Lagoon of the Coorong.

Seawater is approximately 60,000 EC units and in some parts of the South Lagoon of the Coorong the water is seven times more saline than the sea.

The security of the water supply for Adelaide and many country towns could also be threatened by rising salinity in Lake Alexandrina caused by evaporation concentrating salts, with no opportunity for flushing. There is a risk that salty water could accumulate and contaminate potable water at South Australian pumping locations in the River Murray below Lock 1.

Why is managing salinity difficult?

The key management responses to increasing levels of salinity are to flush the system with freshwater or remove hypersaline water. Flushing with freshwater is problematic at this time of drought and low inflows, so should be considered part of a longer-term management strategy should freshwater flows return.

Maintaining an open Murray Mouth at all times is a crucial component of this strategy to ensure that salt water can be both ejected from the Lower Lakes system and flushed from the Coorong.

Biodiversity loss

As a result of prolonged hydrological changes, an assessment of the site's ecological character in 2006 highlighted a decline in the quality of the Coorong and Lakes Alexandrina and Albert wetlands and a subsequent change in species diversity and ecological processes. As an example, deteriorating water quality poses a high risk of major fish kills in the Lower Lakes, and it may take several decades for the fish community to re-establish, if at all. High salinities are also causing a loss of invertebrates in the mudflats, which means a loss of food resources for both resident and migratory waterbirds. Indicative salinity tolerances for key Coorong, Lower Lakes and Murray Mouth species are provided in Appendix Five, and an indication of the ecological response to declining water levels and quality is provided in Appendix Six.

Why is biodiversity loss difficult to manage?

Unless the critical water quantity and water quality needs of the site are addressed, it is expected that its ecological character will continue to decline. It is possible to consider ex-situ[3] conservation measures such as captive breeding programs; however, unless suitable habitat can be secured in the region, an expensive captive breeding program alone remains largely futile.

A key element of the management response will be to address the critical water quantity and quality needs of the site to ensure a diversity of wetland habitats which are healthy, productive and resilient. Restoring and maintaining connectivity between habitats and reintroducing more natural patterns of variability in flows and water levels across the site will assist with securing a healthy future.

2 Electrical conductivity (EC) is a measurement of salinity. The more dissolved salt in the water, the stronger the current flow and the higher the EC value

3 Ex-situ or "off-site" conservation is the process of protecting endangered species of plants or animals by removing them from unsafe or threatened habitat.

Sea level rise

Global temperatures have been rising steadily for at least the last 25 years. Future estimates predict a continuation of this trend.[4]

The current South Australian projections are for at least a 0.3 metre rise by 2050 and a full 1.0 metre rise by 2100. However, more recent projections suggest that the global sea level could rise by as much as 0.5 metres by 2050 and 1.5 metres by 2100.

Sea level rise is not seen as an immediate threat, but it is acknowledged that it may lead to a transition of the Lower Lakes to an estuarine environment in the long-term.

However, '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'.[5] In extreme circumstances such as these, islands which are important nesting grounds for birds are likely to be submerged, and mudflat habitats which support many species of water birds, including migratory wader birds, could be permanently lost. Sea level rise could also threaten the Sir Richard Peninsula and the Younghusband Peninsula and the barrages, 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.

Why is sea level rise difficult to manage?

Short of reducing global warming by immediately and drastically reducing greenhouse gas emissions on a global scale, a possible management response to this issue may be to fortify the coastline (including the barrages and low-lying islands) in the medium term, and in the longer term transition to a more estuarine character at the site when tidal conditions permit. These are considerations for the long-term however, and not considered to be an immediate priority.

Sea level rise is not seen as an immediate threat, 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. Investigations are underway to inform decisions about the timing and speed of such a transition. Accordingly, a component of the management response will be the use of best practice adaptive management to strengthen the resilience[6] of the system to the predicted impacts of climate change.

Socio-economic impacts

The region is home to a diverse range of towns and communities, each with their own unique history and character. The region has gone through a large number of changes in recent years. There has been an increase in population in particular towns which has benefited local industry and has increased the number and range of amenities available to residents.

However, the problems associated with less freshwater, Acid Sulfate Soils, rising salinity and species loss are already impacting on the social fabric of the region. The fishing and irrigation industries have already been directly affected by these issues. Many members of the community have expressed concerns over health issues, the future of local industries and associated effects on employment and their financial future.

Some difficult decisions will need to be made, conscious of the possible trade-offs and implications to the differing sectors of the community. It is important a wide range of management options are explored and that the community is kept well informed and involved in this challenging decision making process.

4 Matthews, C. (2005). *Sea Level Rise and Climate Change: Implications for the Coorong and Lakes Alexandrina and Albert Ramsar Site. A preliminary investigation*. Conservation Programs South East, Regional Conservation, Department for Environment and Heritage, p.3.

5 Mathews, C ibid p.13.

6 Ecosystem resilience refers to the capacity of an ecosystem to cope with disturbances such as drought and sea level rise without ecosystem collapse. A resilient system has the capacity to rebuild itself after disturbance. Without resilience the Coorong, Lower Lakes and Murray mouth could become biologically and economically irreversibly impoverished. Biodiversity plays a crucial role in ecosystem resilience by spreading risks and making it possible for ecosystems to adjust to a disturbance. Ecosystems are resilient if there are many species performing the same essential function (such as photosynthesis or decomposition) but respond in different ways to disturbances.

4. What is being done to manage the current problems and plan for the future?

All levels of Government have been working together with local communities, scientists, technical experts and engineers to respond to the immediate problems due to drought and over-allocation, plan for worst-case future climate scenarios and develop long-term sustainable solutions in a coordinated fashion.

A range of urgent actions has been implemented in response to the current situation, while future planning continues to prepare for worst-case scenarios if triggers are reached. These actions include:

- Dredging to keep the Murray Mouth open.
- The sealing of the barrages.
- Millions of dollars of investment in waste water recycling and storm water re-use and commencing the construction of a new $1.3 billion desalination plant to substantially reduce South Australia's reliance on the River Murray.
- The pumping of water from Lake Alexandrina to Lake Albert to prevent acidification.
- Preparatory work towards the construction of a temporary weir near Pomanda Island to protect South Australia's water supply below Lock 1, in the event of the Government approving its construction as a last resort measure.
- The construction of pipelines and standpipes for the delivery of potable and irrigation water supplies.
- Preparatory work towards the ponding of freshwater within the Finniss River and Currency Creek area to help manage acidification.
- Trials to assess the effectiveness of revegetation and bioremediation techniques to manage Acid Sulfate Soils.
- Investigations into the options available to reduce salinity in the Coorong's South Lagoon.
- Technical investigations and the preparation of an Environmental Impact Statement about the environmental implications of the temporary wetting of the Lower Lakes with seawater to address Acid Sulfate Soils. This is considered to be a last resort management response if trigger levels are reached.
- A Goolwa to Wellington Local Action Planning Group initiative – the *Coorong and Lower Lakes Community Eco-Action Project* – to increase community involvement in helping the area adapt to a rapidly changing environment during the current extreme drought.
- Pursuing a constitutional challenge to upstream States to protect South Australia's rights to water.
- The purchase of water on the temporary water market to provide flows to the Lakes while work towards a lasting solution continues.

Further information on these initiatives is provided in Appendix Seven.

In tandem with the above urgent actions, the Australian Government will provide $200 million to the South Australian Government for medium to long-term projects in support of an enduring response to the environmental problems facing the Coorong, Lower Lakes and Murray Mouth Ramsar site. It is being undertaken through three stages:

Stage 1 – Defining the Issues, by April 2009

This document outlines the issues and a possible direction for the future management of the site. It is based on existing information and research, and is designed for public consultation and discussion in May 2009.

Stage 2 – Defining the Solution, by June 2009

This stage will propose a sustainable future for the Coorong, Lower Lakes and Murray Mouth, based on community feedback on the Directions document and the latest scientific developments. This will be released in July 2009 for further public consultation and discussion.

Stage 3 – Implementation Plan, by October 2009

Completion of the long-term plan for the Coorong, Lower Lakes and Murray Mouth, based on further community feedback and science, research and modelling.

The urgent actions now being undertaken are not intended to limit future management options. By implementing these actions now, and in tandem planning for the future, we are making our best attempt to insure against irreversible damage to the Coorong, Lower Lakes and Murray Mouth.

5. Will climatic conditions improve the situation naturally?

Freshwater outlook

It is not certain whether future climatic conditions will improve the situation naturally.The recent CSIRO *Sustainable Yields* project acknowledges that the precise impacts of climate change by 2030 remain subject to much conjecture and debate. The *Sustainable Yields* project considered a number of future climatic scenarios including the continuation of historic climatic conditions, the continuation of recent climatic conditions and multiple projected global warming scenarios determined by international climate change experts.

In considering a number of historic, recent and projected global warming scenarios, the project predicted that the atypically low annual flows of 2007-08 would continue to occur 1% of the time under a continuation of the 1997-2006 climate, and 4% of the time under a future extreme dry climate.

The CSIRO *Sustainable Yields* report is optimistic that under the extreme dry climate change scenario, the Lower Lakes will remain predominantly freshwater, but that there would be occasional periods where the levels would fall below sea level. The timing and severity of these events remains uncertain. However, it is acknowledged that the modelling contains significant uncertainties about the rate and extent of climate change. Additionally, the length of time for which records exist does not allow events which recur at intervals of more than 50 years to be accurately modelled.

Significantly, the CSIRO *Sustainable Yields* report makes the point that revised water allocation policies could reduce the time the Lower Lakes were below sea level. The recently established Murray-Darling Basin Authority is now commencing the development of its Basin Plan under the authority of the *Water Act 2007* (Commonwealth). The Act states, amongst other things that it must

- give effect to relevant international agreements (such as those applying to this site);
- establish and enforce environmentally sustainable limits on the quantities of surface water and ground water that may be taken from the Basin; and
- promote sustainable use of the Basin water resources to protect and restore the ecosystems, natural habitats and species that are reliant on the Basin water resources and to conserve biodiversity.

The Basin Plan is expected to progressively come into effect from 2011. The legally enforceable Plan will include a sustainable diversion limit that may be extracted from the Basin and from individual water resource areas within the states. However, given the uncertainties of future rainfall predictions, it is not clear when the operation of this Plan will have a practical impact for the Coorong, Lower Lakes and Murray Mouth.

It is also important to note that the CSIRO *Sustainable Yields* report does not incorporate water recovery targets already established under the Living Murray Initiative, which aims to recover an average of 500GL of water/annum by 30 June 2009. This water will be directed to six Icon Sites along the length of the River Murray, including the Lakes and Coorong. In addition, other Commonwealth water recovery programs have been established to recover water specifically for environmental use. Combined with major landscape scale environmental infrastructure projects, the recovery, allocation and wise use of environmental water will assist in maximising environmental outcomes across the Murray-Darling Basin, including the Coorong, Lower Lakes and Murray Mouth.

Sea level rise

As outlined previously, sea level rise is not seen as an immediate threat to the Coorong, Lower Lakes and Murray Mouth, but it is acknowledged that it may lead to a transition of the Lower Lakes to an estuarine environment in the longer term.

The longer term implications of sea level rise on the Coorong, Lower Lakes and Murray Mouth are currently being assessed. Coastal vulnerability assessments are being undertaken to identify possible 'weak points' in the coastline of the Coorong. These are to be followed by analyses to determine when breaches of the barrages and low-lying islands may begin to occur more frequently and on a larger scale. Only when these predictions are modelled can informed decisions be made about the timing and speed of the transition of the Lower Lakes to an estuarine environment.

An immediate transition to a permanent marine environment is not considered to be environmentally responsible. Given the structure of the Coorong, Murray Mouth and low-lying islands, the likely tidal flow and means of flushing the system are not considered sufficient to support a healthy, functioning marine ecosystem in the short to medium term. It is anticipated that any increase in the tidal influence on the Coorong, Lower Lakes and Murray Mouth will result in increased sand loading at the Murray Mouth, which in turn will exacerbate issues associated with a blocked Murray Mouth.

The uncertainties highlighted by the CSIRO report and future rainfall predictions coupled with the unknown timing and impact of the Basin Plan and sea level rise, mean that we must find ways to adapt to a future of variable water availability.

The outlook under future climates will see changes in terms of freshwater availability and sea level rise; however, the precise timing and implications remain uncertain. We will need to respond to the conditions without knowing in advance what the conditions will be.

6. How do we secure a healthy future?

Primary focus on conservation

We have a shared responsibility to conserve the ecological character of the Coorong, Lower Lakes and Murray Mouth. In addition to the site's exceptional environmental significance, we are mindful of its cultural, social, recreational and economic value, and our obligation to promote its wise use.

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

Our goal is to secure a future for the Coorong, Lower Lakes and Murray Mouth as a healthy, productive and resilient wetland system of international importance.

This will be achieved in four phases as follows:

Phase 1	Year 1 (2009) *"Short-term emergency response and planning"*	**Manage the current threats and plan for the future** to secure existing ecological character (including feasibility assessment). This will include the establishment of an adaptive management regime and responsive management approach and technical investigations and research. This is currently underway. It is vital that the regional communities remain involved in this on-ground action and planning process. Opportunities for this involvement will be explored as part of the planning process in Phase 1.
Phase 2	Years 2-6 (2010 - 2014) *"Medium-term response"*	**Manage through the current period of uncertainty and help the system to adapt** by building resilience within the system to survive, evolve and adapt to greater climatic variability. Ensure core management elements are put in place to conserve the processes that support healthy and diverse habitats in the region. This approach challenges the notion of conserving 'what we have now where it is now'. Ambitiously it attempts to actively protect dynamic and broad scale ecosystem processes and ameliorate the impacts of changing climatic variables. Building resilience within both the Coorong, Lower Lakes and Murray Mouth ecosystem and regional communities will be important components of Phase 2[7].
Phase 3	Years 7-20 (2015 – 2028 *"Long-term response"*	**Implement responsive management arrangements depending upon future climatic scenario.** The success of this will be reliant upon regional community involvement. Opportunities for this involvement will be explored as part of the planning process in Phase 1 and progressively adopted throughout Phases 2 and 3.
Phase 4	Years 21-40 (2029 – 2048) *"Very long-term response"*	**Undertake the necessary preparatory works for a transition to a more estuarine character,** given current sea level rise predictions.

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

This approach will also ensure that short-term remedies do not limit future management options for providing positive ecological outcomes.

In realising our vision for the future we are committed to community involvement. We acknowledge the vital work already being done by a raft of community organisations in undertaking on-ground works and making an active contribution to the planning process. For example, there are community projects working on revegetation and mulching to mitigate Acid Sulfate Soils; fencing; and education about Acid Sulfate Soils and the role of plants in bioremediation.

7 This recognises that human and ecological systems are dynamic, interacting and interdependent. It acknowledges that where there is a decline in ecological character, regional communities can suffer in terms of health, wealth and livelihood and vice versa.

We will continue to exchange information with community groups, build the capacity of the surrounding communities and landholders to assist with management of the Ramsar wetland, and engage with the Ngarrindjeri people throughout the process.

This response will require all levels of Government to work together with local communities, scientists, technical experts and engineers to address the immediate drought response issues, plan for worst-case future scenarios and develop long-term sustainable solutions.

Assessing the ideas put forward by scientists and the community

A diversity of ideas have been proposed by scientists, the community and government agencies, as solutions to the problems being experienced at the Coorong, Lower Lakes and Murray Mouth. These vary markedly in scope, cost and key objectives, outcomes and timeframes for delivery. Some address the key issues facing the site; others don't. Some involve significant engineering works and fundamental changes to the functioning of the ecosystem. Others involve less drastic measures. Some are linked to and must be implemented together with others; some stand alone. Conversely some are in contradiction to others. Appendix Eight provides a listing of many of these ideas and a preliminary ecological assessment.

Much more work is required in the coming months to assess these ideas from a socio-economic perspective. It is important to identify those which both deliver the best environmental outcomes and also the best social and economic outcomes to the region. More work is also required to identify the optimum combination of complementary actions.

The feasibility of these ideas – together with any new ideas that are consistent with what is trying to be achieved, as proposed by scientists, the community and government agencies – will be considered further in the coming months.

Putting in place the core elements

The ideas put forward have been considered, assessed and used to identify the core elements of a response to secure a future for the Coorong, Lower Lakes and Murray Mouth as a healthy, productive and resilient wetland of international importance.

Putting in place six core elements ensures that the Coorong, Lower Lakes and Murray Mouth are in the best position to deal with any future climatic scenario. It also retains, to the maximum extent practicable, the ecological values which make this area a wetland of international significance.

The core elements can be achieved by pursuing a number of management actions. The precise nature of the management actions to be deployed will vary depending on the climatic scenario faced in any year. The best approach to implementation will therefore need to be determined in response to those conditions. For example, under future climatic scenarios which are at the wetter end of the scale, barrage operations can be managed to maintain an open Murray Mouth, whereas dredging of the Murray Mouth will be required under dryer climatic scenarios. There can be many varying scenarios – further years of low inflows, followed by one or more years of average inflows, then a further dry period or, alternatively, periods of higher flows.

Rather than presenting multiple climatic scenarios and associated management responses in this document, the likelihood of particular scenarios occurring must first be considered. Detailed response planning based on the below core elements will follow in the coming months, together with planning on the best way to manage the implementation of the plan.

The core elements and management actions are as follows:

Core Element 1. A responsive management approach based on robust research, adequate monitoring and extensive community involvement	
Suite of potential actions include: - Use best practice adaptive management[8] - Implement a coordinated collective, efficient and effective response to the issues and in the development of policy - Collaborate with the community to define outcomes required - Ensure that a diversity of voices are heard on issues that matter to local people.	*Benefits* • Strengthens the resilience of the system to the predicted impacts of climate change • Enables timely and informed management decisions to be made • Relevant and practical to regional needs and practicalities • More viable, effective and efficient delivery of outcomes • Provides an earlier indication of emerging issues and provides for a proactive response • Greater levels of community ownership of solutions to current problems.
Core Element 2. Engagement of the traditional owners – the Ngarrindjeri	
To be completed after discussion with the Ngarrindjeri	
Core Element 3. Freshwater provided to the Lakes	
Suite of potential actions include: - Ensuring that policy mechanisms such as the Murray-Darling Basin Plan and Water Allocation Policies provide sufficient freshwater for environmental purposes - Purchasing water entitlements (temporary or permanent licence).	*Benefits* • Treats the cause of multiple key issues (Acid Sulfate Soils, Salinity and Species Loss) • Will ensure that ecological functions are maintained • Ensures critical habitat for important resident and migratory species.
Core Element 4. The Murray Mouth open and connecting the Coorong to the sea	
Suite of potential actions include: - Conduct barrage operations to maintain an open Mouth and flushing of saline water out of the Coorong Estuary - Maintain an open Murray Mouth by dredging or a similar suitable alternative means. - Pumping of hypersaline water out of the South Lagoon of the Coorong - Diverting freshwater from upper south east drainage schemes, if viable.	*Benefits* • Treats some of the rising salinity and species loss issues. • Allows for the flushing of the system to release salts and contaminants • Allows for fish passage • Provides critical habitat for important resident and migratory species. • Provides a flushing mechanism to eject saline water from the Coorong estuary • Treats the cause of rising hypersalinity in the South lagoon and species loss issues • Ensures the maintenance of a suitable range of salinity for ecosystem function and species diversity to adapt, evolve and respond to changing conditions • Provides critical habitat for important resident and migratory species.

8 A management approach that involves monitoring the outcomes of a project or issue and, on the basis of the monitoring, improving the way the project is managed

Core Element 5. Accepting variable Lake levels, yet maintaining system connectivity	
Suite of potential actions include: - Barrage operations to establish variable Lake levels - Reduce reliance upon Lakes for extractive purposes so that Lake levels can be lowered periodically - Provision of fish passage structures - Revegetation for the provision of habitat for key species.	*Benefits* • Treats species loss issues by building system resilience to a future variable climate • Provides critical habitat for important resident and migratory species • Provides capacity to flush salt from the system • Addresses system resilience requirements under variable climatic conditions • Provides critical habitat for important resident and migratory species.
Core Element 6. Managing localised threats, especially acidification	
Suite of potential actions to address specific threats include: *Acidification* - Developing and implementing bioremediation[9] and limestone treatment techniques - Pooling of freshwater to saturate soils - Pooling of seawater to saturate soils (as directed by the Murray-Darling Basin Ministerial Council) *Introduced herbivores* - Fencing to exclude domestic stock from riparian vegetation - Localised rabbit control measures *Pest Plants* - Localised weed control measures *Wind erosion* - Revegetation to hold soils and slow localised winds *Provide ecological refuges* - Protected areas managed specifically for nature conservation.	*Benefits* • Treats Acid Sulfate Soils issues • Addresses system resilience requirements under variable climatic conditions • Provides critical habitat for important resident and migratory species.

9 Bioremediation refers to the use of living organisms to clean up contaminated soil, water and air.

An illustrative example of one scenario for Phase 2 (2010-2014)

As the precise nature of the actions to be undertaken will vary depending on the situation which we face in any climatic future, the following list of actions has been developed as an example of the types of activities that are appropriate given one potential future scenario for Phase 2 of the response (i.e. 2010-2014). This listing does not represent a final management response, nor does it represent a formal South Australian Government position. It is simply provided to illustrate how detailed action planning will need to be undertaken which considers the six core elements and provides a listing of management actions appropriate to various climatic scenarios. The scenario is as follows:

- The outlook over the next five years for the Coorong, Lower Lakes and Murray Mouth is for the continuation of a relatively dry period.
- Sufficient freshwater to secure existing ecological character will be available within five years and can be sustained in most years in accordance with the proposed Murray-Darling Basin Plan.
- There is insufficient freshwater available across the Murray-Darling system to secure and maintain ecological character within the Coorong, Lower Lakes and Murray Mouth, without other remedial works also being required as part of an holistic management response.
- The level of uncertainty about the effectiveness of the acid mitigation process will diminish as further trials and tests are undertaken and will prove successful until freshwater is available.
- The introduction of seawater to the site is a last resort to mitigate the effects of acidification. Nonetheless, the impacts of seawater introduction and recovery will be explored.

The management actions for this future are presented in the following table. An approximate indication of cost and timing of each component of the solution is listed in the table.

For ease of presentation, solutions have been grouped by the components of the Coorong, Lower Lakes and Murray Mouth site. However, the value (or potential risk) of each solution should not be considered in isolation from the other components of the site, nor other proposed solutions.

All proposed solutions require risk assessment to identify the impacts they may have on the ecological character of the system. There may be some ecological risks associated with taking any of the actions identified. However, the risk of 'doing nothing' could equally be of high risk.

Furthermore, detailed economic and socio-economic feasibility assessments will need to be undertaken before formulating a business case for Australian Government funding by the end of 2009. This will be done over the next 6 months, so that by the end of September 2009 a clear way forward has been fully scoped, detailed and costed. A funding bid will then be submitted to the Australian Government for its consideration and funding as soon as possible. Where practical, those elements which can be progressed quickly will be submitted for early consideration to enable early implementation.

An illustrative example: The Phase 2 management response to one dryer future climatic scenario

Note: This listing does not represent a final management response, nor does it represent a formal South Australian Government position.

Actions (*Costs: * $0-3M, ** $4-10M, *** $11M +*)	Year 1 2010	Year 2 2011	Year 3 2012	Year 4 2013	Year 5 2014	Assumptions/Questions/Project risks that are to be investigated
COORONG AND MURRAY MOUTH						
Freshwater provided to the Lakes						
• Freshwater from the Upper South East.	*	**	**	**	**	Requires further investigation/consideration. Contribution of freshwater inflow may not be significant. Possible value in terms of ecological refuge/seed source. Water quality issues & implications. Need to consider possible impacts on Upper South East wetlands.
The Murray Mouth open and connecting the Coorong to the sea						
• Additional dredging of Murray Mouth to mitigate siltation due to pumping.	*	*	*	*	*	This assumes that by pumping out the South Lagoon, sand may accumulate at the Mouth and reduce tidal flow.
• Pumping out of the South Lagoon.	***	*	*	*	*	Assumes practical application options. Questions about pump locations, practicalities of disposal of hypersaline water (how to pump offshore), possible implications for North Lagoon. 50GL pumped out annually (150ML x 360 days or 450ML x 120 days).
Clearing of sills near Parnka Point.	*	*				This will facilitate mixing potential.
• Improving the Murray Mouth Estuary & North Lagoon (by enhanced Murray Mouth dredging).	*	*	*	*	*	Assumes that greater flows are beneficial. Unclear how significant a contribution this may make.
• Continue current Murray Mouth dredging to maintain open mouth in accordance with an existing agreement with the Murray-Darling Basin Authority.	**	**	**	**	**	The South Australian Murray-Darling Basin Natural Resources Management Board is currently re-assessing practical options to maintain an open Murray Mouth, including dredging given prolonged drought conditions.
Accepting variable lake levels, yet maintaining system connectivity						
• Variability in lake levels is not a significant element for the management of the Coorong and Murray Mouth under this under this future due to limited water supplies. This is an element that would be considered under wetter futures.						
• Fish passages through to the Coorong at Goolwa.	*					5-10 ML/day, small bodied fish only
Managing localised threats, especially acidification and hypersalinity						
Transplanting of Ruppia sp.	*	*	*	*	*	Assumes that the system is operable within required ecological (salinity) limits and that we have a good knowledge of the Ruppia salinity tolerances (currently being worked on) and ability to transplant.

Actions (*Costs: * $0-3M, ** $4-10M, *** $11M +*)	Year 1 2010	Year 2 2011	Year 3 2012	Year 4 2013	Year 5 2014	Assumptions/Questions/Project risks that are to be investigated
LAKE ALBERT						No seawater, no connection to the Coorong, retain Narrung bund until sufficient freshwater flows
Freshwater provided to the Lakes						
• Pumping from Lake Alexandrina.	***	***	***	***	***	Continuing operations – may not be practical in the medium term.
The Murray Mouth open and connecting the Coorong to the sea						
• The requirement to maintain an open Murray Mouth in this future is addressed in the Coorong and Murray mouth section above.						
• The requirement to maintain the natural variable salinities in the Coorong in this future is addressed in the Coorong and Murray Mouth section above.						
Accepting variable lake levels, yet maintaining system connectivity						
• Variability in Lake Levels is not a significant element for the management of Lake Albert under this future due to limited water supplies. This is an element that would be considered under wetter futures.						
• Narrung Narrows remedial works – remove bund, dredge narrows, undertake remedial works including modifications to ferry causeway to provide for natural flows through The Narrows.					**	Need to consider costs of cartage and dumping of spoil etc. The ferry causeway built in 1966 severely reduces the funnel effect at this point and inhibits flow through The Narrows and compounds the problem experienced with the movement of water through this area.
Managing localised threats, especially acidification and hypersalinity.						
• Hot spot Acid Sulfate Soil mitigation (e.g. cracking clays, sand, Mono-sulfidic Black Oozes)		*	*	*	*	Assumes practical application options are sufficiently effective. Questions about off site impacts, source materials. Positive and negative socio-economic impacts will need to be considered.
• Consider stopping pumping to Lake Albert and implement bioremediation actions (as described below) along with monitoring of success. Consider resuming pumping if bioremediation is found to be insufficient.						Will require careful consideration of implications to Lake Albert and its communities.

Actions (*Costs: * $0-3M, ** $4-10M, *** $11M +*)	Year 1 2010	Year 2 2011	Year 3 2012	Year 4 2013	Year 5 2014	Assumptions/Questions/Project risks that are to be investigated
• "Bioremediation basin" (Calcium Carbonate + Carbon + Iron).	***					Assumes practical application options are sufficiently effective. Questions about off site impacts, source materials. Positive and negative socio-economic impacts will need to be considered.
• Revegetation (native) for Acid Sulfate Soil remediation around Lake edges.	*	*	*	*	*	Assumes practical application options. Questions about what species where for best outcomes. Need to ensure no introduction of weeds or other future issues. Positive and negative socio-economic impacts will need to be considered.
• Planting of annual crop type species on exposed areas to contain wind erosion.	*	*	*	*	*	Assumes practical application options. Questions about what species where for best outcomes. Need to ensure no introduction of weeds or other future issues. Positive and negative socio-economic impacts will need to be considered.
• Natural resource management activities (weed control, fencing, rabbit control to ensure success of revegetation and cropping).	*	*	*	*	*	Weed control, fencing, rabbit control necessary to ensure success of revegetation and cropping

Actions (*Costs: * $0-3M, ** $4-10M, *** $11M +*)	Year 1 2010	Year 2 2011	Year 3 2012	Year 4 2013	Year 5 2014	Assumptions/Questions/Project risks that are to be investigated
LAKE ALEXANDRINA						No seawater, need to manage and mitigate ASS (includes treatment of eastern end of Hindmarsh Island).
Freshwater provided to the Lakes						
• Under this future it is assumed that sufficient freshwater is made available to secure existing ecological character within five years and can be sustained in most years in accord with the proposed Murray-Darling Basin Plan.						
The Murray Mouth open and connecting the Coorong to the sea						
• The requirement to maintain an open Murray Mouth in this future is addressed in the Coorong and Murray mouth section above.						
• The requirement to maintain the natural variably salinities in the Coorong in this future is addressed in the Coorong and Murray Mouth section above.						
Accepting variable lake levels, yet maintaining system connectivity						
• Variability in Lake Levels is not a significant element for the management of Lake Alexandrina under this future due to limited water supplies. This is an element that would be considered under wetter futures.						
• The requirement to maintain ecological connectivity in this future is addressed in the Coorong and Murray Mouth and Lake Albert sections above.						
Managing localised threats, especially acidification and hypersalinity.						
• Revegetation (native) for Acid Sulfate Soil remediation around Lake edges.	**	**	**	**	**	Assumes practical application options. Questions about what species where for best outcomes. Need to ensure no introduction of weeds or other future issues. Positive and negative socio-economic impacts will need to be considered.
• Cropping of annual species in exposed areas to contain wind erosion.	**	**	**	**	**	Assumes practical application options. Questions about what species where for best outcomes. Need to ensure no introduction of weeds or other future issues. Positive and negative socio-economic impacts will need to be considered.
• Natural resource management activities (weed control, fencing, rabbit control to ensure success of revegetation and cropping).	**	**	**	**	**	Weed control, fencing, rabbit control necessary to ensure success of revegetation and cropping
• Bioremediation basins/pools (Calcium Carbonate + Carbon + Iron).	***	*	*	*	*	Assumes practical application options are sufficiently effective. Questions about off site impacts, source materials. Positive and negative socio-economic impacts will need to be considered.
• Hot spot Acid Sulfate Soil mitigation (e.g. cracking clays, sand, Mono-sulfidic Black Oozes).		**	**	**	**	Assumes practical application options are sufficiently effective. Questions about off site impacts, source materials. Positive and negative socio-economic impacts will need to be considered.

Actions (*Costs: * $0-3M, ** $4-10M, *** $11M +*)	Year 1 2010	Year 2 2011	Year 3 2012	Year 4 2013	Year 5 2014	Assumptions/Questions/Project risks that are to be investigated
TRIBUTARIES - FINNISS RIVER AND CURRENCY CREEK						No seawater, need to manage and mitigate Acid Sulfate Soils.
Freshwater provided to the Lakes						
• Under this future it is assumed that sufficient freshwater is made available to secure existing ecological character within five years and can be sustained in most years in accord with the proposed Murray-Darling Basin Plan.						
The Murray Mouth open and connecting the Coorong to the sea						
• The requirement to maintain an open Murray Mouth in this future is addressed in the Coorong and Murray mouth section above.						
• The requirement to maintain the natural variable salinities in the Coorong in this future is addressed in the Coorong and Murray Mouth section above.						
Accepting variable lake levels, yet maintaining system connectivity						
• Variability in Lake Levels is not a significant element for the management of the Tributaries under this future due to limited water supplies. This is an element that would be considered under wetter futures.						
• Installation of fish passage into blocking bank	*					
Managing localised threats, especially acidification and hypersalinity.						
• Installation of blocking banks to retain moisture in creeks to address Acid Sulfate Soils (& removal in Year 5).	***				*	Assumes structures are required to address Acid Sulfate Soils. Questions about required height, construction, decommissioning and hydrodynamic implications. Positive and negative socio-economic impacts will need to be considered.
• Revegetation (native) for Acid Sulfate Soil remediation around Lake edges.	*	*	*	*	*	Assumes practical application options. Questions about what species where for best outcomes. Need to ensure no introduction of weeds or other future issues. Positive and negative socio-economic impacts will need to be considered.
• Cropping of annual species to contain wind erosion.	*	*	*	*	*	Assumes practical application options. Questions about what species where for best outcomes. Need to ensure no introduction of weeds or other future issues. Positive and negative socio-economic impacts will need to be considered.
• "NRM" activities (weed control, fencing, rabbit control to ensure success of revegetation and cropping).	*	*	*	*	*	Weed control, fencing, rabbit control necessary to ensure success of revegetation and cropping
• Hot spot Acid Sulfate Soil mitigation (e.g. cracking clays, sand, Mono-sulfidic Black Oozes).		*	*	*	*	Assumes practical application options are sufficiently effective. Questions about off site impacts, source materials. Positive and negative socio-economic impacts will need to be considered.

Actions (*Costs: * $0-3M, ** $4-10M, *** $11M +*)	Year 1 2010	Year 2 2011	Year 3 2012	Year 4 2013	Year 5 2014	Assumptions/Questions/Project risks that are to be investigated
A RESPONSIVE MANAGEMENT APPROACH BASED ON ROBUST RESEARCH, ADEQUATE MONITORING AND EXTENSIVE COMMUNITY INVOLVEMENT	**	*	*	*	*	Undertake a review of the current status of Ecological Character and then monitor the recovery of Ecological Character (birds, fish, vegetation, water quality) as a result of actions being undertaken. People and software requirements etc. Research example includes Coorong, Lakes And Murray Mouth Ecology under the direction of the Scientific Advisory Group. Research will need to be in the order of 5% of the total budget. Community engagement, project managers, finance, procurement, policy, governance. This is to include policy work such as water allocation planning and other mechanisms.
ENGAGEMENT OF THE TRADITIONAL OWNERS – THE NGARRINDJERI	*	*	*	*	*	

Appendix One

Overview of the system - map

Overview of the system

The Coorong, Lower Lakes and Murray Mouth covers approximately 140,500 hectares (ha), with 23 different wetlands types existing as an interconnected mosaic of fresh water to estuarine and saline habitats.

Freshwater system units

Lake Alexandrina is the largest of the lakes – approximately 76,000 ha. This shallow lake receives the majority of its fresh water from the Murray, although local rainfall and runoff from the Mt Lofty Ranges also (potentially) contribute substantial inflows. The Murray passes through Lake Alexandrina to the sea. The water in the Lake has been predominantly fresh for the last 7,000 years. Currently it is relatively saline near the barrages and brackish in the centre.

Lake Albert is a smaller (about 16,800 ha) and shallower, fresh water lake to the south-east of Lake Alexandrina, to which it is connected via a narrow channel (Narrung Narrows) near Point Malcolm. It has no other significant inflows, except local rainfall and groundwater flows, and is not connected to the Coorong, the Murray Mouth or to the sea.

The **Tributary wetlands** are the lower reaches of three Mt Lofty Ranges streams: the Finniss River, Tookayerta Creek and Currency Creek. These also lie within the Ramsar site. They are considered to have 'permanent' flows, but flow may stop for periods in summer depending on local climatic conditions and extraction rates.

Estuarine-saline system units

The **Murray Mouth and Estuary** – this part of the Ramsar site includes the Murray Mouth from the Goolwa Barrage to Pelican Point, and includes the Goolwa, Coorong and Mundoo channels.

The **Murray Mouth** is the only site where water contaminants such as silt, salt and nutrients can exit the Murray-Darling Basin. Prior to European settlement, flows of water out of the Murray River were adequate to maintain an open Mouth. However, more recently, through-flow has been dependent on dredging and co-ordinated barrage releases from a system of five barrages which regulate flow, separating the fresh waters of the River Murray and Lake Alexandrina from the more saline waters of the Murray Mouth estuary and the Coorong lagoons.

The Coorong is a series of lagoons which stretch along the coast for approximately 140 kilometres (km). The aquatic environment usually ranges from estuarine-saline in its **North Lagoon** to hyper-saline in the far reaches of its **South Lagoon**.

Appendix Two

Ramsar criteria used to designate Wetlands of International Importance.

In order to qualify a site must satisfy one or more of the following. The Coorong and Lakes site qualifies against criteria 1-8 (shown shaded) below.

Criterion 1	Contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate bioregion.
Criterion 2	Supports vulnerable, endangered or critically endangered species or threatened ecological communities.
Criterion 3	Supports populations of plant and/or animal species important for maintaining the biological diversity of the region.
Criterion 4	Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
Criterion 5	Regularly supports 20,000 or more waterbirds.
Criterion 6	Regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.
Criterion 7	Supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.
Criterion 8	Is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.
Criterion 9*	Regularly supports 1% of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.

* It is not possible yet to confirm if the site qualifies against this recently added ninth criterion.It may be that it does so for some of the native fish species found there.

Appendix Three

Legislative and Policy context

A range of international agreements and Commonwealth and state legislation and policies govern the management of the Coorong, Lower Lakes and Murray Mouth.

An overview of these is presented in the table following, and some of the most important ones are discussed briefly below.

Commonwealth Legislation	*Environment Protection and Biodiversity Conservation Act 1999* *Water Act 2007* *Water Amendment Bill 2008.*
Relevant Commonwealth strategies & plans	*Living Murray, 2002* *The Lower Lakes, Coorong, and Murray Mouth Icon Site Environmental Management Plan, 2006-2007* *The Murray-Darling Basin Authority's Basin Plan, 2007* *Commonwealth Wetlands Policy, 1997* *Water for the Future, 2008*
State Legislation	*Waterworks Act 1932* *National Parks and Wildlife Act 1972* *Coast Protection Act 1972* *Native Vegetation Act 1991* *Environment Protection Act 1993* *Development Act 1993* *Water Resources Act 1997* *Aboriginal Heritage Act 1988* *River Murray Act 2003* *Natural Resources Management Act 2004* *Fisheries Management Act 2007* *Marine Parks Act 2007* *Climate Change and Greenhouse Emissions Reduction Act 2007* *Water (Commonwealth Powers Bill) 2008.* *Murray-Darling Basin Act 2008*
Relevant State strategies and plans	*State Water Plan of 2000* *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 Draft Regional Natural Resources Management Plan, 2008*

Commonwealth legislation, initiatives and plans

One of the major Commonwealth pieces of legislation relevant to the Coorong, Lower Lakes and Murray Mouth is the *Environment Protection and Biodiversity Conservation Act 1999*. This Act provides a legal framework for ensuring that the ecological character of all Australian Ramsar sites is retained and that heritage sites and listed migratory and threatened species and communities are protected.

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 is the deployment of 500 gigalitres (GL) of water for the environment, to be delivered to these six sites by 30 June 2009. (South Australia has already secured its 35GL share of the national target of 500GL, at a cost of $75 million).

The Icon Site 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:

1. An open Murray Mouth
2. Enhanced migratory water bird habitat in the Lower Lakes and Coorong
3. More frequent estuarine fish spawning and recruitment.

The *Water Act 2007* established the Murray-Darling Basin Authority, the main function of which is to address over-allocation and protect, restore and provide for the ecological values and ecosystem services of the Murray-Darling Basin. This will be achieved through a Basin Plan, to commence in 2011. Among other things, it will specify: limits on the amount of water (both surface water and groundwater) that can be taken from Basin water resources on a sustainable basis; an environmental watering plan to optimise environmental outcomes for the Basin; and rules about trading of water rights in relation to Basin water resources.

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

A component of *Water for the Future* is the Sustainable Rural Water Use and Infrastructure Program, a 10 year, $5.8 billion program. State Priority projects will be funded from the Program with South Australia receiving up to $530 million for a range of activities. A further $80 million has been made available for the purchase of water entitlements from willing sellers, with water to be held by the Commonwealth Environmental Water Holder. As part of the South Australian Priority Project activities, the Australian Government is providing up to $200 million to South Australia to support an enduring response to the environmental problems facing the Lower Lakes, Murray Mouth and Coorong. This includes a $10 million feasibility study of the long-term options for the management of the site.

State legislation, plans and strategies

Two particularly relevant state Acts are the *River Murray Act 2003* and the *Murray-Darling Basin Act 2008*. 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; and
- Human dimensions such as community interests, community knowledge and the importance of a healthy river to the economic, social and cultural prosperity of communities.

The *Murray-Darling Basin Act 2008* specifies that the Murray-Darling Basin Authority must be informed of any proposal that may significantly affect the flow, use, control or quality of any water in the River Murray in South Australia. The Authority's approval is required in order to carry out any works (for example, a temporary weir) not already provided for under the agreement. In considering an authorisation, the MDBA must assess any possible effects on the water, land or other natural resources within the Murray-Darling Basin.

Murray Futures, 2008

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

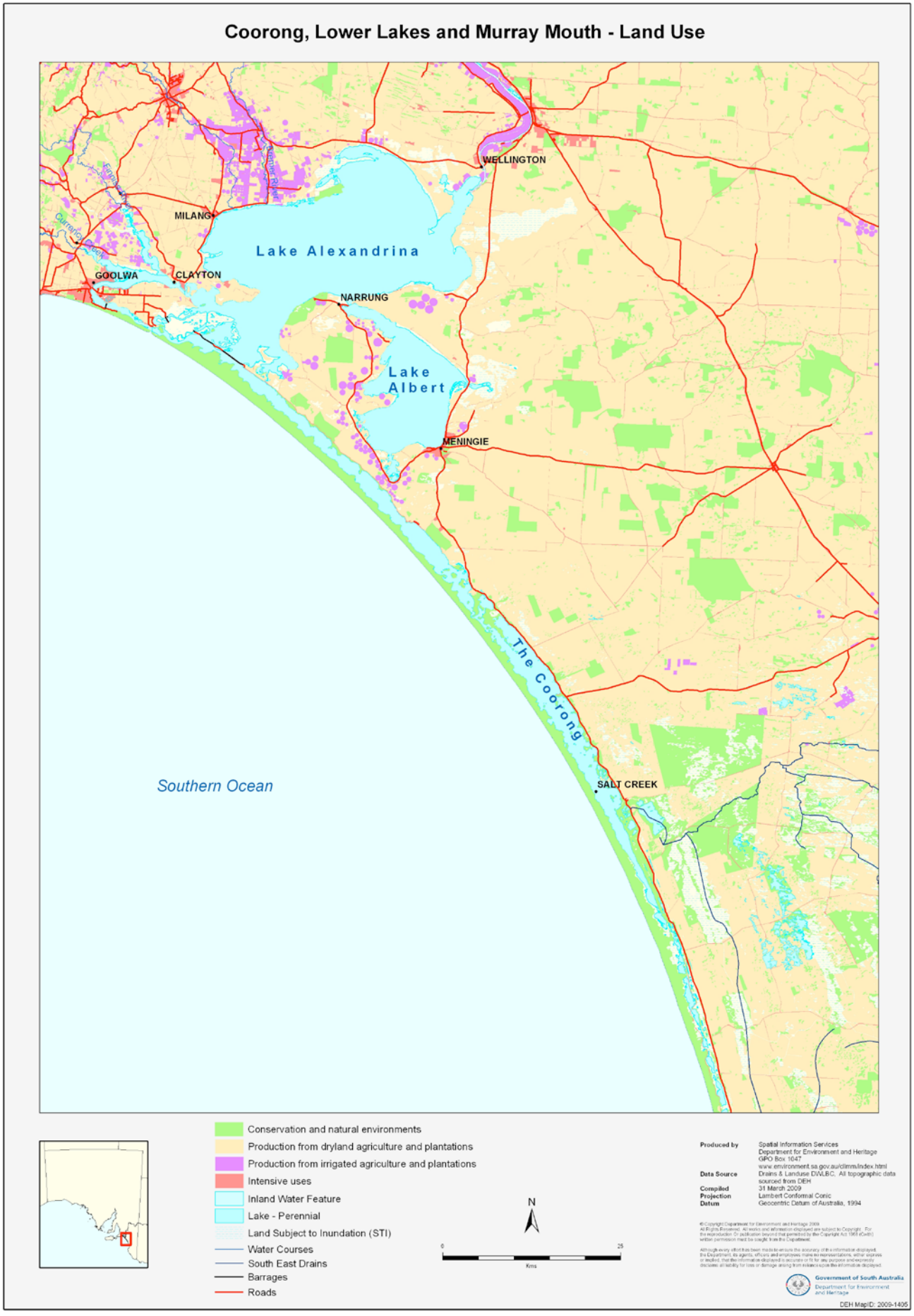
The ten-year integrated package aims to ensure that South Australia will respond proactively to climate change by adopting flexible, adaptive environmental management practices to achieve long-term community, industry and environmental outcomes. It aims to maximise the use of existing environmental water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

Importantly, *Murray Futures* also supports National and Murray-Darling Basin initiatives, in recognition of the shared responsibilities to:

- Address over-allocation
- Address the immediate and worsening crisis in the Lower Lakes and Coorong
- Develop a true 'One River' approach, and
- Set and meet a sustainable target for end-of system flows into the future.

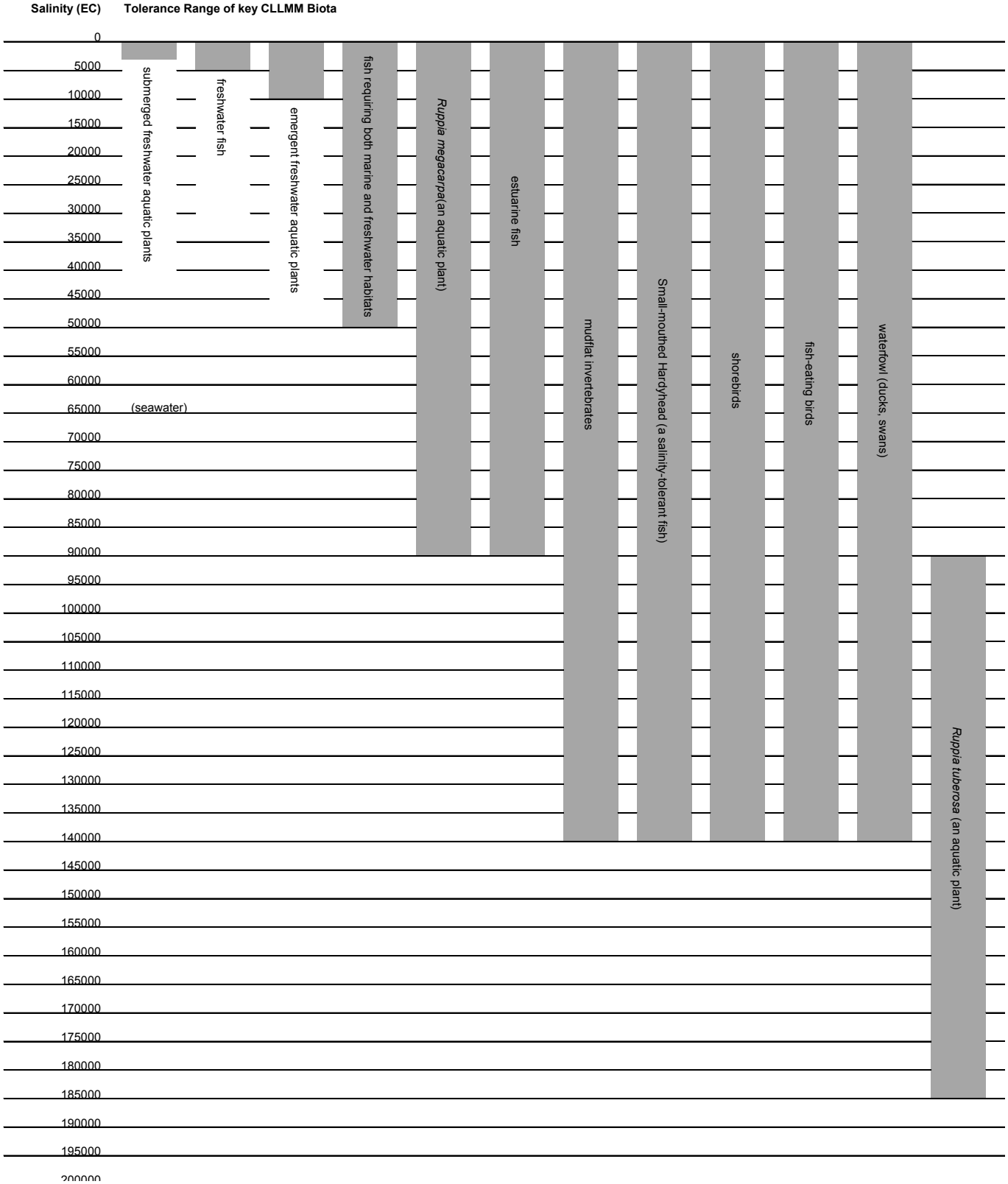
Appendix Four

Land use – Map



Appendix Five

Indicative salinity tolerances for key Coorong, Lower Lakes and Murray Mouth species



Appendix Six

Indicative ecological response to declining water levels and quality

Lake Level (m AHD)	Total Volume (GL) (Lakes Alexandrina and Albert combined)	Total Surface Area (ha)	Average Annual Evaporative Loss (GL)	Measured / Modelled Lake Alexandrina Salinity (EC)	Ecological and Management Implications
0.8	1957	82177	803	400 - 2300	Lower Lakes surcharge level under pre-drought conditions.
0.75	1932	82057	802	400 - 2300	Lower Lakes full supply level.
0.7	1907	81938	800	400 - 2300	
0.6	1825	81753	799	400 - 2300	
0.5	1744	81131	793	400 - 2300	Lower Lakes preferred minimum level under pre-drought conditions. Barrage opening not possible below this level under current operational arrangements, therefore: • fish that require both marine and freshwater habitats are unable to migrate between sea and Lower Lakes and are therefore unable to complete their life cycles; • water level and salinity targets for the Coorong are not met due to inadequate freshwater flows, therefore all Coorong biota (aquatic plants, mudflat invertebrates, fish, shorebirds, fish-eating birds, waterfowl) are threatened; • Dredging required to maintain an open mouth. Mouth closure leads to: ➢ salinisation of estuary and exacerbation of inappropriate salinity and water levels in Coorong; ➢ all Murray estuary biota threatened.
0.4	1662	80143	783	400 - 3000	
0.3	1582	79114	773	400 - 3000	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	1503	78072	763	400 - 3000	
0.1	1425	76985	752	400 - 3000	
0	1348	75688	739	400 - 3000	
-0.1	1273	74262	725	3000	
-0.2	1198	72786	711		
-0.3	1126	71386	697	3250	Lakes Alexandrina and Albert become disconnected at this level, therefore: • fish communities in each lake become isolated.
-0.4	1054	69960	683	3500	

Lake Level (m AHD)	Total Volume (GL) (Lakes Alexandrina and Albert combined)	Total Surface Area (ha)	Average Annual Evaporative Loss (GL)	Measured / Modelled Lake Alexandrina Salinity (EC)	Ecological and Management Implications
-0.5	985	68498	669	4000	Acidification of Lake Albert occurs at this level and lower, therefore: • all biota in Lake Albert threatened. Salinity in Lake Alexandrina exceeds threshold for most freshwater fish: • likely loss of freshwater fish from Lake Alexandrina and tributary wetlands.
-0.6	917	66835	653		
-0.7	851	65067	636	4500	
-0.8	786	63238	618	5000	
-0.9	724	61537	601	5500	
-1	663	59622	582	5750	
-1.1	605	57236	559	6250	
-1.2	550	54024	528	6700	
-1.3	497	51304	501	7000	
-1.4	448	47948	468	7500	
-1.5	402	43753	427	7800	Acidification of Lake Alexandrina occurs at this level and lower, therefore: • all biota in Lake Alexandrina and tributary wetlands (estuarine fish, waterfowl, fish-eating birds) threatened.
-1.6	359	40435	395	8000	
-1.7	318	38649	378	8300	
-1.8	278	37000	361	8700	
-1.9	241	34833	340	8900	
-2	205	32678	319		
-3	3	2978	29		

Appendix Seven

What has been the response to the current challenges?

Dredging to keep the Murray Mouth open

Reduced flows to flush sediment through the Murray Mouth and into the sea means ongoing dredging operations are in place to keep the Murray Mouth open. Currently the Mouth would close without this intervention – and dredging will continue until flows are restored.

The construction of a new $1.3 billion desalination plant

To be located at Port Stanvac, this will substantially reduce South Australia's reliance upon water from the River Murray.

Pumping from Lake Alexandrina into Lake Albert to prevent acidification

In March 2008, low water levels in Lake Albert forced the decision to start pumping water from Lake Alexandrina to Lake Albert at the Narrung Narrows. This will maintain minimum water levels to avoid the potential for soil acidification in Lake Albert.

Protecting South Australia's water supply below Lock 1

A temporary weir near Pomanda Island remains a last resort measure to protect domestic water supplies for 90 percent of South Australians who rely on water from below Lock 1. The two issues are declining water levels and declining water quality. If it had to be built, a temporary weir would maintain a weir pool between Pomanda Island and Lock 1, and would provide a physical barrier to prevent poor quality water moving from Lake Alexandrina into the River Murray. The State Government does not want to build the weir. It would rather allocate the money to long-term projects to secure the State's water supply, but must plan for the worst-case scenario. An environmental impact assessment is currently underway.

Potable pipelines

Pipelines to supply drinking quality water for people and stock at Clayton, Jervois, Langhorne Creek, the Raukkan Aboriginal Community, Narrung and Poltalloch Peninsulas were completed in January 2009.

Construction of an irrigation pipeline

A pipeline to deliver irrigation water to the Langhorne Creek and Currency Creek communities is expected to be completed in time for the 2009/10 irrigation season.

Goolwa Channel regulators to protect freshwater ecosystems from acidification

This project will help manage acidification and prevent irreversible ecological collapse of the Goolwa Channel and wetlands of the tributary freshwater inlets of the Finniss River and Currency Creek. It is proposed that temporary environmental flow regulators across the Goolwa Channel and at the end of Currency Creek and Finniss River will create a pool in the channel. Initially 27.5 gigalitres would be pumped into that pool from Lake Alexandrina to re-wet the main areas of exposed sediments. However, it is anticipated that after the initial pumping, the water level in the Goolwa Channel would be maintained by natural winter inflows from Currency Creek and the Finniss River. The project will prevent further acid production in the Goolwa Channel area and bioremediation will mitigate the impacts of acid that has already been generated.

Bioremediation and re-vegetation to neutralise Acid Sulfate Soils

Trials are underway in two locations within the Lake Albert area to test the effectiveness of revegetation to neutralise the negative impacts of Acid Sulfate Soils. This is a natural way to restore the chemical balance in the soil by decreasing acidity levels. The trial locations are testing which reeds, seedlings and annual grasses will work best to offset potential acidification depending on soil condition. It is expected that suitable revegetation will be part of the solution to help rehabilitate degraded areas of wetlands and exposed lakebeds and build greater resilience in the Lower Lakes for future periods of stress through minimal water flows. Trials using finely ground limestone are also underway to find out how effectively it can increase alkalinity which will buffer acidity. However it is important that remedial actions such as revegetation are well coordinated and based on sound scientific information, so they are effective and do not increase the risk of acidification. Planting the wrong type of plants, or planting in the wrong location, may actually make the Acid Sulfate Soil problem worse by reducing soil moisture in the area. Ultimately, soil moisture content is the key to reducing the risk of acidification, and the best solution is to ensure Acid Sulfate Soils remain wet.

Reducing salinity in the Coorong's South Lagoon

Investigations to divert rainfall run-off from the Lower South-East into the Coorong's South Lagoon are currently underway. It is conservatively estimated that around 50 gigalitres of rainfall could be captured and returned to the Coorong five years in every 10, thus going some way to maintaining the health of the Coorong's South Lagoon. Likewise, other diversions following natural watercourses would return flows to wetlands in the Upper South-East – and it is expected that in big rainfall years some flows could reach as far as the Coorong. Furthermore studies are underway to consider the feasibility of pumping hyper-saline water out of the South Lagoon of the Coorong into the ocean. Creating more tolerable salinity levels would enable the unique and protected hyper-marine system fish stock and flora species to be reintroduced, as well as encourage migratory bird life back to the area.

Considering the ecological implications of the introduction of seawater into the Lakes

Technical investigations are underway as to the ecological impacts of the temporary wetting of the Lower Lakes with seawater to address Acid Sulfate Soils as a last resort measure. The State Government does not want to introduce seawater to the Lower Lakes, but must consider all options for the worst-case scenario. An environmental impact assessment is currently underway.

Coorong and Lower Lakes Community Eco-Action Project

The Goolwa to Wellington Local Action Planning (LAP) Group is being supported to increase community involvement in managing the Coorong and Lower Lakes through the Coorong and Lower Lakes Community Eco-Action Project. This involves a series of workshops and trials to involve the community in helping the area adapt to a rapidly changing environment during the current extreme drought. The LAP group will work closely with the SA Department for Environment and Heritage on identifying and mapping Acid Sulfate Soils, undertaking revegetation trials and investigating ways to protect the Lower Lakes' shorelines.

Appendix Eight

A list of management ideas put forward by scientists and the community

This listing does not represent a final management response, nor does it represent a formal South Australian Government position. Refer to Section 6 for explanatory notes.

Management actions	Rationale	Assumptions	Aspects of ecological character this would protect or enhance	Aspects of ecological character this may compromise
1. Do Nothing	No management intervention is undertaken to increase inflows from the River Murray to the lakes. The barrages are not opened, even temporarily.	Lake levels will continue to drop to -1.5 m AHD in Lake Alexandrina by February 2010 under worst-case scenario modelling. Water will continue to be pumped from Lake Alexandrina to Lake Albert until acidification of the former is imminent, at which time pumping will cease and Lake Albert will receive only regional groundwater inflows. Inflows from Eastern Mount Lofty Ranges tributaries to Lake Alexandrina will dominate water balance, as in recent years, and River Murray inflows to the site will be low for the foreseeable future.	The whole of the site would ultimately be impacted by the 'do nothing option'. First the lakes would salinise, and then as levels fall, acidify, leading to loss of the freshwater components of the system. Rehabilitation through recolonisation of the Lakes upon rewetting will be compromised by acidification, heavy metal toxicity, habitat disconnection and loss of species, assemblages and genetic variance.	Irreversible loss of freshwater ecological character of the Ramsar site. The impact on the Eastern Mount Lofty Ranges tributaries would depend on their flow and acidification rates, with the lowest lying wetlands and the exposed flats between tributaries and lakes being most affected. Ultimately the Murray Mouth estuary and the Coorong lagoons would be affected by lack of freshwater inflows and lack of connectivity with freshwater environments.
2. Secure a minimum of River Murray flows past Wellington to prevent acidification of both Lakes.	Freshwater delivered to the site is the preferred option for preventing acidification and promoting rehabilitation of ecological character. This option is limited by water availability to the site from the upstream sections of the Murray and Darling Rivers and the Eastern Mount Lofty Ranges tributaries. It may also be limited by future climate patterns.	Acidification of the water bodies will be prevented by keeping ASS below -1.5 m AHD submerged with sulfate-poor fresh water. Lower Lakes integrated pipeline in place. Bioremediation of exposed ASS around Lake edges from +0.6 m AHD to water level (-1.5 m AHD in Lake Alexandrina and -0.5 m AHD in Lake Albert). Pumping to Lake Albert can continue until additional freshwater flows are secured without causing acidification of Lake Alexandrina. Avoids loss of fish and other aerobic organisms from the water column.	Prevention of acidification will enable more rapid and complete rehabilitation of freshwater component of ecological character. Provision of freshwater will sustain the freshwater ecological components until Lakes recover to long-term target of water levels between +0.3 to +0.6 m AHD and freshwater salinities below 800 EC.	Freshwater fish will be able to access only unvegetated, open water habitats with poor connectivity. Murray Mouth estuary and the Coorong lagoons will remain disconnected. Diadromous species will be unable to complete life cycles. When Lakes are full enough to discharge to the Murray Mouth and estuary, the pollutants leaving the Lakes will need to be managed to minimise harm to downstream environment.

Management actions	Rationale	Assumptions	Aspects of ecological character this would protect or enhance	Aspects of ecological character this may compromise
3. Secure greater freshwater inflows from the River Murray, Eastern Mount Lofty tributaries and on-site re-allocations that allow for recovery of Lake levels to greater than +0.3 m AHD.	Protect threatened habitats and biota to secure Ramsar values. Submerge ASS and promote sulfidic conditions. Build resilience of ecosystem to climate change impacts. Secure ecosystem services derived from the site.	Australian Government buy-back delivers additional flows to Coorong and Lakes. South Australia's water savings initiatives on the lower Murray yield additional flows. Lower Lakes integrated pipeline in place. Water levels in the Lakes will be managed primarily for ecological benefit in long-term (beyond 2012 target +0.3 to +0.6 m AHD). Flows from Eastern Mount Lofty Ranges tributaries are not further reduced and natural variation retained. Additional inflows from South East region delivered during high flow periods as part of regional plan. On-site water savings achieved through integrated pipeline and operating the Lakes at lower levels.	All elements of ecological character in both the freshwater and saline areas of the site likely to benefit unless the short-term goals are not met and species or ecological functions are lost.	When Lakes are full enough to discharge to the Murray Mouth and estuary, the pollutants leaving the Lakes will need to be managed to minimise harm to downstream environment.
4. Bioremediation of exposed ASS – direct seeding with crops or revegetation.	Bioremediation of exposed ASS using direct seeding of crops or native seed will promote sulfidic conditions and reduce mobilisation of heavy metals. This will prime the exposed ASS for other management options such as inundation of exposed ASS with freshwater.	The provision of carbon (as decomposing plants), and growth of the plants themselves, will promote sulfate reduction and reduce risk of acidification and heavy metal mobilisation. Plants will either not take up heavy metals or will contain them within the root zone, thus reducing the mobilisation of heavy metals into the water and air (via dust). Application methods are practical and effective. Sufficient and appropriate seed available. Plants are established with consideration for promoting freshwater-brackish habitat and suppressing weed species.	Bioremediation of ASS sites to re-establish vegetation communities for Lake edge rehabilitation and recharge the carbon cycle leading to fundamental shift to a recovery phase for ecological character. Enhanced growth of terrestrial plants, herbland species and reeds. Enhanced habitat for macroinvertebrates and migratory birds around Lake edges and on exposed lakebed.	Freshwater fish will be able to access only unvegetated, open water habitats with poor connectivity. Murray Mouth estuary and the Coorong lagoons will remain disconnected. Diadromous species will be unable to complete life cycles. When Lakes are full enough to discharge to the Murray Mouth and estuary, the pollutants leaving the Lakes will need to be managed to minimise harm to downstream environment.
5. Bioremediation of exposed ASS – mulch.	Bioremediation of exposed ASS using mulch will promote sulfidic conditions and reduce mobilisation of heavy metals. This will prime the exposed ASS for other management options such as inundation of exposed ASS with freshwater.	The provision of carbon (as mulch) will promote sulfate reduction and reduce risk of acidification and heavy metal mobilisation. Application methods are practical and effective. Sufficient and appropriate mulching materials available.	Bioremediation of ASS sites to re-establish vegetation communities for Lake edge rehabilitation and recharge the carbon cycle leading to fundamental shift to a recovery phase for ecological character. Enhanced growth of terrestrial plants, herbland species and reeds in the mulched areas leading to enhanced habitat for macroinvertebrates and migratory birds around Lake edges and on exposed lakebed.	Freshwater fish will be able to access only unvegetated, open water habitats with poor connectivity. Murray Mouth estuary and the Coorong lagoons will remain disconnected. Diadromous species will be unable to complete life cycles. When Lakes are full enough to discharge to the Murray Mouth and estuary, the pollutants leaving the Lakes will need to be managed to minimise harm to downstream environment.

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Management actions	Rationale	Assumptions	Aspects of ecological character this would protect or enhance	Aspects of ecological character this may compromise
6. Liming of exposed lakebeds.	Application of lime as finely ground particles will neutralise acid that has been generated and will promote sulfidic conditions and the re-establishment of keystone plant and faunal species.	Sufficient lime can be sourced and applied to acid generating soils as well as directly to the water column in a practical and efficient manner. Lime does not form crusts on the soil that will prevent plant establishment and faunal colonisation. Addition of lime to the water will not lead to losses of fish and other water-borne biota. Avoids loss of fish and other aerobic organisms from the water column.	Prevention of acidification of the water column will enable more rapid and complete rehabilitation of freshwater component of ecological character. Neutralisation of acid in exposed ASS will promote colonisation of plants and animals.	Freshwater fish will be able to access only unvegetated, open water habitats with poor connectivity. Murray Mouth estuary and the Coorong lagoons will remain disconnected. Diadromous species will be unable to complete life cycles. When Lakes are full enough to discharge to the Murray Mouth and estuary, the pollutants leaving the Lakes will need to be managed to minimise harm to downstream environment.
7. Lower Lakes integrated pipeline	Remove reliance of agriculture sector and domestic water users from the Lakes. Provide better quality water to irrigators and domestic users. Allow for greater flexibility with managing water levels in Lakes for ecological benefits.	Agriculture sector and domestic users will receive greater certainty of water supply and quality through the pipeline. Lake water level manipulation has been limited by the need to surcharge in winter/spring to ensure adequate water to supply requirements for irrigation and domestic users over summer. River Murray inflows will be provided to the Lakes for recovery of ecological character. Water levels will be managed primarily for ecological benefit in long-term (beyond 2012 target +0.3 to +0.6 m AHD). Water saved through reducing the operational volume of the Lakes and evaporative losses would be used to benefit the ecological character of the site as a whole (e.g. barrage releases, targeted inundation and connectivity).	Uncoupling the Lakes' water supply functions from ecological management provides an opportunity to operate the Lakes under more natural variability regimes (particularly with regard to seasonal changes in water levels). This will promote rehabilitation of the freshwater ecology and Ramsar values of the Lakes. It will also allow for greater volumes to be released through the barrages at lower levels with greater flexibility to meet key ecological needs such as fish passage. Less static Lake levels in spring and summer will stimulate growth of more complex keystone aquatic plant and macroinvertebrate communities; reduce erosion, thereby reducing turbidity and improve habitat connectivity in some locations. Re-vitalising the plant communities will have significant flow-on biodiversity benefits.	Important to ensure that installation of the pipeline does not reduce priority for River Murray freshwater delivery to the site. Inflows are still required to ensure no loss of freshwater ecological character. Continuing reduced flows would also further compromise the Coorong components where lack of flows is converting these estuarine environments into simplified marine systems.
8. Construct a (temporary) structure at Clayton.	A barrier from the mainland to Hindmarsh Island near Clayton will address ASS in the tributaries by allowing tributary water to be captured and pooled so as to inundate ASS and prevent formation of acid and heavy metal salts. Additional water to be pumped from Lake Alexandrina into the ponded area if required.	Sufficient water is available from the tributaries and from Lake Alexandrina to inundate ASS to a level that prevents acidification of the water in the tributary wetlands. Any Lake Alexandrina water pumped into the ponded area will be sufficiently low in salinity to not promote formation of more ASS, nor cause losses of freshwater character. Construction and operation will not cause ecological harm through processes such as ASS disturbance, scouring of the channel or increased turbidity.	Provision of a freshwater refuge in the ponded area is likely to enhance the freshwater ecological components found there and may act as a store for freshwater plants and animals that could recolonise the Lakes environment once Lake levels have been recovered to +0.3 m AHD and salinities are suitable (e.g. less than 1,000 EC).	Movement of fish and other ecological components will be compromised by construction of the regulator. May be able to manage Dunn's Lagoon and other local ecological hotspots. False salinity gradients may be established that may cause fish to move in the wrong direction and perish due to high salinities or fatigue.

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Management actions	Rationale	Assumptions	Aspects of ecological character this would protect or enhance	Aspects of ecological character this may compromise
9. Construct (temporary) blocking banks across Finniss River and Currency Creek.	Isolate and conserve the freshwater ecosystems in the wetlands of the tributaries: Finniss River Tookayerta Creek and Currency Creek.	Insufficient freshwater in the system to protect all freshwater assets, therefore protect the areas with greatest diversity, healthiest keystone species and hope that recolonisation will occur once Lake water and salinity levels recover. Water level in this section can be maintained at a minimum of +0.3 m AHD and salinities below 1500 EC. Care taken to avoid displacing sulfidic soils during construction. Lower Lakes integrated pipeline in place. The structure can be used to slow water, potentially containing acid and heavy metals, entering Lake Alexandrina from the tributaries and allow for bioremediation.	Conserve limited habitat for Murray Hardyhead, Yarra pygmy perch and other freshwater species. Possible protection for Eastern Mount Lofty Ranges tributary wetlands (dependent on flow regime and capacity to counter upstream seawater movement from Goolwa channel).	Possibly reversible loss of freshwater ecological character of Dunn's Lagoon, Lake Alexandrina and lower River Murray channel from disconnection of freshening tributary inflows.
10. Construct a (temporary) structure at or near Laffin's Point and fill Goolwa channel with seawater.	Temporary barrier to prevent upstream movement of seawater if a lock in the barrages was opened for recreational boating use, and to assist regional economy.	Lake levels remain below level needed to open Goolwa Barrage. Lower Lakes integrated pipeline in place. Care taken to avoid displacing sulfidic soils during construction and operation. Seawater can be introduced at Mundoo, or other barrages, to mitigate acidification risk in Lake Alexandrina as effectively as at Goolwa, if Actions 9 or 10 were implemented. Water levels downstream of structure are maintained at +0.3 to +0.7 m AHD to allow for boating use. Salinities vary from 5,000 to 60,000 EC.	Inundation of ASS with seawater to prevent further generation of acid and heavy metal salts and prevent dust blowing over Goolwa township and surrounds. Risk of increasing mono-sulfidic black ooze is likely to counteract any benefits of above. Possible protection of the freshwater ecological character of Lake Alexandrina and the Eastern Mount Lofty Ranges tributaries, which would otherwise be threatened by seawater moving upstream from Goolwa channel. *Note*: Goolwa channel salinities currently reach around 30,000 EC over summer due to reverse head driving seawater movement through dunes. Increased habitat range for estuarine species for the period that salinities stay at estuarine levels.	Possibly reversible short-term loss of freshwater and estuarine ecological character of Goolwa channel through conversion to habitat of marine salinities. May lead to loss of vulnerable species (e.g. freshwater fish and plants). Will further interrupt fish passage between fresh and estuarine/saline system units unless passage provided. May lead to recharging of the regional groundwater with seawater resulting in irreversible damage and increase in sulfate supply to ASS in Lakes and tributary wetlands.

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Management actions	Rationale	Assumptions	Aspects of ecological character this would protect or enhance	Aspects of ecological character this may compromise
11. Allowing seawater into the lakes – permanently	Introduction of seawater to sea level (+0.1 to +0.2 m AHD) may mitigate Acid Sulfate Soils (ASS) impacts in lakes by keeping sediments wet. See caveat at right regarding risks posed to shoreline areas and potential formation of more ASS.	Lake levels continue to fall to below acidification trigger of -1.5 m AHD in Lake Alexandrina and no freshwater is available to increase Lake level. Seawater holds Lake level at approximately +0.1 to +0.2 m AHD through open barrages. Wind seiching of ± 50 cm and storm surges are major drivers of water level variation. Salinities increase to more than 60,000 EC within 12 months of introduction in the formerly freshwater lakes. Permanent weir built at Pomanda Point to protect South Australia's water supplies from upstream movement of seawater. Regulators built on Eastern Mount Lofty Ranges tributary streams to prevent upstream movement of seawater (See above). Lower Lakes integrated pipeline in place for agriculture and domestic users.	The freshwater wetland part of the system would be 'sacrificed'. Modelling indicates a rapid increase in salinity that may preclude positive outcomes for estuarine components. Estuarine components will be enhanced only temporarily due to salinities rapidly increasing to greater than 60,000 EC (hypersaline). Seagrasses are poor colonisers and unlikely to establish in highly turbid and energetic water column. Therefore, establishment of a healthy estuarine ecosystem is highly unlikely. Tube worms are likely to proliferate in the lakes at high salinity concentrations. Connectivity between the Lakes, the Murray Mouth and the Coorong would be reinstated, but the freshwater habitat would be lost, thus making migration unfavourable. Conditions would, overall, tend towards the current hypersaline condition of the Coorong lagoons.	Irreversible loss of freshwater ecological character of the Ramsar site. Increased sulfate supplies likely to promote formation of most powerful ASS, Monosulfidic black ooze. Wind driven wave action likely to generate significant sulfuric acid and heavy metals around shoreline due to wind seiching, even if main Lakebed is kept submerged. Salt crust will form around lake margin, inhibiting growth of saline tolerant plants. Those wetlands that sit above sea level around the Lakes would have to be sacrificed under this option, or freshwater would need to be pumped into them over the long-term to retain their original freshwater Ramsar values. Estuarine species entering Lakes likely to perish from entrapment along false salinity gradients and/or hypersaline conditions.
12. Allowing seawater into both Lakes – temporarily (a 'shandying' effect)	Designed to maintain Lake levels above critical 'tipping point' for acidification (-1.5 m AHD in Lake Alexandrina) using a combination of River Murray water and seawater.	Lake levels continue to fall to near acidification trigger or to below level for stopping pumping to Lake Albert. Pumping to Lake Albert will cease, causing salinisation and acidification. Lake Alexandrina salinity levels will range from 25,000 to 60,000 EC. Assumed that the "dilution flow" of 350 GL of River Murray will be insufficient to prevent seawater entering River Murray channel; therefore temporary weir at Pomanda Point will be required. Lower Lakes integrated pipeline in place. Eastern Mount Lofty Ranges tributaries disconnected at -1.5 m AHD. Seawater incursions to tributaries may still come through sand dunes/groundwater into tributary wetlands even if structures in Actions 6 and 7 are constructed.	The freshwater wetland part of the system likely to be 'sacrificed' even if seawater intrusion is temporary. Modelling indicates a rapid increase in salinity to more than 60,000 EC within 12 months of introduction in the formerly freshwater Lakes. This is highly likely to preclude positive outcomes for estuarine components. Estuarine components will be enhanced only temporarily, due to salinities rapidly increasing to greater than 60,000 EC (hypersaline). Seagrasses are poor colonisers and unlikely to establish in highly turbid and energetic water column. Therefore, establishment of a healthy estuarine ecosystem is highly unlikely. Tube worms are likely to proliferate in the Lakes at high salinity concentrations. Connectivity between the Lakes, the Murray Mouth and the Coorong would be reinstated but the freshwater habitat would be lost, thus making migration unfavourable. Conditions would, overall, tend towards the current hypersaline condition of the Coorong lagoons.	Only likely to reverse ecological damage to freshwater ecological character of the Lake Alexandrina part of the Ramsar site if seawater were introduced for less than 6 months. The longer and more extensive the intrusion, the more difficult it will be to reinstate a functional and diverse freshwater system, if at all. See above in relation to shoreline impacts and on those wetlands that sit above sea level around the Lakes. Lake Albert is likely to become acidified if pumping from Lake Alexandrina ceases under this option. Estuarine species entering Lakes likely to perish from entrapment along false salinity gradients and/or hypersaline conditions.

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13. Allowing seawater into Lake Albert temporarily	Cease pumping water from Lake Alexandrina into Lake Albert, and provide seawater into Lake Albert from the Coorong to mitigate ASS problem.	Lake levels continue to fall to below acidification trigger (-0.5 m AHD for Lake Albert) and pumping from Lake Alexandrina ceases. Bunding between lakes prevents seawater intrusion from Lake Albert into Lake Alexandrina. Minimal seawater introduced to Lake Albert to maintain water levels at -0.5 m AHD. Lake Albert salinities will range from 40,000 to 65,000 EC. Assume that it is hydrologically possible to introduce seawater into Lake Albert from the Coorong. Lower lakes integrated pipeline in place.	Lake Albert's ecological character expected to respond as above under actions 11 and 12. Water 'saved' from stopping pumping would be available to maintain refugia and delay Lake Alexandrina levels dropping to acid tipping point (-1.5 m AHD). Connectivity between Lake Albert, the Murray Mouth and the Coorong would be created but the freshwater habitat would be lost, thus making migration unfavourable. Conditions would, overall, tend towards the current hypersaline condition of the Coorong lagoons.	Lake Albert's ecological character expected to respond as above under actions 11 and 12. Seawater inputs likely to promote formation of Monosulfidic black ooze and therefore promote acidification. Estuarine species entering lakes likely to perish from entrapment along false salinity gradients and/or hypersaline conditions.
14. Connecting Lake Albert to the Coorong's North Lagoon (one way flow option into the Coorong)	High River Murray flows from Lake Alexandrina could be delivered directly to the North Lagoon via Lake Albert.	Sufficient River Murray flows will enter the site to allow for discharge of water to the Coorong, while maintaining the lakes above the threshold for acidification (-0.5 m AHD). Salinities in the lakes would not exceed 1,500 EC. NB: Lake Albert water is already higher than this threshold.	Freshwater inputs to the North Lagoon from Lake Albert should help reduce salinity and thus assist recovery of keystone aquatic plants and the food webs these support. Fresher water moving into the Coorong may also assist with its recovery, depending on water quality.	Increased transport of sediments to the Coorong may increase suspended solids and smother mudflats, alter energy pathways, and otherwise threaten aspects of ecological character. Mobilisation of acid and heavy metals into Coorong may compromise health of a range of biota and contaminate consumptive fish species. Flow dynamics in Lake Albert will be changed leading to altered patterns of scouring and sedimentation. Disturbance of sulfidic materials may increase acidification potential.
15. Connecting Lake Albert to the Coorong's North Lagoon (two-way flow option)	Envisaged as a long-term climate change adaptation strategy to allow seawater from the North Lagoon to flow back into Lake Albert.	Assumption is that this would convert Lake Albert into an estuarine system with salinities ranging from 35,000 EC to 60,000 EC depending on freshwater inflows. Regulator at Narrung Narrows in place to prevent Lake Alexandrina also becoming estuarine.	The freshwater wetlands of Lake Albert would be sacrificed in favour of an assumed increased area of estuarine wetlands along with their associated fish communities, shorebird habitats etc. The rapid changes in salinity that would occur are highly likely to prevent establishment of a healthy estuarine ecosystem. Condition would tend towards the current hypersalinity of the Coorong lagoons unless significant River Murray flows were available, in which case employ Option 3.	Loss of freshwater ecological character of the Lake Albert component of the Ramsar site. Increased sulfate supplies and wind driven wave action likely to increase potential for acidification. Increased transport of sediments to Coorong and Murray Mouth may smother mudflats, alter energy pathways, increase sedimentation around the Mouth and otherwise threaten the ecological character. Mobilisation of acid and heavy metals into Coorong may compromise health of a range of biota and contaminate consumptive fish species. It is likely that with limited tidal flushing due to the narrow connecting channel of the Coorong, Lake Albert would become a hypersaline system similar to that of the Southern Coorong Lagoon currently.

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16. Dry out (and remediate) Lake Albert	Cease pumping water from Lake Alexandrina into Lake Albert, allow it to dry out and remediate with lime, mulch and direct seeding in Actions 4, 5 and 6 above. Convert Lake Albert to a "bioremediation basin" with patches of ephemeral wetland or swamp. Water savings of up to 200 GL per year to be reallocated across the site.	Lake levels continue to fall to below acidification trigger. Groundwater inflows are not significant enough to prevent drying out to -0.5 m AHD. Hypersaline conditions will persist in standing water. Pumping from Lake Alexandrina to Lake Albert ceases and bunding remains in place to prevent interchange. Lower Lakes integrated pipeline in place. Bioremediation of the Lakebed is effective at preventing acidification.	Loss of freshwater ecological components from this part of the Ramsar site. Possible establishment of salt- tolerant plants. If *Melaleuca halmatuorum* woodlands established, that may benefit wading birds and also possibly Orange-bellied parrots. Significant threat to this from discharges of saline groundwater, which may prevent "drying" out of ASS affected areas.	Likely irreversible loss of freshwater ecological character of the Lake Albert part of the Ramsar site. Discharging groundwater is likely to provide fresh sulfide to ASS, which coupled with the drying process, may enhance production of sulfuric acid and heavy metal mobilisation from ASS. This may limit future management actions.
17. Pumping out of South Lagoon of the Coorong (approx 50 GL) with refilling from seawater.	Immediate reduction of salinity in Coorong lagoons below thresholds for keystone species, to stimulate recovery.	Without some immediate intervention, salinity concentrations in the South Lagoon of the Coorong will continue to rise and the remaining ecological character will be lost from this part of the Ramsar site. Complementary works will be undertaken, such as dredging of Murray Mouth or junction between the North and South Lagoon if required. It is likely that multiple pumping locations will be needed and that pumping will occur over several years.	Rehabilitation of *Ruppia* keystone plant communities and with it small-bodied native fish, shorebirds etc Prevent local extinction of shorebirds and fish. ASS risk during pumping out phase may need to be managed to prevent impacts on refilling.	Depending on disposal site may impact on near and offshore marine communities through saline water disposal.
18. Diversion of water from the Upper South East Drainage scheme (USED) into the Coorong via Salt Creek.	Possible reduction in salinity in South Lagoon depending on volume, quality and timing of inflows. Restoration of original fresh surface water flow path from wetlands of USE to the South Lagoon of the Coorong. Note – drainage of USED water to the sea and reduced freshwater (including groundwater) inputs are lower than original which will compromise capacity to keep salinity below seawater concentrations.	It is unlikely that in its current configuration, the USED scheme would be able to provide sufficient freshwater flows to South Lagoon to significantly reduce salinity, given that current salinity levels in the South Lagoon are greater than 5 times seawater concentrations. Additional water to that currently captured by the USED scheme can be delivered to the South Lagoon of the Coorong by preventing loss of water to the sea or by connecting more drains to the scheme. Investigation proposed into regulator between North and South lagoons to give opportunities for more refined manipulations of levels and flows.	Potential to create salinity regime in South Lagoon that is more spatially variable and lower in peak salinity. Re-establish flow from the South Lagoon, through North Lagoon and toward the Murray mouth as described by the Ngarrindjeri. Rehabilitation of *Ruppia* keystone plant communities and with it small-bodied native fish, shorebirds etc	Removal of water from wetlands in the USED may reduce their health and compromise the capacity of the South East of South Australia to support current ecological assets. Risk of damaging small-bodied native fish populations that now take refuge in the drains. Also risk introduction of pest plants and animals. Disturbance of groundwater flow paths in constructing new drains to connect flow paths may also cause ecological harm and may interrupt groundwater flow in remaining freshwater soaks along mainland side of Coorong.

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19. Maintain an open Murray Mouth.	An open Murray Mouth is critical to the hydrology of the Murray Mouth Estuary and the Coorong lagoons, regardless of whether freshwater is being released through the barrages.	In times of no or low flow through barrages, tide signal through the Murray Mouth is the main driver of water level change in the Coorong lagoons. Continuous dredging of the Murray Mouth will continue until flows through the barrages are adequate to prevent closure or significant obstruction of the Murray Mouth.	Adequate transfer of the tidal signal through the Murray Mouth allows for the Coorong lagoons to drain as well as receive water from the sea, thus maintaining keystone *Ruppia* spp. beds and allowing wader birds access to the mudflats. This action in itself is unlikely to secure ecological character to the Coorong but if it were not continued there would be immediate collapse of remaining components of ecological character in North Lagoon. South Lagoon is not currently able to support keystone species such as *Ruppia*. Therefore this action cannot be implemented alone rather requires other intervention such as the pumping suggested in Action 13 or the inflow of water from USED in Action 14.	If the Murray Mouth is closed or significantly obstructed, the water level in the Coorong lagoons rise incrementally following periods of storm activity or high tide because more seawater enters than leaves the lagoons. This causes losses of the keystone plant, *Ruppia* spp., and prevents wader birds accessing macroinvertebrates in the mudflats.
20. Installation of fish passages.	Fish passages such as vertical slot or rock ramps are essential structures to enable fish movement between parts of the Ramsar site that have been disconnected through the construction of barrages, weirs, regulators and other devices.	Many of the fish species that occupy the Ramsar site have requirements to move between seawater and freshwater to complete their life cycles (e.g. diadromous fish) or to opportunistically feed on abundant prey or require freshwater pulses to stimulate breeding. Lack of fish passage effectively disconnects the fresh and estuarine/ saline parts of the Ramsar site unless the Lake levels are high enough to allow for opening of most or all barrages gates (i.e. +0.7 or higher). Other biota are dependent on connection between the Lakes to enable colonisation of new habitats, and it is assumed that these propagules and adults will use the fish passages if provided.	Rehabilitation of fish communities, prevention of loss of diadromous fish species and stimulus of a greater range of age classes in species that are vulnerable to loss because of simplified cohort structure. Benefits for other biota such as plants and macroinvertebrates that can move between parts of the Ramsar site and colonise new, or recolonise existing, but degraded habitats.	When fish passages are operational, the pollutants leaving the Lakes will need to be managed to minimise harm to downstream environment.

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21. Permanent regulator at Narrung Narrows.	Allow for semi-independent manipulation of water levels in the two Lakes. This may result in better water quality in one or both of the Lakes depending on flows, timing and source water. Likely also to be water savings. Opportunities for implementation of other actions such as controlled bioremediation of ASS or connection of Lake Albert to the sea via Coorong without affecting Lake Alexandrina.	Enough River Murray and Eastern Mount Lofty Ranges flows will enter the site to allow for manipulation of water levels above the threshold for acidification. Salinities maintained below 1,500 EC in both Lakes at all times in order to secure freshwater ecological components. Water savings from this option dedicated to helping recover the ecological character of the Ramsar site.	Outcomes will depend on water regime. Variable levels above +0.5mAHD would better support fringing vegetation and keystone aquatic plants leading to recovery of native fish and bird communities. Levels below +0.5mAHD will assist with establishment of vegetation to bioremediate ASS, which will also be managed through water level manipulation.	Operation may hinder movement of fish and other biota between Lakes, although movement is currently blocked by bunding. Blocking bank would limit wind-induced flushing from Lake Albert to Lake Alexandrina.
22. Remedial works to improve connection at Narrung Narrows.	Infrastructure at the Narrung Narrows associated with the ferry has decreased connectivity between the Lakes, leading to build up of sediments and extensive reed growth.	Removal of the causeway and other infrastructure on the lakebed will improve connection between Lakes Alexandrina and Albert. This will improve water flow, which in turn will reduce accumulation of sediments, lead to better transfer of water level changes between the Lakes and improve water quality in Lake Albert. That any dredging or earth works are undertaken so as to avoid ecological harm. Also that Lake levels are greater than -0.5 m AHD which is the trigger for acidification of Lake Albert. Restricted flow promotes sedimentation and simplification of the aquatic flora, which in turn simplifies the faunal communities.	Outcomes will depend on water regime and water quality. Improved connection is likely to improve movement of fish and other biota between the Lakes leading to increased ecological resilience from outbreeding. Water quality in Lake Albert also likely to improve which will positively impact on all freshwater components of ecological character. Greater variability and flow rates around the Narrung Narrows are likely to increase aquatic plant diversity with flow-on benefits to wader birds and other fauna that do not favour mono-stands of *Phragmites australis*.	Unlikely to compromise any components of ecological character unless sediments disturbed during construction lead to increased turbidity or exposure of ASS.
23. Construct artificial islands in Lake Alexandrina.	Natural island habitats in the southern parts of Lake Alexandrina have very high ecological value; therefore creating artificial islands may improve habitat availability.	Island habitats will contain flowing freshwater creeks and suitably shallow gradients into the water that will support establishment of keystone aquatic plants.	Wader birds and small-bodied freshwater fish may benefit, depending on the topography and plant species established on and around the islands.	Changes to sedimentation and erosion patterns are likely to increase turbidity, which will adversely impact on many freshwater ecological components. Construction also likely to expose and disturb ASS which may lead to acidification and loss of fish and other aerobic fauna.

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24. Desalinisation of seawater for introduction to Lakes Alexandrina and Albert.	Lack of freshwater inflows to the site have compromised its ecological character. Desalinisation of seawater could provide a large source of freshwater to the site.	Enough freshwater could be generated via desalinisation to reduce salinities in the Lakes to 800 EC or less, thereby promoting the recovery of the full suite of freshwater ecological components.	All freshwater ecological components would be enhanced by controlled reduction in the salinity of the water to less than 800 EC.	Desalinisation plants generate volumes of hypersaline effluent commensurate with the volumes of freshwater provided. It could also wash back into the Murray Mouth and cause salinisation of the Murray Mouth estuary. Noise and vibration are also likely to negatively impact on fish and birds, in particular.
25. Contain River Murray channel within levee banks between Wellington and Murray Mouth and convert lakebed to agriculture.	Conserve water through reducing evaporation and enhance local agriculture.	Channelized flow will be better at maintaining an open Murray Mouth.	Minor improvements to water quality may benefit some fish species, although adverse impacts on keystone species likely to result in overall adverse impact on fish.	All freshwater and estuarine components are likely to be adversely impacted. The Lakes biota are dependent on variable water levels across shallow beds of plants that are unlikely to be supported by channelizing the water. Erosion, sedimentation and turbidity are likely to increase and the channel may not be stable. It will also be susceptible to severe erosion during flood flows that may cause deoxygenation of the water column and loss of fish and other aerobic biota.
26. Create a major canal housing development for Lake Alexandrina.	No rationale for improving ecological character provided.	Unknown.	None.	All freshwater components likely to be adversely impacted upon. Unlikely to enhance any aspects of ecological character given that human induced impacts on system have already caused major damage.
27. Install a permanent weir and lock south of Tailem Bend.	Weir and lock would be built to secure domestic and irrigation water supplies.	River and Lakes would be permanently disconnected. Suitable solid base could be found for new lock and weir to be built on.	None.	Unlikely to enhance any aspects of ecological character. All freshwater components likely to be adversely impacted upon. Disturbance of ASS and potential acidification of Lakes.

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28. Operate barrages to allow for slow ingress and rapid egress of seawater.	Introduction of seawater to sea level (+0.1 to +0.2 m AHD) may mitigate Acid Sulfate Soils (ASS) impacts in Lakes by keeping sediments wet. See caveat at right regarding risks posed to shoreline areas and potential formation of more ASS.	Lake levels continue to fall to below acidification trigger of -1.5 m AHD in Lake Alexandrina and no freshwater is available to increase Lake level. Seawater holds Lake level at approximately +0.1 to +0.2 m AHD through open barrages. Wind seiching of ± 50 cm and storm surges are major drivers of water level variation. Slow ingress and rapid egress would promote effective flushing of Lake Alexandrina with seawater. Salinities still likely to increase to more than 60,000 EC within a year or two from evapoconcentration. Permanent weir built at Pomanda Point to protect South Australia's water supplies from upstream movement of seawater. Regulators built on Eastern Mount Lofty Ranges tributary streams to prevent upstream movement of seawater (See above). Lower Lakes integrated pipeline in place for agriculture and domestic users.	The freshwater wetland part of the system would be 'sacrificed'. The increase in salinity may be less rapid than in Action 9, but it is likely that there would be few positive outcomes for estuarine components. Estuarine components will be enhanced only temporarily due to salinities increasing to greater than 60,000 EC (hypersaline). Seagrasses are poor colonisers and unlikely to establish in highly turbid and energetic water column even if salinities are favourable. Therefore, establishment of a healthy estuarine ecosystem is highly unlikely. Tube worms are likely to proliferate in the lakes at high salinity concentrations. Connectivity between the Lakes, the Murray Mouth and the Coorong would be reinstated, but the freshwater habitat would be lost, thus making migration unfavourable. Conditions would, overall, tend towards being marine or hypersaline.	Irreversible loss of freshwater ecological character of the Ramsar site. Increased sulfate supplies likely to promote formation of most powerful ASS, Monosulfidic black ooze. Wind driven wave action likely to generate significant sulfuric acid and heavy metals around shoreline due to wind seiching, even if main lakebed is kept submerged. Salt crust will form around lake margin, inhibiting growth of even the most saline tolerant plants. Those wetlands that sit above sea level around the Lakes would have to be sacrificed under this action, or freshwater would need to be pumped into them over the long-term to retain their original freshwater Ramsar values. Estuarine species entering Lakes likely to perish from entrapment along false salinity gradients and/or hypersaline conditions.
29. Engineer Lake Alexandrina to become a marine lake with a freshwater margin.	Build a bund around the entire margin of Lake Alexandrina and fill the centre with seawater via the barrages and allow freshwater to flow around edges.	It can physically be built on soft sediments and that bank material will be able to withstand wind and tides and not collapse. That seawater will not move through the banks and into the surrounding freshwater.	None or very few transient positive outcomes for estuarine components. See above.	Disturbance of ASS are likely to cause acidification of water body leading to loss of fish and other aerobic biota. High rates of evaporation from very shallow margins mean that freshwater area is unlikely to be maintained. Central marine lake is likely to become hypersaline and therefore estuarine species entering lakes likely to perish from entrapment along false salinity gradients and/or hypersaline conditions.
30. Relocate Murray Mouth 30km south and construct channel from South Lagoon to the sea.	Relocate Murray Mouth away from River Murray channels and islands and create another channel through the dunes. This might allow for seawater to flush out the Coorong Lagoons.	It can physically be done. Ngarrindjeri would allow for cutting through dunes in terms of cultural damage. That once created these new connections could be maintained.	None. Salinities in the Coorong would presumably drop to marine/hypersaline depending on flushing efficiency but salinity gradients unknown.	The estuarine part of the system would be 'sacrificed'. There would be no capacity to reduce salinity to below seawater concentrations; therefore, it would be converted to a marine system. Losses of remaining keystone species.

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31. Increase height of barrages and develop as tourist drive.	Higher level of barrages would prevent cars being damaged by seawater or storm surges.	It can be done and that a budget could be found. That tourists would want to travel along barrages that would be dangerous and through a highly degraded landscape.	None. Even further reduced capacity to open barrages and connect fresh and saline ecological components.	Further losses of estuarine species and further increases in salinities in the Lakes and the estuarine parts of the Ramsar site due to lack of capacity to connect. System requires lowering of barrage height and more frequent connectivity.

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