Expert Panel Assessment of the Likely Ecological Consequences in South Australia of the Proposed Murray-Darling Basin Plan

A report to the South Australian Government

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The Goyder Institute for Water Research is a partnership between the South Australian Government through the Department for Water, CSIRO, Flinders University, the University of Adelaide and the University of South Australia. The Institute will enhance the South Australian Government's capacity to develop and deliver science-based policy solutions in water management. It brings together the best scientists and researchers across Australia to provide expert and independent scientific advice to inform good government water policy and identify future threats and opportunities to water security.

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Director's foreword

I am proud to present this report on the Expert Panel Assessment of the South Australian analysis of the proposed water recovery scenario under the proposed Basin Plan to the Government of South Australia and to the community and stakeholders within the Murray-Darling Basin. This report represents another important input from the Goyder Institute for Water Research to the South Australian Government in formulating the South Australian response to the proposed Murray-Darling Basin Plan.

In 2011, the Goyder Institute for Water Research undertook a comprehensive review of the Guide to the proposed Basin Plan (the Guide) to assess the ability of the scenarios presented in the Guide to meet South Australia's environmental water requirements, and to assess likely water quality impacts and socio-economic costs and benefits to major water users in South Australia.

In moving on from the Guide to the proposed Basin Plan, the Murray-Darling Basin Authority has continued to refine its modelling and analyses and has proposed alternative Sustainable Diversion Limits across the Basin. The South Australian Government has thus evaluated the latest MDBA modelling outputs for the proposed Basin Plan scenarios for the South Australian sections of the River Murray. The South Australian Government subsequently invited the Goyder Institute for Water Research to advise on the methods adopted by South Australian state agencies, to review the outcomes of the State Government assessments, and to provide additional expert advice on the potential ecological outcomes for South Australia.

Given the limited time available, a detailed analysis as undertaken for the Guide was not possible; instead the Goyder Institute established an Expert Panel to provide advice as described further in this report. The Expert Panel draws upon the wealth of expertise and knowledge from the Goyder Institute partners and associates and has provided an invaluable platform bringing together science from a range of experts.

I am very pleased that the Expert Panel has been able to prepare such a succinct and informative review of the South Australian Government analysis of the hydrological and ecological modelling within a very tight time frame, and informed by constructive interactions with South Australian Government agency technical staff.

I trust once more that this report will be seen as an informative and constructive contribution to the debate on the proposed sustainable diversion limits for the Murray-Darling Basin.

Dr Tony Minns
Director, Goyder Institute for Water Research
Adelaide

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Executive Summary

Background

The South Australian Government has evaluated the extent to which the South Australian Government's and the Murray-Darling Basin Authority's (MDBA) Environmental Water Requirements (EWRs) would likely be met for key environmental assets in South Australia under the proposed Basin Plan. These evaluations were provided as interim reports for consideration by the Expert Panel and are now documented in final reports (Bloss *et al*. 2012; Heneker and Higham 2012; Higham 2012).

In the interim reports, the South Australian Government evaluations were based primarily on a modelled 2800 GL/year water recovery scenario provided by the MDBA and, to a lesser extent, on a more recent 2750 GL/year scenario also provided by the MDBA. The EWRs consisted primarily of previously defined flow and salinity targets corresponding to specified ecological objectives for key environmental assets. The environmental assets in South Australia considered in these evaluations are:

1. The River Murray channel, connected streams and wetlands;
2. The valley section floodplains (including Chowilla and other Riverland floodplains);
3. The gorge section floodplains;
4. The Coorong, Lower Lakes and Murray Mouth (CLLMM).

The South Australian Government sought advice from the Goyder Institute for Water Research on the likely ecological consequences for South Australia of the proposed Basin Plan. Given the very limited time available to formulate and provide advice, the Goyder Institute assembled an Expert Panel to provide (largely qualitative) advice based on the interim reports.

In this report the Expert Panel:

- Provides advice on the adequacy of the methods used by the South Australian Government to evaluate performance of the proposed Basin Plan against EWRs;
- Evaluates the likely ecological consequences of the modelled 2800 GL water recovery scenario relative to a "do nothing" (or *baseline*) scenario, including considerations of:
    - key indicator species and communities;
    - the Riverland-Chowilla Floodplain and CLLMM Ramsar sites and their ecological character;
    - biodiversity at other non-Ramsar sites.
- Provides advice on how ecological risks could be mitigated to enhance ecological outcomes from the proposed Basin Plan.

In finalising this report, the Expert Panel considered feedback from an "Ecological Reference Group" established by the South Australian Government to also comment on the interim reports. This feedback was provided at a workshop where the interim report findings were presented, run by the Goyder Institute on 10 February 2012.

The Expert Panel were asked to review the South Australian Government's assessment of the proposed Basin Plan and not that of the MDBA.

Key Findings

The Expert Panel reviewed the current state of the South Australian Murray-Darling Basin key environmental assets, and where information was available, evaluated post-drought ecological change. While some post-drought recovery has been observed, conditions overall remain poor relative to the definitions of ecological character given in current management plans. Despite their poor condition, environmental assets in South Australia continue to provide important ecological services.

Based on interim versions of the relevant reports describing South Australian Government evaluations, and considering the modelling and analytical tools currently available, the Expert Panel concludes that the evaluations of the 2800 GL/year water recovery scenario are fit for purpose but are subject to the limitations of the MDBA's modelling and assessment on which the Government's work was based. The primary limitation of these evaluations is that the 2800 GL/year scenario provided by the MDBA represents only one of many flow regimes that could occur under the proposed Basin Plan. The actual flow regime will depend on future climate, and hence inflows, the actual portfolio of recovered water entitlements, environmental watering plans, and whether operational constraints will be relaxed or overcome. Other limitations of the MDBA modelling relied upon in the SA Government evaluations include:

- The available MDBA model for the Lower Lakes is inaccurate under very low flow conditions, compromising its ability to evaluate water level and salinity targets in the lakes or flows into the Coorong during droughts;
- Several potential important environmental stressors (e.g., floodplain salinity and climate change) are not considered in the current assessment provided by the MDBA; and
- The tools to evaluate the impact of flow regime changes on the salt balance for the South Australian River Murray, in particular for floodplains, are currently not available.

The value in assembling the Expert Panel is that their combined expertise, knowledge and understanding of the South Australian environmental assets contributes to the consideration of EWRs and strengthens this evaluation despite the above limitations.

Benefits

The proposed Basin Plan is likely to deliver ecological benefits to South Australia relative to a 'do nothing' scenario. The most likely benefits are:

- Improvement in native fish habitat, spawning and recruitment relative to current conditions enabled by improvement in the degree of lateral connectivity between the channel and low-level floodplain wetlands, and by opportunities to generate more variations in flow velocities in the main channel;
- Potential improvement in condition for river red gum, black box and tangled lignum communities found at lower floodplain elevations (that is, below the 60,000–70,000 ML/day flow bands) however these communities are unlikely to return to healthy condition if the flood duration and interval metrics are also not met;
- The number of events where there are low water levels and elevated salinities in the Lower Lakes is reduced under the BP2750 Scenario;
- Improved connectivity between the Lower Lakes and Coorong by enabling longer periods when the barrages are open or when the barrage fish ladders can be operated;

- The BP2750 scenario is likely to improve the effective depth of the Murray Mouth, improving connectivity to the sea and allowing increased opportunity for fish migration. However, the Murray Mouth will still likely require dredging during extended droughts.

Risks

The State's analysis of the proposed Basin Plan shows that many SA and MDBA EWRs are partially met or not met in South Australia. Some of the potential ecological risks of not achieving EWRs under the proposed Basin Plan include:

- The middle and high elevation areas of floodplains, where most black box and river red gum woodlands occur, will receive little or no additional water. Declining vegetation health is likely to continue.
- In the longer-term, the contraction of river red gum and black box distributions on floodplains, with losses of corresponding ecological services (organic carbon production and provision of habitat);
- Ongoing degradation of mid- and high-elevation floodplain wetlands caused by salinity and other factors, with a loss of provision of habitat;
- An accumulation of salt in the Lower Murray region during drier periods as a result of insufficient salt export through the Murray Mouth;
- Extreme low-water levels and salinities may still occur in the Lower Lakes and Coorong under extended drought conditions, which would reduce the habitat available for fish and migratory waterbirds, and may threaten several endangered native fish in the CLLMM region;
- The likelihood that the Murray Mouth will still require some dredging to be kept open during extended droughts.

Because of the limitations of the analyses provided and the short time available, it was not possible for the Expert Panel to comment extensively on the risks for individual endangered and threatened species in the South Australian section of the River Murray. However, without changes as a part of its adaptive implementation, the Basin Plan is unlikely in the longer-term to maintain the ecological character of the Riverland-Chowilla and CLLMM Ramsar sites (and the other non-Ramsar environmental assets). This process may already be underway, with some indicators of the ecological character of the CLLMM Ramsar site currently not found in the region. A change in the ecological character of key environmental assets could lead to loss of biodiversity, however, this does not mean that the assets would not retain some environmental value or provide any ecosystem services.

Opportunities

More benefits could potentially be achieved under the proposed Basin Plan if upstream delivery constraints were relaxed, providing more flexibility in managing environmental flows in the 40,000–80,000 ML/day range. Improving the frequency and duration of flow events in this flow band may improve river red gum and black box distributions on floodplain in the longer term, maintain a higher diversity of ephemeral floodplain wetlands, improve connectivity between the channel and floodplains, and improve longitudinal connectivity in the river channel. These benefits would help preserve biodiversity at Ramsar and non-Ramsar sites, including for threatened and endangered species. Conversely, lesser environmental benefits could eventuate as a result of other stressors, such as climate change and floodplain salinity, that have not been considered by the MDBA modelling.

The view of the Expert Panel is that only limited environmental benefits could be gained by additional local infrastructure in South Australia. Better environmental outcomes would be achieved by investing in opportunities upstream to improve flow diversity in the 40,000–80,000 ML/day flow band in South Australia. Active rehabilitation, such as species re-introduction, could also be considered once suitable conditions in a given asset are reinstated.

The Expert Panel believes that:

- Between now and 2015, it would be useful for a wider range of possible scenarios under the proposed Basin Plan to be evaluated to identify potential options in achieving additional EWRs, including scenarios with relaxed physical and operating constraints;
- Where feasible, interventions to rehabilitate currently degraded assets to reduce the risk that the desired ecological character will deteriorate prior to 2019 when full compliance with Sustainable Diversion Limits is expected;
- The MDB Plan and associated Environmental Water Plans should pay attention to the aspect of drought recovery of degraded assets following prolonged periods of low flows.

Conclusions

Overall, there are important benefits identified under the BP2750 scenario that has been analysed, however, for much of the area of the floodplain environmental assets that require medium to high flows, the environmental water requirements are not met. Thus, the ecological character of the South Australian environmental assets, as defined in current water management plans, is unlikely to be maintained under the BP2750 scenario. Between now and 2015, a range of options should be explored that support management of the environmental assets such that their ecological function in the longer term is protected.

Acknowledgements

The Expert Panel would like to thank the Ecological Reference Group for their contribution at the workshop, including: Michelle Bald (DFW), Chris Bice (SARDI), Chrissie Bloss (DFW), Adrienne Frears (DFW), Mike Harper (DENR), Theresa Heneker (DFW), Jason Higham (DENR), Judith Kirk (DFW), Neil Power (DFW), Dan Rogers (DENR), Mandy Rossetto (DFW), Russell Seaman (DENR), Tracey Steggles (DFW), Rebecca Turner (SA MDB NRM Board), Ian Webster (HYDROWEB) and Brenton Zampatti (SARDI). We also thank those involved in the organisation and running of the workshop: Don Bursill (Chief Scientist for SA), Andrew Millington (Flinders University), Claire Punter and Michele Akeroyd (Goyder Institute for Water Research). Glen Walker (CSIRO) provided additional advice to the Panel about the implications of the proposed increases in groundwater allocations under the proposed Basin Plan.

Glossary

Acid Sulfate Soils	Sediments formed naturally under water-logged conditions, containing iron sulfide as pyrite or oxidation products. If exposed to air, the sulfides react with oxygen to form sulfuric acid. In turn, this may release iron, aluminium, arsenic and other heavy metals that may be toxic for aquatic organisms.
Active Floodplain	The part of the Lower Murray floodplain that is inundated by flows that are within the control of infrastructure and river operations.
AHD	Metres above the Australian Height Datum.
Allochthonous	Of external origin. Allochthonous organic matter is imported to the river channel as leaves, branches, wood etc. from the catchment. Compare with *autochthonous* organic matter, produced by photosynthetic plants within the channel.
Amphibious	Able to live in water and on land.
Anabranch	A branch of a river that leaves the channel and re-joins it further downstream**.**
Baseflow	The steady, sustained flow in the river due to groundwater discharge or surface water releases from reservoirs.
Benthic	Living in the bottom sediments or loosely on the bottom (compare *demersal*).
Biofilms	Communities of algae, bacteria and fungi in a polysaccharide matrix, growing on the surfaces of submerged wood, rocks and sediments. The proportions of algae, bacteria and fungi may vary with environmental conditions (e.g. underwater light, drying/wetting, current or wave action); this affects their nutritional value for grazing animals (e.g. some insects, snails and fish).
Biota	All living organisms.
CAMBA	China-Australia Migratory Bird Agreement
CLLMM	Coorong, Lower Lakes and Murray Mouth
Connectivity	The degree of hydraulic connectedness between reaches of a river (*longitudinal* connectivity) and between a river and its floodplain wetlands (*lateral* connectivity).
Cyanobacteria	An important group of bacteria (loosely called 'blue–green algae'), often implicated in formation of blooms.
Demersal	Living on (but not in) the bottom sediments, or near the bottom. Contrast *benthic*.
Ecological Character	The biodiversity and the physical and biological patterns and processes that characterise a particular area. Has particular meaning for Ramsar-listed wetlands, according to the articles of listing.
Ecological production	The growth of algae, cyanobacteria and plants in general in a time interval. *Productivity* refers generally to the extent of production.
Ecosystem Engineer	A species that has a disproportionate influence on its environment, and one whose removal would cause substantial changes. The common carp, for example, acts as an ecosystem engineer in Lower Murray wetlands.
Electrical Conductivity	Electrical conductivity (EC) units are one of the measurement methods for salt concentration. Local conversion ratios, which vary due to differences in water temperature, can be applied to estimate milligrams per litre (mg/L) from EC. At Morgan, South Australia, 800 EC is approximately 500 mg/L. Sea water salinity is approximately 54,000 EC.
Emergent plants	Plants rooted in the sediments but with stems, leaves or flowers above the water surface.

Environmental Water Requirement	The water regime needed to maintain water-dependent ecosystems, including ecological processes and biological diversity. Abbreviated EWRs.
EPBC-listed	The Environment Protection and Biodiversity Conservation Act 1999 (The EPBC Act) provides a legal framework to protect and manage matters of national environmental significance.
EWRs	See Environmental Water Requirement
Geomorphic	Synonym for *geomorphological*. Refers to the science of landforms.
Flood	An overbank flow, exceeding the channel capacity
g/L	Grams per litre. A measure of Total Dissolved Solids, roughly equivalent to salinity. Sea water has a salinity of about 35 g/L.
GL	Gigalitre. One billion litres, equivalent to the volume of a 1-metre layer of water covering a square kilometre.
Hydraulics, hydrology	*Hydraulics* is concerned with the mechanics and movements of water, whereas *hydrology* considers the water cycle and regional patterns of runoff and flow. Thus, water-level changes, flow velocity and turbulence are in the realm of hydraulics. Local variations in flow ('hydraulic complexity') affect water depth, instream cover and the nature of the sediments, and provide habitats for organisms. *Hydrology* is often used loosely to include *hydraulics*.
Hypolimnion	The bottom layer of water in a thermally-stratified water column. Circulates slowly within itself but is isolated from surface currents. If stratification persists, water in the hypolimnion may be cool and low in oxygen.
JAMBA	Japan-Australia Migratory Bird Agreement
Keystone species	Broadly, a species whose loss or removal would lead to major changes in the structure of the animal or plant communities of which it is part.
LD_{50}	The Lethal Dose required to kill 50 percent of a test population of organisms, and a crude measure of the tolerance of the 'average' individual. Usually refers to adult organisms, without regard for reproductive processes or young stages. Typically based on an observation period of 96 hours.
Littoral	The shallow edge zone of an aquatic environment. In rivers, lakes and wetlands the littoral zone often is marked by stands of emergent reeds or rushes. The zone is narrow if the bottom slopes sharply, and broad if the slope is gentle.
Macroinvertebrate	An invertebrate large enough to be seen with the naked eye. For example, a crayfish, snail or dragonfly nymph.
Macrophyte	A water plant. For example, common reeds, cumbungi (bulrush) or water ribbons.
MDBA	Murray-Darling Basin Authority
Microbial	Pertains to microorganisms (for example, bacteria, fungi).
ML	Megalitre, or one million litres of water. Used to specify flow (discharge) in the Murray (hence ML/day). Compare GL, gigalitres.
MSM–BigMod	Two computer models of river operations maintained by the Murray-Darling Basin Authority.
Natural Flow Paradigm	An ecological concept suggesting that the goal in managing riverine environments should be to mimic the natural flow pattern as far as practical.
Pelagic	The open water (thus, *pelagic* fish). Contrast *benthic*, *demersal*, *littoral*.
Phytoplankton	Microscopic algae and cyanobacteria that float freely in the water.

Ramsar	The Convention on Wetlands of International Importance (the **Ramsar** Convention) is an international treaty that provides a framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. The 'Ramsar Convention' defines conditions under which the Riverland, Banrock and Coorong, Lower Lakes and Murray Mouth wetlands are listed as *Wetlands of International Importance*.
Recruitment	The addition of organisms to a population. Can refer to the production of seedling trees or other plants, or larval fish or other animals, but may also refer specifically to the numbers of organisms once they have reached maturity and potentially can reproduce.
Recurrence interval	The number of times an event occurs within a given time.
Resilience	The ability of an individual, population, community or ecosystem to recover after a disturbance of some kind.
Riparian	Along the banks of the river.
ROKAMBA	Republic of Korea Australia Migratory Bird Agreement.
Salinity	*Refer to Electrical Conductivity*
Sensitivity Analysis	Running a model (say, a spreadsheet) by slightly altering one or more variables to gauge their effect on the results.
Submergent plant	A plan rooted in the sediments and usually without stems and leaves above the water surface.
Thermal stratification	The tendency of water bodies to separate into an overlying warm layer (*epilimnion*) and a lower cooler layer (*hypolimnion*), separated by a thermocline. Typical of deep reservoirs in summer and autumn, may also occur transiently in slow-flowing weir pools and wetlands.
Turbidity	The cloudiness of water, caused by suspended particles and dissolved matter. Measured in Nephelometric Turbidity Units (NTU).
Turions	Starch-filled asexual reproductive organs produced by some species of aquatic plants (e.g. *Ruppia tuberosa)*, enabling the plants to persist through periods of desiccation. Often formed as salinity increases and sometimes at salinities less than that of seawater. In the Coorong, an important part of the diet of ducks and other waterfowl.
Zooplankton	Microscopic crustaceans and other animals that float freely in the water.

Introduction

The *Water Act* (2007) requires the Murray-Darling Basin Authority (MDBA) to prepare and implement a Basin Plan for the integrated and sustainable management of water resources in the Basin. The October 2010 release of a *Guide to the proposed Basin Plan* (the Guide) was the first step in this process. The South Australian Government commissioned the Goyder Institute for Water Research to assess the ability of the scenarios presented in the Guide to meet South Australia's environmental water requirements, and to assess likely water quality impacts and socio-economic costs and benefits to major water users in South Australia. This assessment was undertaken by CSIRO as a member of the Goyder Institute, in collaboration with State agencies and other Goyder partners. The findings of this review are summarised in 'A science review of the implications for South Australia of the Guide to the proposed Basin Plan: Synthesis' (CSIRO 2011).

The MDBA released the proposed Basin Plan for public consultation on 25 November 2011. The proposed Basin Plan suggests a water recovery target of 2750 GL per year, on average. Modelling was undertaken by the MDBA to assess the effectiveness of the proposed Basin Plan scenario of 2750 GL (BP2750) in meeting the Environmental Water Requirements (EWRs) of key environmental assets in the Basin. For South Australia, the MDBA considered the Riverland-Chowilla Floodplain and the Coorong, Lower Lakes and Murray Mouth sites.

Determination of environmental water requirements requires specification of specific ecological objectives (Maltby and Black 2011). The MDBA ecological objectives for key environmental assets in the Murray-Darling Basin are presented in MDBA (2011a, 2011b). The South Australian Government's ecological objectives for environmental assets within the Murray-Darling Basin are described in various management plans and reports (see Pollino *et al*. 2011).

The South Australian Government has made its own analysis of the proposed Basin Plan on the basis of modelled flow scenarios provided by MDBA. These scenarios were:

- Baseline – historical climate and current water sharing arrangements for the period 1895-2009; for full description see MDBA (2012a); and
- BP2400, BP2750, BP2800, BP3200 – historical climate and water recovery scenarios representing the specified increases in average annual environmental water (GL/year) across the entire Murray-Darling Basin; for full descriptions see MDBA (2012a).

The South Australian Government evaluated the extent to which the South Australian and the MDBA environmental water requirements would be likely to be met for key environmental assets in South Australia under the proposed Basin Plan. The key environmental assets considered were:

- The River Murray channel, connected streams and wetlands;
- The valley section floodplains (including Chowilla and other Riverland floodplains);
- The gorge section floodplains; and
- The Coorong, Lower Lakes and Murray Mouth (CLLMM).

The Expert Panel

The South Australian Government sought advice from the Goyder Institute for Water Research to review the assessment undertaken by the South Australian Government and to provide expert advice regarding the likely ecological consequences for South Australia of the proposed Basin Plan.

The Goyder Institute Expert Panel was formed, bringing together expertise from the Goyder Institute partners in the areas of riverine, floodplain and estuarine ecology. No modelling was undertaken by the Goyder Institute or any members of the Expert Panel in relation to the assessment of the proposed Basin Plan.

Membership of the Expert Panel, by area of expertise, included:

Area of Expertise	Panel Expert
Vegetation	Jason Nicol (SARDI) Todd Wallace (Adelaide U.)
Birds	David Paton (Adelaide U.)
Fish	Qifeng Ye (SARDI)
Primary production/biogeochemistry	Kane Aldridge (Adelaide U.) Rod Oliver (CSIRO)
Floodplain, salinity, groundwater and hydrology	Ian Jolly (CSIRO) Kate Holland (CSIRO)
System Integration	Keith Walker (Adelaide U.) S. Lamontagne (CSIRO)

The Expert Panel was asked to:

- Provide advice on the adequacy of the methods used by the South Australian Government to evaluate the performance of the proposed Basin Plan against EWRs;
- Evaluate the likely ecological consequences of the modelled 2800 GL water recovery scenario relative to a "do nothing" (or *baseline*) scenario, including considerations of:
    - key indicator species and communities;
    - the Riverland and CLLMM Ramsar sites; and
    - biodiversity at non-Ramsar sites.
- Provide advice on how ecological risks could be mitigated to enhance ecological outcomes from the proposed Basin Plan.

This Expert Panel evaluation of likely ecological consequences is based on consideration of interim versions (dated between 3 and 8 February 2012) of the three South Australian Government reports that are now documented in final reports (Bloss *et al*. 2012; Heneker and Higham 2012; Higham 2012). Any material changes to the interim reports prepared by the South Australian Government potentially would invalidate the findings in this report.[1]

At the time of the Expert Panel review, the South Australian Government had completed its analysis of the BP2800 Scenario for all assets, but had only completed an analysis of the BP2750 Scenario for the Lower Lakes. The differences between the BP2750 and the BP2800 scenarios are small.

The Expert Panel also considered feedback from an "Ecological Reference Group" established by the SA Government to also comment on the interim reports. This feedback was provided at a workshop, run by the Goyder Institute on 10 February 2012, where the interim report findings were presented. As a part of the workshop, the Expert Panel was also invited to consider the potential ecological implications of the proposed Basin Plan, including:

- Does not achieving an EWR equate to a long-term ecosystem collapse, or to decline for any particular species?
- Can currently specified EWR be relaxed or modified?
- Can other mitigation strategies be used to complement partially-achieved EWR?
- Should the ecological indicators that have been used be revised or should additional indicators be considered?

[1] At the time of completing this report the SA Government advised that there is consistency between the interim and final reports (28 March 2012)

The outcomes from the workshop and the Expert Panel's evaluation of the interim reports are synthesised in this report. The basis for evaluation was the ecological character for South Australian River Murray environmental assets as defined in current management plans (see Pollino *et al.* 2011). These definitions are not for 'natural' (pre-European) states, but are designed to meet obligations under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), international conventions for protection of wetlands (Ramsar) and migratory waterbirds (CAMBA, JAMBA, ROKAMBA etc.) or other targets. Each environmental asset is described in its current condition together with the evaluation of the baseline and BP2750/BP2800 modelled scenarios. A synthesis relative to the Terms of Reference is provided in the Discussion.

Review of Environmental Assets

River Channel, Connected Streams and Wetlands

Rivers are characterised by their flow regimes. Base flows due to groundwater are slow and steady; variable surface flows increase depth, velocity and turbulence in the channel. Floods overflow the banks connecting the river longitudinally, and between the river and floodplain, recharging floodplain wetlands and woodlands. The flow regime governs the diversity of habitats, triggers spawning or migration, transports food and removes waste and controls access to habitats. The 'natural flow paradigm', for example, acknowledges that different elements of the hydrograph deliver different ecological responses and suggests that, to sustain natural communities, managed flows should mimic the natural pattern (Poff *et al.* 1997). In the following, the current condition is reviewed followed by an evaluation of the potential ecological consequences of the Baseline and BP2800 scenarios.

Current Condition

Channel and connected stream habitats

Ecological concepts of floodplain-river systems highlight the importance of flow regime, particularly longitudinal and lateral connectivity, flow seasonality and variability (e.g. Walker *et al.* 1995; Puckridge *et al.* 1998). These factors vary in relative importance, in response to changing climate, catchment and management controls.

The Lower River Murray is an intensively-regulated system (Maheshwari *et al.* 1995), dominated by seven pools with relatively stable water levels: thus, the pools formed by barrages near the river mouth and six weirs on the main channel (e.g. Walker 2006). The impoundment and raised water levels of the weirs have significantly changed the ecological condition of the floodplain-river ecosystem.

As a consequence of stable water levels, the littoral zones of permanent wetlands have narrowed, although they may vary due to wind or river operations. The vegetation in the main channel is dominated by emergent species such as willows (*Salix* spp.), cumbungi (*Typha* spp.), common reed (*Phragmites australis*) and river clubrush (*Schoenoplectus validus*), and submerged species including ribbon weed (*Vallisneria australis*), curly pondweed (*Potamogeton crispus*) and milfoils (*Myriophyllum* spp.) are restricted to shallow areas by unstable sediments and high turbidity (Blanch *et al.* 1999; 2000; Nicol *et al.* 2010). Permanent wetlands are shallower, more stable habitats and have higher diversity (e.g. Nicol *et al.* 2006; Nicol 2010), particularly of submergent species.

As the River Murray generally is turbid, most photosynthesis occurs in shallow water near the surface, in the case of phytoplankton, or along the river margins, in the case of emergent and submerged plants. The regulated water level regime has been responsible for changes in the composition of biofilms (algae, bacteria and fungi associated with submerged surfaces), and these may have caused local extinctions of aquatic snails (Sheldon and Walker 1997).

Water velocity is another key characteristic. The biomass and productivity of phytoplankton in the River Murray increase substantially at flows < 0.2 m s^{-1} (Oliver and Lorenz 2010; cf. Reynolds 1988; Bowles and Quennell 1971) and, as flows decline in summer and autumn, there is a greater chance of thermal stratification. This may improve the light climate and promote the growth of phytoplankton, especially of cyanobacteria ('blue-green algae'). In the weir pools, low cross-sectional velocities of c. 0.05 m s^{-1} occur at discharges below 3000 ML/day, favouring the development of blooms.

The reduction of free-flowing habitat has caused declines or local extinctions among invertebrate species including the Murray crayfish (*Euastacus armatus*), the river mussel (*Alathyria jacksoni*) and many snail species (Sheldon and Walker 1997; Walker K.F. *et al.* 2009). Free-flowing habitats now remain only in major anabranches, particularly three permanently connected anabranch systems (Chowilla, Pike, Katarapko) that provide fast-flowing streams as well as slow-flowing streams and backwaters. These diverse hydraulic habitats are artificial, but they are important refuges for key biota such as Murray cod (*Maccullochella peelii*) (Zampatti *et al.* 2011).

Floodplain wetland habitats

Wetlands can be defined by the flow or flood size required to inundate them. Low-level flows (<40,000 ML/day) that formerly connected the diverse aquatic and terrestrial environments associated with the River Murray have been greatly reduced, disconnecting the channel and floodplain. Raised water levels in weir pools have flooded low-level connected wetlands and backwaters, so that many have become perennial rather than temporary habitats.

Moderate flows (40,000 – 80,000 ML/day) also have been much reduced. These connect higher areas of the floodplain to the channel, and are important in transferring salt, nutrients, organic matter and other materials between floodplain and channel habitats. This flow band includes many wetlands of different sizes and vegetation types, so that changes in flooding characteristics have had marked effects on vegetation distribution.

The current condition of unmanaged low and moderate elevation temporary wetlands is similar throughout the South Australian riverine corridor. Plant communities in these habitats generally were in very poor condition (Marsland and Nicol 2009; Gehrig *et al.* 2010; Zampatti *et al.* 2011) but there has been some recovery following the most recent flooding (Gehrig *et al.* in review).

Major flows (>80,000 ML/day) are 'unregulated' and less impacted by regulation, although they have been reduced by upstream storage and diversions. In temporary wetlands at higher elevations, there is less frequent flooding, and areas where groundwater is near the surface have become salinised (Marsland and Nicol 2009; Zampatti *et al.* 2011).

Fish

Fish communities in the Lower River Murray occupy a range of habitats, including the deep channel, anabranches, tributaries, billabongs and other wetlands (Ye and Hammer 2009). The flow regime, through complex interactions with physical habitat, plays a pivotal role in the life history processes and population dynamics of fish (Ye *et al.* 2009). Native fish populations in the Murray-Darling Basin are estimated to be about 10% of their pre-European levels (MDBC 2004), in response to key threats including river regulation, habitat degradation, interactions with alien species like common carp (*Cyprinus carpio*), and fisheries exploitation. Regulation may directly affect fish life cycles and recruitment (Harris and Gehrke 1994), create barriers to movement and migration (e.g. Barrett *et al.* 2008) and indirectly affect habitat and food resources (Bunn and Arthington 2002). Currently, many native fish in the Lower River Murray are listed or protected at State and/or national levels (Ye and Hammer 2009). About half of 35 native fish species in the Lower River Murray are listed in higher extinction risk categories (DEH 2003; Hammer *et al.* 2007).

Fish in the Lower River Murray can be classified into seven life-history groups, considering the influence of flows and habitat type on spawning and recruitment processes (King 2002; CRCFE 2003). Most small-bodied species are wetland specialists, low-flow specialists or main-channel generalists. They are short-lived (1-5 years) (Pusey *et al.* 2004), and many need to breed annually, including drought periods, to maintain local populations. These species generally do not require high flows to facilitate spawning and recruitment. Carp gudgeons (*Hypseleotris* spp.), Australian smelt (*Retropinna semoni*), unspecked hardyhead (*Craterocephalus stercusmuscarum*), flathead gudgeon (*Philypnodon grandiceps*) and bony herring (*Nematalosa erebi*) (a medium-bodied species) are most common. Other small-bodied species are in very low numbers and some may be regionally extinct (Smith *et al.* 2009; Ye and Hammer 2009; Bice *et al.* 2011).

Large-bodied species include flood/flow-cued spawners, i.e. golden perch (*Macquaria ambigua)* and silver perch (*Bidyanus bidyanus*), main channel specialists, i.e. Murray cod, trout cod (*Maccullochella macquariensis*) and river blackfish (*Gadopsis marmoratus*) (a medium-bodied species), and freshwater catfish (*Tandanus tandanus*). Life history strategies of these species are more dependent on flows, which influence spawning, recruitment, migration or dispersion (e.g. Ye and Zampatti 2007; Cheshire and Ye 2008; Ye *et al*. 2008; King *et al.* 2010; Leigh and Zampatti 2011). Consequently, they are most impacted by river regulation. Currently all these are threatened/protected species except golden perch, although it too has declined (Ye 2005). Trout cod are extinct in South Australia.

The MDBA *Sustainable Rivers Audit* in 2004–07 indicated that condition was 'poor' for hydrology, fish and macroinvertebrates in the Lower River Murray Valley, and that overall ecosystem health also was 'poor' (Davies *et al.* 2008). Only 40% of expected native fish species were observed during the Audit, compared to pre-European 'Reference Condition', and the community was dominated by alien species, overwhelmingly by common carp (Davies *et al.* 2008).

Baseline

Based on Bloss *et al*. (2012), under the Baseline Scenario no South Australian EWRs will be met. As a consequence, the system would not improve, as described in the previous section, and possibly may degrade further.

BP2800

Channel

In the interim reports (Bloss *et al*. 2012), the assessment of EWR targets focussed on perennial floodplain vegetation (e.g. river red gum woodlands) and did not assess the channel. Only one SA EWR was assessed for the channel. The SA EWR (FV) (Appendix A2) aims to restore variability in flows up to 40,000 ML/day. No specific durations or timings were set, and fluctuations were to occur 4-in-5 years, with a maximum interval of 2 years. Ultimately, this target was not analysed in detail in the SA Government Report (Bloss *et al.* 2012).

Under the BP2800 scenario, flows <80,000 ML/day will occur more frequently than current conditions, providing scope to manage in-channel flow pulses. No detailed analysis was provided of this potential in the interim report. The MDBA EWR (Appendix A1) aims to provide a 20,000 ML/day fresh (in-stream flow pulse) for 60 days, but the seasonality is not specified, and this is a single height flow peak that does not provide the variable heights that might be preferred, from pool-level to 40,000 ML/day. In addition, the information needed to assess its influence was not available.

Increased rates of discharge will also improve channel hydraulic diversity, expand the littoral zone and inundate low-elevation temporary wetlands more frequently. Lateral connectivity might be improved, promoting carbon/nutrient flow, productivity and the food supply to the channel, and allowing mobile biota to move between the channel and wetlands. No information was provided to enable assessments of these possibilities.

Full longitudinal connectivity does not occur until the navigation passes are removed from the weirs, at flows of 50,000–70,000 ML/day. These discharges do not differ greatly in frequency of occurrence between the Baseline and the BP2800 scenarios, so it appears that longitudinal connectivity will not be greatly improved other than by increased flows.

It would appear that with increased flows there would be potential for some improvement in particular aquatic habitats, but to quantify this improvement would require more detailed work than can be done within an Expert Panel framework.

Low-level wetlands and intermittent connected streams

The distinction between once-temporary but now permanent wetlands and those still intermittently connected is important because these have different ecological roles. The EWR targets proposed by MDBA and SA vary significantly because of inconsistencies in nomenclature. The MDBA-applied EWR is that 80% of the current extent of wetlands is kept in good condition with flows up to 40,000 ML/day, based on a test site at Riverland-Chowilla Floodplain. The report by Ecological Associates (2010) indicates that only 10% of these wetlands are temporary, and the remaining 70% are permanent wetlands flooded by regulating structures. The SA EWR recognises this distinction, with the target for EWRs (Appendix A2) being 80,000 ML/day, to inundate 80% of temporary wetlands, and the target for EWR (Appendix A2) being 40,000 ML/day, to inundate 20% of temporary wetlands. In the valley section of the SA River Murray, which includes the MDBA hydrologic site, these numbers are closer to 48% and 93%, respectively (the SA targets are lower because differences in responses on the river at Katarapko and Pike were included in the analysis). More detailed assessments are required to account for these differences in wetland types. This would be desirable because these are significant for Murray cod and perhaps other species.

In the anabranches at Chowilla that bypass a weir, there is evidence that hydraulic complexity increases at flows from 15,000 to 40,000 ML/day (Mallen-Cooper *et al.* 2008). Other anabranch systems (e.g. the Hunchee–Amazon–Ral Ral system, upstream of Renmark but with inlets/outlet in the Lock 5 weir pool), or large wetlands with multiple connections (e.g. Lake Carlet, Toolunka Flat), also may become more hydraulically diverse at flows from 15,000 to 40,000 ML/day. In the interim reports, no analyses are included in the EWR for these areas, although they could increase the availability of fast-flowing habitats.

Medium-level wetlands

Some increase in the frequency and duration of wetland inundation up to 60,000 ML/day (approximately 46% of wetlands) might extend the area of the "lower-level" type of wetland. However the maximum interval metric set for these wetlands is only met at 35,000 ML/day. Overall it is likely that the condition of medium level wetlands will continue to decline (Table 1).

Higher level wetlands

There will be no improvements in these wetlands, as the flood frequencies are unchanged. They are likely to continue to decline. It should be noted that flows of >80,000 ML/day probably are also important to facilitate large-scale recruitment of iconic fish species such as Murray cod and golden perch (Ye 2005; Ye and Zampatti 2007).

Table 1. Summary of ecological consequences based on performance against South Australian EWR target achievements for the channel, connected streams and wetlands for the BP2800 scenario as evaluated by Bloss *et al*. (2012). The 'flow range of influence' represents the flow band with most potential benefits for the target. The SA Government assessments of MDBA EWR achievements can be found in Appendix A1 and the assessment of SA EWR achievements in Appendix A2.

Target Community, Process or Species	Flow range of influence (ML/day)	Comments
High-level temporary wetlands	>80,000	No increase in frequency or duration of watering of high-level temporary wetlands, hence continued environmental decline.
Medium-level temporary wetlands	40,000 – 80,000	Some increase in the frequency and duration of wetland inundation up to 60,000 ML/day (c. 46% of wetlands) might extend the area of the "lower-level" type of wetland. However the maximum interval metric set for these wetlands is only met at 35,000 ML/day. Overall, it is likely that the condition of medium level wetlands will continue to decline.
Low-level temporary wetlands and connected streams	10,000 – 40,000	Increased small floods will inundate low-level temporary wetlands and may reinstate semi-permanent connections to some very low-level temporary wetlands. Increased lateral connectivity between main channel and connected streams and low-level temporary wetlands, improved carbon/nutrient flow and enhanced productivity, more access to temporary wetlands for mobile biota.
Main Channel and connected wetlands	<10,000 – ~33,000 (bankfull)	Expected increase in the variability and frequency of freshes, resulting in more water level variability and hydraulic complexity, but not sufficient to improve longitudinal connectivity. Expected minor improvement in condition; further improvement would be likely if the upper band of mid-range flows was reinstated to increase longitudinal connectivity.

Environmental risks under BP2800

The EWR for high-level temporary wetlands will not be met under the BP2800, and these systems will continue to degrade. Climate change has not been considered; this may mean less water availability and fewer benefits than anticipated for the channel, connected streams and low-level wetlands.

There are numerous alien plant species adapted to fluctuating water levels; these may expand their distribution and abundance as a result of increased water level variability (e.g. Nicol 2007a). Similarly, increased wetland inundation would benefit recruitment of alien fish species, particularly common carp (Smith and Walker 2004). Provided that these environmental risks are managed effectively, the benefits of increased flows and variability in flows would outweigh the negatives for the low-lying wetlands.

Summary

The limited channel analysis in the interim report makes the assessment of ecological outcomes under BP2800 and other scenarios difficult. However, while changes as a result of BP2800 can be confidently predicted to occur in plant communities and to a lesser extent other biota, the underlying processes are not clear and the effects on ecosystem function are less so. The main benefits of the BP2800 would be to create more opportunities for in-channel variations in stream flows and to increase the flooding frequency and duration of low-elevation wetlands. In summary:

- There will be limited improvements in the medium and higher elevation wetlands as the flood frequencies are unchanged. Flows greater than 80,000 ML/day are probably required to facilitate large scale recruitment of iconic fish species such as Murray cod and golden perch. These are not met under the BP2800 Scenario;
- Low level wetlands and intermittently connected streams: there are opportunities for flow variations in the channel that could be used to improve carbon/nutrient flow and enhanced productivity, greater access to temporary wetlands for mobile biota, which result in improved instream fish habitat;
- Main channel and connected wetlands could improve in condition as a result of an increase in variability and frequency of freshes, resulting in more water level variability and hydraulic connectivity and diversity. Improvements in longitudinal connectivity, which are important for fish migration, are unlikely.

Some recommendations from the review include to:

- Articulate EWRs for the main channel that include hydraulic complexity (e.g. variability of cross-sectional velocity profiles), longitudinal connectivity, area of the littoral zone and large-bodied native fish recruitment would assist in achieving environmental outcomes in this highly managed but critical component of the aquatic ecosystem;
- Use the approach proposed by Cottingham *et al.* (2010) to develop conceptual flow-response models for geomorphology, ecological production, macro-invertebrates, bankside vegetation and native fish. This approach can be used to identify critical flow drivers or stressors affecting ecosystem processes, or the amount and timing of habitat available;
- When feasible, use hydrodynamic or other modelling approaches to determine how a daily flow regime translates into 'habitat' for fish and other biota in river channels. The Panel notes that one-dimensional models of mean velocity for the Chowilla (Mallen-Cooper *et al.* 2008), Pike and Katarapko systems include the adjacent main channel, but they were not used here;
- The varying flow requirements for delivery of environmental and consumptive water need to be integrated, as conditions within the channel are intimately linked to flow delivery for all other components. It is imperative that the requirements of the channel are considered early in the modelling process, if it is to recover its ecological functions and not continue to be merely a conduit for water delivery;
- To revert to a more river-like than lake-like environment, future management plans will need to re-introduce greater water-level variations and restore flowing habitats outside of floods, such as through sustained and gradual weir pool level manipulations;
- Further research is needed into the influence of flow regime, habitat and other environmental requirements that drive recruitment success of many Murray-Darling Basin fish species.

Floodplains

In the interim report (Bloss *et al*. 2012), a greater number of EWRs had been defined for floodplains relative to the river channel and wetlands. In the following, the current state of the terrestrial component of South Australian floodplains (that is, excluding floodplain wetlands) is reviewed, especially in regard to salinity. This information is used to help interpret the evaluation of the floodplain EWRs made in the interim report for the Baseline and BP2800 scenarios.

Current Condition

Cause of floodplain vegetation decline

The native riparian vegetation on many parts of the floodplains of the Lower River Murray in South Australia is in severe decline, due to high soil salinity and lack of flooding. The Lower River Murray acts naturally as a drain for the highly saline regional groundwater systems of the Murray Basin (Evans and Kellett 1989), and much of the groundwater passes through the floodplains (Barnett 1989). High groundwater salinities mean that the floodplain soils also contain high amounts of salt. This, combined with the semi-arid climate, and hence irregular flooding, has meant that salt accumulated naturally in the dry periods between floods was leached or flushed by flooding, creating a long-term, quasi-stable equilibrium, evidenced by the numbers of mature floodplain trees older than 100 years (Slavich 1997). However, the weir pools of the Lower River Murray have caused the naturally saline groundwater to rise nearer the surface in some areas, and irrigated areas nearby also have contributed to shallower floodplain water tables. In addition, river regulation has reduced the frequency and duration of the floods that leach salt from the plant root zone. The combined effect is long-term salt accumulation in floodplain soils, and this, with lack of flooding *per se*, is a primary cause of vegetation dieback (Jolly *et al.* 1993). It looms as a continuing problem for South Australia.

The large changes in flow regime can be visualised using the concept of an 'active' floodplain. The flow that is required to inundate c. 95% of river red gum (*Eucalyptus camaldulensis*) and black box (*Eucalyptus largiflorens*) woodlands under natural conditions is about 140,000 ML/day, which had a natural recurrence interval of 1 in 7 years. Under current conditions, this recurrence interval is equivalent to a flow of about 70,000 ML/day, which is about the maximum flow for which engineering infrastructure can be used to 'water' the floodplain. A 70,000 ML/day flow therefore defines the current-day 'active' floodplain, and represents a critical ecological and engineering threshold in the Lower River Murray in South Australia (Holland *et al.* 2005).

To illustrate the concept of the active floodplain, the areas of vegetation flooded by a flow of 70,000 ML/day are shown for the Valley section in Figure 1. Flows of this magnitude inundate 33.6% of the vegetated area of the South Australian River Murray floodplain (K.Holland, CSIRO). This does not mean, however, that the flooding frequency, duration or maximum interval values for EWRs in this area are met under the 2800 GL water recovery scenario.

Ecosystem services provided by floodplain vegetation

The major plant communities perform a range of ecosystem services linking the river channel, wetlands, floodplain and surrounding mallee environments. River red gums and black box are regarded as 'ecosystem engineers' (Colloff and Baldwin 2010) that play an important functional role in floodplain and wetland systems through provision of carbon (leaf litter) and habitat for aquatic and floodplain fauna. The distribution of river red gums is influenced by the magnitude and frequency of floods, and by proximity to permanent surface water or groundwater sources. Black box is relatively more tolerant of soil salinities and dry conditions, and tends to occur on more elevated parts of the floodplain. Black box communities have strong habitat linkages to the surrounding mallee landscape, supporting ground- or canopy-foraging hollow-nesting bird species. River cooba (*Acacia stenophylla*) is common on floodplains on heavy, clay soils and is more common in association with river red gum than with black box.

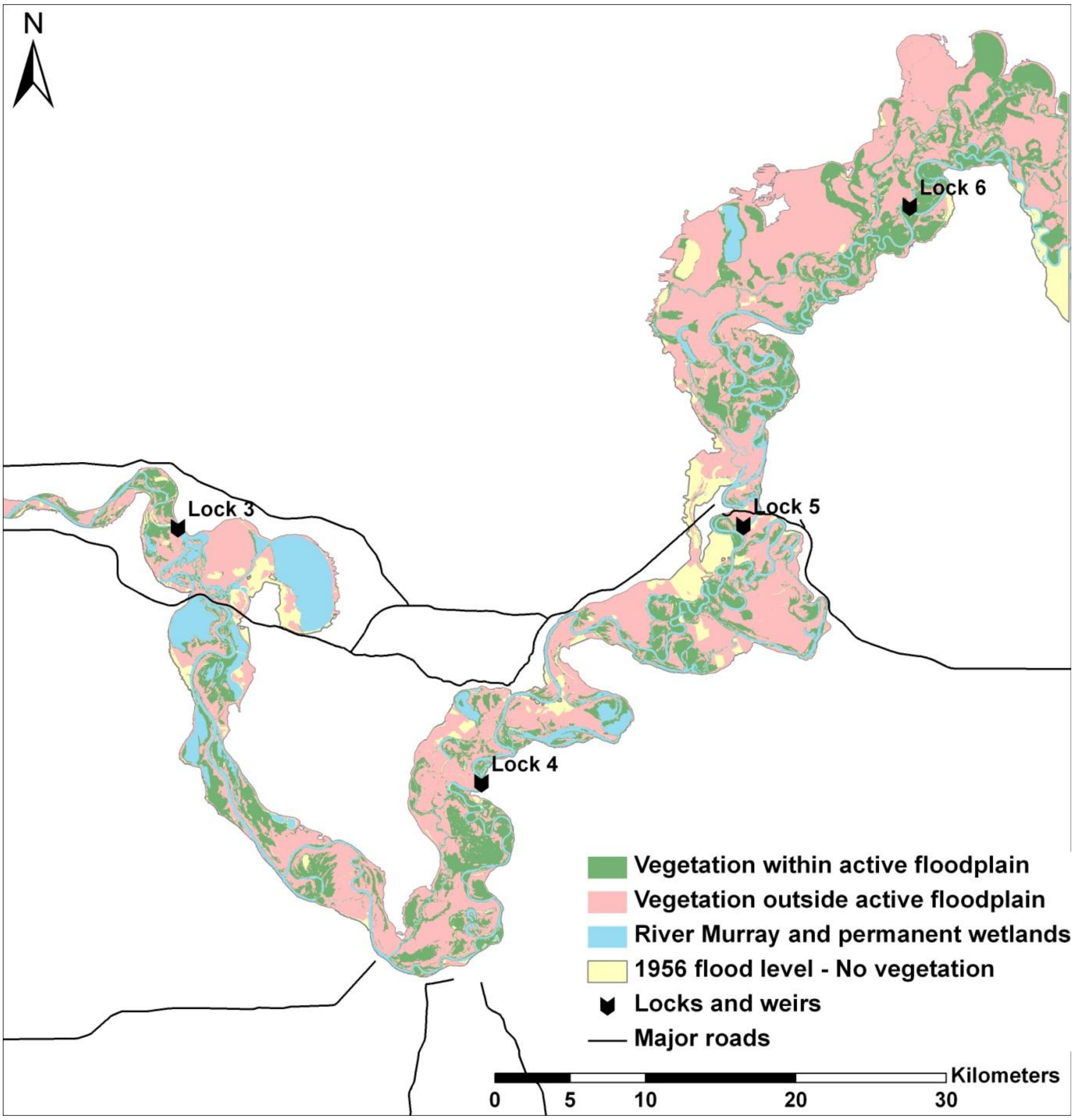

Figure 1. Vegetation distribution in the 'active' floodplain of the valley section of the Lower River Murray at 70,000 ML/day. Areas highlighted in 'green' are those which can be actively managed (Source: K. Holland, CSIRO).

Floodplain eucalypts, particularly river red gum and to a lesser extent black box, generate a large annual biomass of leaf litter (c. 2500 g m^{-2} and 600 g m^{-2} respectively: Wallace 2009). This is a major source of organic matter to the system (Glazebrook and Robertson 1999; Francis and Sheldon 2002). For example, even one flood of relatively small extent (e.g. 40 km^2) can deliver as much carbon to the river channel as the river channel produces itself (e.g. phytoplankton) in a year in the flooded area (Robertson *et al.* 1999; Gawne *et al.* 2007, O'Connell *et al.* 2000; Francis and Sheldon 2002; Wallace *et al.* 2008). The carbon and nutrients released from inundated material are rapidly incorporated into microbial and algal biomass (Schemel *et al.* 2004) and assimilated into the food web.

The composition of the understorey vegetation affects the habitat value of riverine woodlands. This is strongly influenced by flooding frequency, as flood-dependent native plants typically are short-lived. Flooding may eliminate drought-tolerant species that become established during the dry phase (Nicol 2004). After flooding, the understorey plants are dominated by amphibious and flood-dependent species that persist for about 12 months and are progressively replaced by drought- tolerant species, pending the next flood (Capon *et al.* 2009; Marsland *et al.* 2009; Nicol *et al.* 2009, 2010). A return frequency of 3-

5 years may maintain seed banks and ensure the long-term persistence of amphibious and floodplain species, although some seeds may still survive longer (Leck and Brock 2000).

Tangled lignum (*Muehlenbeckia florulenta*) is a native, woody, often leafless, perennial shrub up to 2-3 m high and 3 m diameter, forming dense thickets in low-lying areas of the floodplain (Craig *et al*. 1991). It provides vital habitat for terrestrial animals during dry periods and for fish and invertebrates during floods. When inundated, lignum provides breeding habitat for colonial waterbirds such as ibis (Lowe 1982; Maher and Braithwaite 1992) and for the threatened freckled duck (*Stictonetta naevosa*) (Frith 1965; Lowe and Lowe 1974; NRE 2000a,b). It forms an understorey to river red gum rather than black box.

System wide assessment of tree condition

In 2002–03, a floristic and tree health mapping survey (Smith and Kenny 2005) reported that about 40% (40,000 ha) of the River Murray floodplain in South Australia was 'severely degraded' (Walker *et al.* 2005). Surveys elsewhere in the Murray–Darling Basin have shown that less than a quarter of the dominant riparian trees (river red gum, black box, river cooba) are in 'good' health (Cunningham *et al.* 2007; George *et al.* 2005; MDBC 2005). The limited extent and duration of environmental flows under current conditions of river regulation, water extraction and climate (Mac Nally *et al.* 2011) are not sufficient to remove accumulated salts from floodplain soils.

Since the study by Smith and Kenny (2005), there have been several site-specific studies, including a survey of the Pike River Floodplain (Wallace 2009). In this case, more than half (57%) of the sites assessed had floodplain trees in 'poor' (38% of sites) or 'extremely poor' condition (19% of sites). While some individual trees were scored in 'good' condition, only one of 630 assessed trees received the maximum score, and none of 21 transects had mean or median scores in the 'good' category. The substantial decline in condition observed in some areas between the assessments in 2002–03 and 2009 was judged likely to continue, and to become more widespread. In all such areas, it is extremely unlikely that tree condition will improve without above-average rainfall or a return to more frequent inundation.

Baseline

Under the baseline, there likely will be a continuing contraction in the extent of dominant riparian vegetation to the 'active' floodplain, or about one third of its former extent. Vegetation in other floodplain areas is likely to continue to decline in the absence of major floods (>100,000 ML/day). There are also likely to be transitions in species/community distributions, in response to increasing soil salinity and reduced flood frequency and duration (e.g. from river red gum to black box woodlands). The spatial extent and temporal behaviour of these transitions have not been studied in detail, but have been considered in field studies and in flow-management modelling at Chowilla (Overton *et al.* 2005). At Bookpurnong, for example, riparian river red gums have died and been replaced by black box and river cooba (Dr K. Holland, CSIRO, unpublished data). Shifts in the dominant trees have occurred along the lower Great Darling Anabranch, where river red gums are now established in areas where water availability has been increased by river regulation (Dr T. Wallace, University of Adelaide, unpublished data). Shifts in river red gum distribution due to the impacts of river regulation have also been observed in the Barmah-Millewa forest (Bren 1988). The overall picture is that under the Baseline Scenario the distributions of key species will contract significantly.

Lack of regeneration is a critical factor for long-term management of tree communities in the Lower River Murray. The age-class distribution of woodland trees is an indicator of recruitment and survival, where the growth and recruitment of young trees must at least match the mortality of old trees if a stand is to remain viable (George *et al.* 2005). Data from Pike and Banrock Floodplains (George *et al.* 2005; Wallace 2009) show that the numbers of juvenile trees presently are insufficient to maintain either the existing (live trees only) or pre-existing (all standing trees) structure. Similar observations are reported from wetland surveys along the River Murray between Locks 1–4 (Aldridge *et al.* 2012).

BP2800

Based on the interim report by Bloss *et al*. (2012), the BP2800 Scenario increases the frequency and duration of small to medium (up to 40,000 ML/day) flows. However, this flow band does not support the large overbank flows needed to maintain lateral connectivity between the river and floodplain in either the valley or gorge sections of the Lower River Murray. Some benefits are achieved by increasing the frequency and duration of 40,000 to 80,000 ML/day flows, but not to levels sufficient to maintain the character of these areas. BP2800 does not provide any benefits in the high flow (>80,000 ML/day) range. Therefore, a continuation of the decline in condition under current conditions is indicated for these parts of the floodplain. Again, this is consistent with a 70,000 ML/day flow being regarded as a boundary for the 'active' floodplain in the regulated River Murray (Holland *et al.* 2005).

Consequently, the BP2800 Scenario does not allow for 'reactivation' of the higher floodplain, and results in a long-term or permanent 'downsizing' of the floodplain. Many of the risks associated with the Baseline Scenario (i.e. lack of regeneration, change of habitat character) are invoked also by the BP2800 Scenario.

In terms of the major vegetation communities, the interim report by Bloss *et al*. (2012) concluded that only 11% of the current extent of river red gum, 3.2% of black box, and 3.2% of tangled lignum vegetation achieved all of the SA EWR metrics under the BP2800 Scenario. However, there is potential for improvement in the condition of many floodplain vegetation communities based on an improvement in flooding frequency, duration and interval in comparison to the Baseline Scenario. There is potential for an improvement in vegetation condition based on meeting just the flooding frequency target specified in the MDBA and SA EWRs. If we just consider those areas where the flooding frequency targets are met, there should be some improvement in the condition of black box and red gum communities between the 70,000 and 95,000 ML/day flow range, however these communities are unlikely to return to a healthy condition if the flood duration and interval metrics are also not met. This assessment did not account for the current vegetation condition, *i.e.* many areas are currently degraded and may require additional rehabilitation measures to return to their stated ecological character.

The interim report by Bloss *et al*. (2012) identified several physical and operational delivery constraints assumed by the MDBA modelling that preclude the delivery of higher flows. Relaxation of some or all of these delivery constraints could improve the delivery of water in the higher flow bands (80–100,000 ML/day), and this may increase the achievement of EWRs in other areas of the floodplain. Addressing these constraints should be a management priority.

Environmental risks under BP2800

Limitations of the current EWRs

The MDBA and SA EWRs are assumed to be representative of the water requirements of all Lower River Murray floodplain communities, although the MDBA and SA EWRs were developed for sites in the valley section, notably the Riverland-Chowilla Floodplain (MDBA EWRs) and Pike and Katarapko floodplains (SA EWRs). However, the interim review by Bloss *et al*. (2012) identified flow-related differences in the distributions of vegetation types in the valley and gorge sections, suggesting that it may be necessary to develop separate EWRs for these regions.

The River Murray floodplain is contained in a wide valley from upstream of the SA border to Overland Corner, where it enters a narrow limestone gorge (1 – 2 km wide). In the River Murray valley section, upstream of the Hamley Fault, the regional groundwater is from the Pliocene Sands Aquifer. Downstream of the fault, in the River Murray gorge section, the groundwater is from the Murray Group Limestone Aquifer (Bone 2009). Groundwater salinities in the Murray Group Limestone Aquifer are lower, and there are reductions in salinity inputs to the river downstream of Overland Corner (Walker G.R. *et al.* 2009). With the change from Pliocene sands to limestone geology, the floodplain contracts from a 5–10 km wide valley to a 1–2 km wide gorge. This constriction affects the geomorphology of the floodplain, so that wetlands account for 52% of the total floodplain area in the River Murray gorge section and 20% in the Valley section. The narrow floodplain in the gorge section means that runoff from the cliffs and lateral movements of lower salinity groundwater could improve water availability (Holland *et al.* 2006).

Both the MDBA and SA EWRs are intended to maintain 80% of the vegetation in the respective sections, per the *Limits of Acceptable Change* determined as part of the Riverland Ramsar Site Ecological Character Description (Newall *et al.* 2009). There is an implicit assumption that lack of water alone controls vegetation health, so that restoration of flows would produce a recovery. This does not allow for the current poor condition of the vegetation in many areas, nor does it acknowledge the strong influence of soil salinity and other factors. The effect of saline soils on plant growth is like that of drought conditions in non-saline soils, in that the ability of plants to extract water is reduced. It is likely therefore that the EWRs are optimistic, and that more water will be required for recovery than is required to maintain targeted conditions. Experience with artificial watering during the recent drought has shown that vegetation response to watering was strongly dependent on pre-existing canopy condition, so that trees in good condition responded more strongly than those in poor condition (Dr T. Wallace, University of Adelaide, unpublished data; White *et al.* 2009).

Downsizing the 'active' floodplain

Current conditions have reduced the active floodplain by limiting the size and magnitude of floods. The recovery (and appropriate delivery) of 2800 GL of environmental water has the potential to reinstate some of the small to medium flows that regulation has removed. Frequent small floods are a primary source of water in lowland river floodplains in arid regions; they maintain soil moisture for seedlings and water levels in wetlands, increasing the potential for subsequent flows to travel further and/or inundate larger areas (Leigh *et al.* 2010). An inability to reinstate or a choice not to reinstate floods is in effect a decision to downsize a river system (cf. Overton and Doody 2008; Hall *et al.* 2011; Pittock and Finlayson 2011).

The interface between the aquatic (regularly inundated) and terrestrial (never inundated) zones in is important in subsidising terrestrial food webs, so that many apparently terrestrial species in the River Murray corridor depend upon healthy floodplain and river communities. Faunal-transported fluxes of energy (e.g. macrophytes grazed by herbivores; emergent aquatic insects eaten by birds, bats, reptiles, beetles, spiders etc.) are vital for terrestrial foodwebs (review by Ballinger and Lake 2006). Abandonment of large sections of floodplain may sever the links between the riverine floodplain and nearby Mallee ecosystems.

Lateral connectivity

Lateral barriers between rivers and floodplains (diversion and flood-protection levees, reductions in flood magnitude and duration) prevent connectivity and can lead to fragmentation and isolation of populations, failed recruitment and local extinctions (e.g. Bunn and Arthington 2002; Arthington and Pusey 2003). Fish (Balcombe *et al.* 2007; King *et al.* 2009; Meredith and Beesley 2009) and macro-invertebrates, including crustaceans (shrimp, crayfish) and molluscs (snails, freshwater mussels), will re-colonise isolated areas only if there are appropriate habitats (e.g. macrophytes) and food resources (Nielsen *et al.* 1999), and populations and connectivity are maintained (e.g. Kingsford *et al.* 2010). Managed floods that do not meet these conditions, or do not provide lateral and longitudinal transfers of allochthonous material may not produce the desired ecological responses (Wallace *et al.* 2011).

Source of environmental water

The source of water for Environmental Water Allocations (EWAs) may influence ecological outcomes (Wallace *et al*. 2011). An EWA from an upstream storage during very low-flow periods may limit the ecological response, if productivity gains from upstream flooding are not transported to the managed site. In other words, increased upstream connectivity between the channel and floodplain provides downstream benefits. The 'missing pieces' could include plant and invertebrate propagules from upstream sites, increased carbon and nutrient concentrations and other chemical cues resulting from inundation of floodplain soils and plant material, eggs and larvae of fish and other organisms spawned at upstream sites.

Summary

Overall, the analysis of the South Australian and MDBA EWR achievements for floodplains made in Bloss *et al*. (2012) for the BP2800 Scenario indicated that environmental benefits are most likely to occur at low elevations. However, greater benefits could potentially be achieved if current channel capacity constraints were relaxed to enable more frequent flooding at middle elevations, in the 40,000–80,000 ML/day range. Conversely, environmental benefits might be reduced as a result of ongoing salinisation of many floodplain habitats. A key limitation for EWR assessments in Lower River Murray floodplains is that the changed flow regime and other processes influencing salinisation must be considered together. In addition, the re-distribution of some target organisms (especially long-lived trees) can be slow, once conditions change. In summary:

- Analysis of the SA and MDBA EWR for floodplains under the BP2800 Scenario indicate increased flooding frequency and duration for the lower-elevation floodplain area, which could improve the health of low elevation floodplain vegetation and wetlands;
- The middle and high elevation areas of floodplains, where most black box and river red gum woodlands occur, will receive little or no additional water. Salt will continue to accumulate in floodplain soils and wetlands at these middle and high elevations. A recovery period is likely to be required in this habitat, recognising the level of salinisation post-drought. There is likely to be a need in the short-term for a greater frequency of inundation to assist recovery of this environment.
- It is feasible to consider generating managed flows in the order of 40,000 to 80,000 ML/day that inundate the middle elevation areas of floodplains. In the current MDBA modelled scenario the existing operational and delivery constraints are included. Additional environmental benefits may be achieved if these constraints could be modified to allow flows within this flow range to be delivered.

The following are recommendations to improve our ability to evaluate the success of future water recovery scenarios for floodplains:

- Repeat the 2002–03 baseline vegetation survey. While there have been assessments at specific sites, their objectives and locations have varied. A comprehensive new survey is needed urgently to establish an accurate assessment of current vegetation condition.
- EWRs should be developed for the Murray gorge section, to provide a more reliable assessment of the potential outcomes of each water-recovery scenario. This is due to the geological and geomorphic differences between the Murray valley and River Murray gorge sections that will affect the spatial distribution of vegetation and regional hydrological and ecological processes.
- Present SA and MDBA EWRs assume that the spatial distribution of vegetation is fixed, but this is not the case. We recommend a study of the ecological ramifications of spatial shifts in plant communities, to elucidate the timescales and ecological ramifications of shifts toward more drought-tolerant species into low-lying floodplain areas. This shift in plant communities is likely to extend to the other biota depending on them.

Coorong, Lower Lakes and Murray Mouth

Being at the terminus of the system, evaluating the success of water recovery scenarios on EWR targets in the CLLMM region is difficult because success is partly determined by stressors imposed on the system during very low flow conditions, which are difficult to model. The CLLMM region is large and diverse and its primary environmental drivers (water level, salinity) are a complex interplay between river flows and other factors (Lamontagne *et al.* 2004; Webster 2005). The CLLMM region was significantly impacted during the recent drought and has recovered only partially. The current definition of the ecological character for the region and recent changes during and post-drought are reviewed below. While not specifically a CLLMM region EWR, the salt export targets for the MDB are also reviewed here.

Review of ecological character definition and implications for the assessment

The desired long-term ecological character for the Coorong, Lower Lakes and Murray Mouth (CLLMM) region is set at the ecological conditions which prevailed in 1985 (Phillips and Muller 2006). At this time, the region was listed as a *Wetland of International Importance* under the international Ramsar Convention, supported by the *Environment Protection and Biodiversity Conservation Act 1999*) (EPBC Act) and migratory bird treaties (CAMBA, JAMBA, ROKAMBA).

The ecological character description sets simple but general maintenance targets to maintain: (1) the Lower Lakes as a freshwater system, (2) the Coorong with a gradation from estuarine ecosystems in the north to moderately hypersaline ecosystems in the south; and (3) an open Murray Mouth. At the time of nomination, the large-fruit tassel *Ruppia megacarpa* was listed as a critical macrophyte in the North Lagoon of the Coorong and the tuberous tassel *Ruppia tuberosa* was similarly prominent in the South Lagoon. These species are often singled out as key indicators of ecological health, but there are other species, notably various fauna (fish, birds, invertebrates) that are also key components of these systems and should be considered. Some have habitat needs that are likely to be captured within the ecological requirements of the plants, but others do not.

EWR indicators and targets

In the interim documentation provided to the panel, the following EWRs had been set by the MDBA for the CLLMM region (Appendix A3):

- 10-year rolling average flow >3200 GL/year for salt export through an open Murray Mouth;
- Lakes Albert and Alexandrina with water levels >0 m AHD in 100% of years;
- Maximum salinity of 130 g/L in South Lagoon of the Coorong;
- Maximum salinity in South Lagoon of Coorong <100 g/L in 95% of years;
- Maximum period of salinity in South Lagoon of the Coorong >130 g/L of 0 days;
- Maximum salinity of 50 g/L in North Lagoon of the Coorong;
- Maximum period of salinity >50 g/L in North Lagoon of the Coorong of 0 days;
- Barrage outflow: long-term annual average >5100 GL/year;
- Barrage outflow 3-year rolling average >1000GL/year in 100% of years;
- Barrage outflow: 3-year rolling average >2000 GL/year in 95% of years.

Additional South Australian EWR targets were defined for the region (Appendix Table A4) and additional information is available in the report by Lester *et al.* (2011):

- Lake Alexandrina salinity of <1000 EC for 95% of all years;
- Lake Alexandrina salinity of <1500 EC for 100% of all years;
- Barrage outflow 6000 GL/year, over a rolling 3 year period;
- Barrage outflow 10,000 GL/year, 1 in 7 years.

Identifying EWR requirements for the CLLMM region is a relatively recent exercise and the initial EWRs defined by the SA Government have been through an extensive review process. Further improvements could be made to the EWR targets for the purpose of ensuring the preservation of the ecological character of the region, in particular with regards to salinity.

The salinity values proposed for the South and North Lagoons of the Coorong are based largely on the tolerance limits of key plants, notably *Ruppia tuberosa* and *R. megacarpa*. These limits are implied by their distribution. For example, salinity targets for the South Lagoon are generated by correlating average annual salinities with the distribution of *R. tuberosa,* and not necessarily with reference to measured performances of the plants (e.g. densities, reproduction). The data used came from a period when the distribution of this plant was contracting, suggesting that conditions then were sub-optimal. Other key factors, such as appropriate water levels in spring, have not been considered at this stage. Various annual average water levels, however, have been suggested. For example, the distribution of *R. tuberosa* in the South Lagoon correlated most strongly with an average water level in the South Lagoon of 0.27 m AHD (Overton *et al.* 2009), and an average level of 0.37 m AHD was associated with the healthiest ecosystem 'states' in the South Lagoon (Lester and Fairweather 2009). This is presently the focus of work being undertaken as a part of the Australian Government funded DENR CLLMM program using monitoring information correlated to detailed bathymetry in the region. The information is not presently available in a form that permits it to be related to guide inundation requirements and a more detailed sensitivity assessment is a future task (Higham, 2012).

At the time of the review, there was a lack of clarity regarding the metrics being used by the MDBA to evaluate the salinity EWRs as described by the MDBA (2012a,b). Improving any ambiguity in relation to the salinity assessments with regard to spatial and temporal averages should be a priority. As there is no clear guidance from the MDBA on this matter, the interpretation by Higham (2012) and Heneker and Higham (2012) was accepted by the Expert Panel.

The understanding of the Expert Panel is that the revised EWRs include both maximum daily salinity and annual average salinity targets for each lagoon. Not all of the EWRs were evaluated in the SA Government assessment within the timeframes available and subsequently provided to the panel (Appendix A3). Despite the definitional issues, some preliminary comments can be made in relation to the salinity targets regardless of the metrics applied. The Expert Panel believes the maximum daily salinity threshold for the South Lagoon (130 g/L) is too high. This is well above the salinity tolerance threshold for key organisms, including those involved in defining the ecological character for the South Lagoon.

For example, one of the key species in the South Lagoon, the small-mouthed hardyhead *Atherinosoma microstoma*, has an LD_{50} of 108 g/L (Lui 1969; Dr S. Wedderburn, University of Adelaide, unpublished data). Thus, the small-mouthed hardyhead would probably be absent from the South Lagoon (which represents 2/3 the Coorong surface area) even when the new maximum salinity target is achieved. Maintenance of small-mouthed hardyhead populations in the South Lagoon is critical for fish-eating birds, notably the fairy tern *Sternula nereis* (Paton and Rogers 2009; Baker-Gabb and Manning 2011). The salinity threshold should also take into account that the Coorong lagoons usually have salinity gradients (Paton 2010). Thus, achieving the maximum salinity target on average (in time and space) could still result in part of the system having salinities well above the target value.

Current condition

Some knowledge of recent historical perturbations is needed to underpin our summary of the current condition of the CLLMM region. This is best done considering the Lower Lakes and Coorong separately.

Lower Lakes

In 2006–09 the Lower Lakes received record low inflows from the River Murray, causing unprecedented drawdowns to about -1.0 m AHD in Lake Alexandrina and -0.5 m AHD in Lake Albert (normal operating levels are between +0.6 and +0.85 m AHD). The drawdown caused rapid increases in salinity. In January 2007, the average salinity in the Lower Lakes was 1660 ± 250 µS/cm, and there were small differences only between the main body of Lake Alexandrina, Lake Albert and the Goolwa Channel (Aldridge *et al.* 2011). Herein, 'Goolwa Channel' is referred to as the area between the barrages and the main body of Lake Alexandrina, including the tributaries (Finniss River, Currency Creek) to the Goolwa Channel region and the channels around Hindmarsh Island. There was a gradual increase along a line from the River Murray inflow to Lake Alexandrina (711 µS/cm) to the barrages (4467 µS/cm at Goolwa Barrage). By April 2008, however, the salinity ranged from 1479 µS/cm at the upstream end of Lake Alexandrina to 35,075 µS/cm at Goolwa Barrage (Aldridge *et al.* 2011). During this time, the total salt mass increased by 205% in the Lower Lakes; 78% of this was from unknown sources, most likely from barrage leakage (Aldridge *et al.* 2011).

Decreased water levels and increased salinity had major effects on the Lower Lakes, including:

- Increased dissolved nutrient concentrations (Aldridge *et al.* 2011);
- Stratification (and oxygen depletion in the hypolimnion) in Goolwa Channel, reducing habitat for biota (Aldridge *et al.* 2011);
- A bloom of the potentially-toxic cyanobacterium *Nodularia spumigena* in Lake Albert (South Australian Environment Protection Authority, March 2009, unpublished data);
- The disconnection and drying of peripheral wetlands (Gehrig *et al.* 2011);
- The disconnection of fringing vegetation from the lakes due to the receding shoreline (Gehrig *et al.* 2011);
- Complete loss of submerged macrophyte beds, particularly in peripheral wetlands and the Goolwa Channel (Gehrig *et al.* 2011), resulting in loss of habitat for biota;
- An initial decrease in numbers of three EPBC-listed threatened small-bodied fish species (Murray hardyhead *Craterocephalus fluviatilis*, Yarra pygmy perch *Nannoperca obscura* and southern pygmy perch *N. australis*: Wedderburn *et al.* 2011; 2012), possibly followed by complete losses of these species from the lakes (Wedderburn and Barnes 2011);
- Proliferation of the estuarine tube worm *Ficopomatus enigmaticus* on submerged surfaces, including the shells of turtles and freshwater mussels, often resulting in death (Benger *et al.* 2010);
- Mass mortalities of freshwater mussels (*Velesunio ambiguus*) due to salinity, exposure and tubeworm growths (Dr K.F. Walker, University of Adelaide, unpublished data);
- Disconnection of the lakes from the Coorong, disrupting the life cycle of diadromous fish such as congolli, *Pseudaphritis urvillii* (Zampatti *et al.* 2010);
- Significant risks of exposure of acid sulfate soils (Fitzpatrick *et al*. 2008) that required substantial interventions (bunds, lime application, etc);
- Significant changes in the abundances and distributions of birds (Kingsford and Porter 2008; Kingsford and Porter 2009; Paton *et al.* 2011a, Paton and Bailey 2011a).

Many changes were associated with the Goolwa Channel, an area with structurally complex habitats in submerged macrophyte beds. This area was most vulnerable to changes in salinity due to proximity to the Goolwa Barrage, as was highlighted by Wedderburn and Hammer (2003).

Between spring 2009 and the present, the Murray-Darling Basin received widespread, heavy rainfall. This brought strong inflows to the Lower Lakes and water levels returned to near-normal by spring 2010. Water levels now are about 0.65 m AHD, and salinity levels in Lake Alexandrina also are back to normal levels (<1000 µS/cm; Department for Water, unpublished data). Salinity levels in Lake Albert remain high (currently 4000–5000 µS/cm: Department for Water, unpublished data) and, as the only avenue for salt export is via Lake Alexandrina, it will take some time for salinity levels to decline further.

There have been mixed ecological responses to increased flows to the Lower Lakes. As would be expected, some components (e.g. mobile, short-lived species) have recovered and some (e.g. less mobile, long-lived species) have not. Ecological monitoring of the Lower Lakes in 2010–11 suggested that:

- Aquatic plant communities were recovering but were not at pre-drought conditions (Gehrig *et al.* 2011);

- Littoral plants had improved in condition but submerged plants were absent in the lakes proper;
    - There had been limited recruitment of submerged plants in peripheral wetlands;
    - In the Goolwa Channel the submerged plant community was dominated by sago pondweed, *Potamogeton pectinatus* (this was not the case prior to the drought), although it became much less abundant between spring 2010 and autumn 2011 (Gehrig *et al.* 2011);
- One threatened fish species (Yarra pygmy perch) that previously inhabited the Lower Lakes was not detected again in the region (Wedderburn and Barnes 2011; C. Bice, SARDI Aquatic Sciences, personal communication);
- Congolli successfully recruited following the reestablishment of flows and connectivity between the Coorong and Lower Lakes in late 2010 (Wedderburn *et al.* 2011; Zampatti *et al.* 2011);
- The response of the bird community was highly variable among species, with some increasing, some remaining steady and others decreasing (Paton *et al.* 2011a; Paton and Bailey 2011a).

Coorong

The Coorong has changed dramatically since 1985, when the CLLMM was listed as a *Wetland of International Importance* under the Ramsar Convention. In the 1980s, *Ruppia megacarpa* occurred in the North Lagoon, and *R. tuberosa* was widespread and abundant along the length of the South Lagoon. The foxtail stonewort *Lamprothamnium papulosum* and long-fruited water mat *Lepilaena cylindrocarpa* were also still prominent in the North Lagoon. Salinities at this time were 20–50 g/L in the North Lagoon and 50–100 g/L in the South Lagoon (Geddes and Butler 1984; Geddes 1987; Paton 2010). *Ruppia megacarpa* has since disappeared from the North Lagoon (it was last recorded in the 1980s: Snoejis and Ster 1981; Geddes 1987) and in the River Murray Estuary (between Goolwa and Tauwitchere Barrages) in the mid 1990s (Edyvane *et al.* 1996). Extensive surveys in the last five years have failed to detect any plants, but empty testa (seed coats) still occur in surface sediments in the southern half of the North Lagoon, and throughout the South Lagoon (Nicol 2007b; Dr D.C. Paton, University of Adelaide, unpublished data). Re-establishment of *R. megacarpa* as a keystone species in the North Lagoon will be challenging, even if suitable salinities are re-established. The critical issue may not be salinity but the maintenance of adequate water levels year-round. *Ruppia megacarpa* is a perennial species with limited capacity to re-establish following desiccation, partly because it produces relatively low numbers of propagules (Brock 1982).

The loss of *R. megacarpa* highlights the need to maintain the distribution and abundance of *R. tuberosa* in the Coorong. *Ruppia tuberosa* is essentially an annual plant. It has a much greater capacity to re-establish itself following periods of desiccation, provided that conditions are suitable, because it invests in producing large quantities of seeds and turions.

The distribution and abundance of *R. tuberosa* in the Coorong have also declined dramatically in recent years. This has coincided with an extended period of limited flow over the barrages, commencing in 2002, with the plant disappearing progressively northwards from the southern end. In winter 2008, no *Ruppia* were detected growing in four areas distributed along the length of the South Lagoon that have been monitored annually since winter 1998 (Paton 2010, p. 138). Paton (2010) argues that the decline is related more directly to inadequate water levels in spring than high salinities. Low water levels prevent this annual plant from completing its reproductive cycle, failing to replenish its seed banks in spring. Thus, during this period the abundances of the seeds and turions in the propagule bank for *R. tuberosa* declined dramatically (Paton 2010, p. 140). The size and viability of the propagule bank defines *resilience* for this plant, so the resilience of the population also has diminished. Resilience is further compromised by recent assessments showing that about 99% of the seeds in the seed bank lack content and so are not viable (Dr D.C. Paton, University of Adelaide, unpublished data). During this same period, *R. tuberosa* colonised the middle parts of the North Lagoon (Paton 2010), but this was a short-lived expansion—the newly-established beds disappeared by July 2011, some eight months after the resumption of significant flows over the Barrages (Paton *et al.* 2011b). These flows favoured the growth of filamentous green algae such as *Enteromorpha* sp.; the dense algal growths become entangled with the *Ruppia*, leading to its demise (Paton *et al.* 2011b).

The return of significant flows over the barrages after October 2010 dramatically reduced the salinity in the South Lagoon, and by winter 2011 salinities there were within the target range of 60–100 g/L for *R. tuberosa*. Even so, the re-appearance of *R. tuberosa* was limited to the northernmost monitoring site (Dr D.C. Paton, University of Adelaide, unpublished data), suggesting that the seed banks in other areas were not viable. Subsequent reduced inflows to SA resulted in the closure of most of the barrage gates in October 2011. This caused water levels in the Coorong to fall sharply, such that most of the extant *Ruppia* beds were again exposed and the plants dessicated before they could reproduce. These observations highlight the importance of understanding the seasonal requirements for flows to maintain water levels in the Coorong. Even a substantial annual flow over the barrages (approximately 12,850 GL in July 2010 – June 2011 and approximately 4,500 in July-Oct 2011; J. Higham, Department of Environment and Natural Resources, personal communication) does not guarantee suitable conditions to restore the system. This is consistent with hydrodynamic modelling suggesting that several years with significant flows over the barrages following a drought are required to reduce salinity within management targets in the South Lagoon rather than a single year of greater than average flow (J. Higham, Department of Environment and Natural Resources, personal communication).

In summary, the current distribution, abundance and resilience of *R. tuberosa* remain precarious and at unprecedented low levels. Re-establishment of this species and its resilience will require optimal ecological conditions to prevail for several years in succession. Even then, translocation of *R. tuberosa* material is likely to be required into much of the South Lagoon.

Negligible flows of fresh water over the barrages in 2002–10 have also impacted on other organisms. By January 2007, salinities in the South Lagoon in summer exceeded 150 g/L. These exceeded the upper tolerances of the small-mouthed hardyhead and the chironomid (midge) *Tanytarsus barbitarsis*, and both species were eliminated (e.g. Paton 2010, p. 142). This significantly reduced the food supply for various waterbirds, many of which were forced to vacate the South Lagoon (Paton 2010). Once salinities exceeded 120 g/L, the brine shrimp *Parartemia zietziana* became prominent throughout the South Lagoon, and by September 2010 it had expanded its range a further 20 km into the North Lagoon. Brine shrimps were still prominent throughout the South Lagoon in January 2011, even though the salinities were <100 g/L, possibly because the numbers of small-mouthed hardyheads that had recolonised were still low (e.g. Paton and Bailey 2011b). The brine shrimps had disappeared by July 2011, when salinities were <80 g/L. Chironomid larvae responded quickly to the lower salinity and were abundant in January 2011 (Paton and Bailey 2011b). Thus, some but not all of the characteristic fauna of the southern Coorong recovered quickly following the re-establishment of suitable salinities. Similar findings have been reported for fish and aquatic invertebrates in the North Lagoon (Dittman *et al*. 2011; Ye *et al*. 2011a).

Since the mid 1980s, there have been significant reductions in the numbers of migratory waders and other waterbirds using the Coorong (e.g. Wainwright and Christie 2008; Paton 2010; Paton and Bailey 2011b), and other changes in the waterbird communities (Paton *et al.* 2009; Rogers and Paton 2009). In the 1980s, more than 50,000 red-necked stints (*Calidris ruficollis*), 50,000 sharp-tailed sandpipers (*Calidris acuminata*) and 40,000 curlew sandpipers (*Calidris ferruginea*) regularly visited the Coorong. Numbers are now typically around 20,000, 15,000 and 1000, respectively (Paton and Bailey 2011b). Many other species have also declined since the 1980s and, in some cases, prior to the 1980s (Paton 2010). Several key estuarine fish species, such as black bream (*Acanthopagrus butcheri*) and greenback flounder (*Rhombosolea tapirina*), also had a significant decline in abundance and distribution in the Coorong, particularly over the past decade of droughts (Ye *et al.* 2011b).

Despite these changes, the CLLMM still meets the waterbird criteria for listing as a *Wetland of International Importance* (e.g. Paton 2010; Paton and Bailey 2011a,b). Importantly during the period of limited flows (particularly in 2008–09), the region supported more than 90% of all the waterbirds counted across the 'Icon Sites' of the Murray-Darling Basin (Kingsford and Porter 2009). This highlights the importance of the CLLMM as a summer and drought refuge for waterbirds in the Murray-Darling Basin (Paton 2010), if not all of south-eastern Australia. At present, the ability of the Coorong to support some components of the waterbird community during the next period of low barrage flows is likely to be compromised by the scarcity of *Ruppia*. There is an urgent need to address this deficiency.

Baseline

At the time of preparing this review, the report summarising the ecological outcomes of different water-recovery scenarios for the Coorong (Higham 2012) was incomplete. Thus, most of the Panel's assessment was based on additional information provided at the workshop.

Under the Baseline Scenario, few of the MDBA or South Australian EWRs are achieved (Heneker and Higham 2012; Higham 2012), in particular for salinity (Appendix A3 and A4). This means that the condition for the region would remain poor, especially during droughts, with the risk of elevated salinities and low water levels in both the Lower Lakes and the Coorong. Under the modelled Baseline Scenario presented in the interim versions by Heneker and Higham (2012), the average salinity in Lake Alexandrina is greater than 1000 µS/cm in 30% of years and greater than 1500 µS/cm in 5% of years. Modelled water levels for the baseline scenario suggest that water levels fall below the 0.3 m AHD minimum target 15% of the time (Heneker and Higham 2012), with a minimum of -0.5 m (1 event of >500 days) during the modelled timeframe. In total, there are six events during the modelled timeframe below 0.0 m AHD, which is the MDBA target to prevent acidification from exposure of acid sulfate soils. However, as discussed later, the MDBA model outputs available for the assessment undertaken by the State Government under-estimate salinity levels and over-estimate water levels during drought periods. Consequently, as indicated by Heneker and Higham (2012), the EWRs will be met less often than predicted by their analysis.

Lower lakes

Some of the ecological implications of the Baseline Scenario for the Lower Lakes include:

- That low water levels during droughts may expose the shoreline and damage submerged and emergent plant beds, which are key habitat for fish and waterbirds (Wedderburn and Barnes 2009; Gerhig *et al*. 2011);
- That low water levels during droughts would increase the likelihood of salt intrusion through the barrages, including the formation of density stratification in Goolwa Channel (Aldridge *et al*. 2011);
- Increased risk of noxious algal blooms (Codd *et al*. 1994; Cook *et al*. 2010);
- A risk of losing freshwater communities due to high salinity (Hart *et al.* 1991; Nielsen *et al.* 2003), including endangered fish species (Wedderburn and Barnes 2011; Wedderburn *et al*. 2011), freshwater mussels, and turtles;
- Loss of connectivity with the Coorong through barrage and fish ladder closures, with implications for migratory species like congolli.

Coorong

Based on the interim analysis provided, none of the EWRs are achieved for the Coorong and Murray Mouth under the Baseline conditions. The ecological consequences currently being observed in the region include:

- Increased periods of Murray Mouth closure, with resulting loss of connectivity with the sea and necessity to undertake dredging;
- Periods of low water level and elevated salinity in the Coorong, with the likelihood that key invertebrate, fish, plant and bird species will either decrease significantly in abundance or be extirpated from the system;

- The near certainty that *Ruppia* and other formerly common aquatic plants will not recolonise the system;
- Significant risk of failure to maintain suitable habitats and food resources for a range of waterbird species (e.g. fairy tern, migratory waders).

BP2750

Lower Lakes

Under the modelled BP2750 Scenario, presented by Heneker and Higham (2012), average salinities in Lake Alexandrina exceed 1000 µS/cm in 5% of years and 1500 µS/cm in 2% of years. Modelled water levels for the BP2750 Scenario suggest that water levels fall below the 0.3 m AHD minimum target 5% of the time, with a minimum of 0.1 m during the modelled timeframe (Heneker and Higham 2012). There are no events below 0.0 m AHD, which is the MDBA target to prevent acidification.

Overall, the ecological consequences of BP2750 are the same as those listed under the Baseline scenario, but with a lower likelihood of occurrence. The Lower Lakes would be less exposed during short periods of low flows under BP2750, however, there is a residual risk that its freshwater character could be lost during periods of extended droughts.

Coorong

There are improvements relative to the Baseline Scenario for achieving the South Australian and MDBA EWRs for the Coorong under BP 2750 (Higham 2012; Appendix A4). The overall result would be to decrease the likelihood of extreme salinity events in the North and the South lagoons. However, the potential ecological outcomes are difficult to evaluate based on the information presented to the panel. Possible outcomes include:

- Improved conditions for forage fish in the South Lagoon, which are important food resources for piscivorous birds (terns, Australian pelican, etc);
- Improved habitat for fish in the North Lagoon due to potential reduction in extreme salinity events ;
- Reduced likelihood of developing degraded ecosystems states in the South Lagoon, such as the ones characterised by the presence of brine shrimp.

However, the absence of EWR for seasonal water levels precludes a detailed assessment of condition for *Ruppia tuberosa* and *Ruppia megacarpa* under BP2750. Considering the key roles of these aquatic plants in the ecology of the Coorong, the possibility remains that BP2750 will not maintain the ecological character of the Coorong as defined in the current Ramsar plan (Phillips and Muller 2006).

Salinity and salt-load targets

The salinity targets in the proposed Basin Plan are comprised of Murray-Darling Basin and end-of-valley salinity targets, a salt-load target for the River Murray system, and salinity operational targets. While they apply for the whole of the Basin, these are reviewed within the CLLMM section for simplicity.

The purpose of the salinity targets is to: (i) inform long-term planning for water resource plans; and (ii) monitoring and evaluating the effectiveness of the Basin Plan. The purpose of the salt-load target is to: (i) monitor and evaluate the effectiveness of the Basin Plan; and (ii) ensure adequate flushing of salt to the ocean. The Basin salinity target is 800 EC for 95% of the time at Morgan. The two salinity operational targets in South Australia are 500 EC for 95% of the time, at Morgan and 500 EC for 95% of the time at Murray Bridge. The salt-load target is the discharge of a minimum of 2 million tonnes of salt from the River Murray System to the Southern Ocean each year, averaged over the preceding 10 years (MDBA 2011a).

The Panel agrees with the concerns expressed by Bloss *et al*. (2012) regarding the ability of the MSM-BigMod model to represent and predict the salinity impacts of the changed distribution of water under the different water recover scenarios. In particular, Heneker & Higham (2012) found that the Baseline scenario overestimates water levels and underestimates salinity in the Lower Lakes. The Basin Plan runs would exacerbate these problems by taking the salt load calculations beyond the calibration range. Nonetheless, as pointed out by Heneker & Higham (2012), the modelling does provide some insights into the salinity trends. As such, Bloss et al. found that the BP2800 scenario did provide an improvement in the salinity at both Morgan (Basin salinity target site) and Tailem Bend (the most downstream point at which water is extracted for critical human water needs, and is close to the Murray Bridge salinity operational target site). Indeed, the model predictions suggest that the Basin salinity target and the Murray Bridge salinity operational target will be met under both the Baseline and BP2800 scenarios.

The salt-load target is expressed indicatively in the MDBA CLLMM EWRs as provision of sufficient flow to enable export of salt and nutrients from the Basin through an open Murray Mouth. The target is flows through the mouth >3,200 GL/yr, 100% of the time, averaged over the preceding 10 years. Heneker & Higham (2012) found that this flow over the barrages occurred in 73% of the years under the Baseline scenario and in 93% of years under the 2750 GL scenario. The consequence of not achieving the salt export target for all 10-year periods is that salinities during very low flow years in the Lower Lakes and Coorong will increase, as was experienced in the recent 10 year drought. Avoiding this rare situation may be achievable by appropriate operational management of environmental water allocations during drought periods. As experienced by the recent 'Millenium Drought' water was not available to meet the proposed water level and salinity targets.

As highlighted by the high salinities currently observed in Lake Albert and the Coorong, it takes considerable time for salinities to return to normal levels even during periods of high inflows.

Murray Mouth opening

The evaluation of Murray Mouth opening was not completed in the Higham (2012) interim report, but additional information was presented at the workshop. One of the problems with the environmental target for the Murray Mouth in the proposed Basin Plan is that what constitutes an 'open' Murray Mouth is not defined. Using the mouth being completely physically closed is not useful as an indicator because it is difficult to predict and because mitigation strategies (like dredging) must start beforehand. As a measure of Murray Mouth 'openness', the Panel supports the concept proposed at the workshop of using the 'effective depth' of the Murray Mouth channel, estimated by Webster's (2007) hydrodynamic model. As an approximation, the Murray Mouth in the model has a fixed channel width but its depth changes as a function of barrage discharge and other processes (Webster 2005; 2007). What the threshold should be to declare the Murray Mouth 'effectively closed' remains to be determined, but it could be in the range of 1 or 2 m effective depth. This range corresponds to the level of constriction of the mouth when dredging would need to be initiated to prevent complete closure.

According to the analysis presented at the workshop (J. Higham, Department of Environment and Natural Resources, personal communication), the BP2750 Scenario would lead to generally greater effective depths at the mouth, relative to the Baseline Scenario. Dredging may still be required to keep the mouth effectively open during some droughts. By improving the effective depth of the Murray Mouth, the connectivity with the ocean is improved, which would facilitate fish migration and water exchange between the Coorong and the Southern Ocean. However, maintaining an open mouth would not ensure adequate water levels in the Coorong, especially in spring, without adequate flows from the barrages.

Summary

The CLLMM region is still recovering from a decade-long drought, with many indicator species of its ecological character absent or much reduced in abundance and distribution. Despite degraded conditions, the region remains a key habitat for fish and waterbirds in the Murray-Darling Basin, albeit at a much lower base than when the region was declared a Ramsar wetland in 1985. Business-as-usual would likely lead to further ecological degradation in the longer-term. The proposed Basin Plan has the potential to halt the decline in some areas (Lake Alexandrina) but not others (South Lagoon of Coorong). However, because of uncertainties in the definition of BP2750 and in the implementation of the Basin Plan, the ecological outcomes may be better or worse than what is assessed herein. Thus, despite foreseen improvements relative to Baseline conditions, it remains unclear whether the Basin Plan would maintain the ecological character of the region as prescribed in its current definition of a Ramsar-listed wetland. A change in the ecological character could lead to loss of biodiversity, however, this does not mean that the CLLMM region would not retain some environmental value or provide any ecosystem services. In summary:

- The trends between the Baseline and BP2750 scenarios modelled by the MDBA indicate increased flow over the barrages under the BP2750 Scenario and possible improvements in connectivity between the Lower Lakes and the Coorong and improved ecological condition;
- The BP2750 Scenario is likely to improve the effective depth of the Murray Mouth, although the Murray Mouth will still likely require dredging in some droughts;
- Amelioration of extreme salinities in the Coorong, with potential benefits for fish and bird populations. Further investigations are needed to improve: (i) the understanding of salinity thresholds of target species and (ii) the modelling calculations underpinning the determination of the maximum salinity and its implications;
- Extreme low-water levels and elevated salinities may still occur infrequently in the Lower Lakes under extended drought conditions under the proposed Basin Plan.

In the context of adaptive management during the implementation of the Basin Plan, the Panel recommends that:

- A recovery period following drought conditions with subsequent elevated salinities should be factored into the allocation of environmental water by the Commonwealth Environmental Water Holder, such that the CLLMM has dedicated flows over a sustained period to enable the system to recover. Salinities in the Lower Lakes and Coorong still remain elevated post the 'Millennium Drought' despite the subsequent high flows over the past 12 months;
- The current EWR targets for salinity in the Coorong should be revised because they may not be conservative enough —sub-lethal and lethal salinities for key organisms could still occur even when the targets are achieved;
- Specific seasonal water levels EWRs should be defined for the Coorong as it requires the maintenance of winter water levels through spring (at least) to function properly; and
- As the EWR assessment does not take into account that the system is already degraded, with some indicators (like *R. megacarpa*) being already extirpated from the system for decades and others severely depressed (*R. tuberosa*), additional management interventions may be required above achieving the current EWRs to bring back some indicator species.

Discussion

Response to the terms of reference

1. *Provide advice on the adequacy of the methodology used by the South Australian Government to evaluate performance of the proposed Basin Plan against EWRs*.

The Panel found that the methodology used by the State agencies to evaluate the proposed Basin Plan was adequate, considering the tools available for this task. However, as for any modelling exercise, the tools and the assumptions used in the analyses by the MDBA introduce limitations, which have implications for this assessment. The key modelling limitations are:

- The scenarios provided by the MDBA to the State agencies are one of many possible flow regime outcomes for the river under a given water recovery (BP2750, BP2800). The ecological outcomes could be better or worse than described here, depending on how the Basin Plan is implemented;
- The possible impacts of climate change and increased groundwater allocations on future water availability are not evaluated in the flow recovery scenarios provided by the MDBA;
- MSM-BigMod tends to over-estimate flow delivery and water levels and under-estimate salinity in the Lower Lakes during drought and therefore the EWRs will be met less often than suggested by the models; and
- MSM-BigMod tends to over-estimate discharge at the barrages during drought and therefore the EWRs will be met less often than suggested by the models.

At present there are some minor differences between the assessments of EWRs by the SA Government compared to the MDBA. These differences stem from slightly different assumptions used to define a successful environmental watering event. The SA Government has defined a successful as one that meets all of the three EWR metrics, being flow, duration and interval between events. The MDBA has classed near events as a successful event, hence resulting in a slightly higher achievement of the EWRs in the 20,000 to 80,000 ML/day range.

2. *Evaluate the likely ecological consequences of the modelled 2800 GL water recovery scenario relative to a "do nothing" (or baseline) scenario, including considering: key indicator species and communities, the Riverland-Chowilla Floodplain and CLLMM Ramsar sites, and biodiversity at non-Ramsar sites.*

River Murray Channel, Connected Streams and Wetlands

- According to the South Australian Government analysis, there are limited benefits for the medium to high elevation wetlands (above 40,000 ML/day) under either the Baseline or BP2800 scenarios and the decline in these wetlands will result in decreased habitat availability for aquatic plants, water birds and other freshwater biota;
- The main benefits of the BP2800 Scenario would be to create more opportunities for in-channel variations in stream flows, which would improve habitat for Lower River Murray threatened or endangered larger-bodied fish species like Murray cod and silver perch, and to increase the flooding frequency and duration of low-elevation wetlands, which would improve habitat for smaller-bodied native fish, including several threatened species.
- Articulation of EWRs for the main channel that include hydraulic complexity (e.g. variability of cross-sectional velocity profiles), longitudinal connectivity, area of the littoral zone and large-bodied native fish recruitment would assist in achieving environmental outcomes in part of the system that is managed.

Floodplains

- The middle and high elevation areas of floodplains, where most black box and river red gum woodlands occur, will receive little or no additional water. Salt will continue to accumulate in floodplain soils and wetlands at these middle and high elevations. A recovery period is likely to be required in this habitat, recognising the level of salinisation post-drought. There is likely to be a need in the short-term for a greater frequency of inundation to assist recovery of this environment.
- Analysis of the SA EWRs for floodplains under the BP2800 Scenario indicate increased flooding frequency and duration for the lower-elevation floodplain area, which could improve the health of low elevation floodplain vegetation;
- For the Riverland-Chowilla Ramsar site, the likely outcome of the BP2800 presented is a contraction of the desired ecological character over a smaller 'active' floodplain area. A similar contraction of the ecological character will occur at non-Ramsar floodplains.
- It is feasible to consider generating managed flows in the order of 40,000 to 80,000 ML/day that inundate the middle elevation areas of floodplains. In the current MDBA modelled scenario the existing operational and delivery constraints are included and this prevents a robust assessment of what could be delivered. Additional environmental benefits could be achieved if these constraints were modified to allow flows within this flow range to be delivered. However these communities are unlikely to return to a healthy condition if the flood duration and interval metrics are also not met.

Coorong, Lower Lakes and Murray Mouth

- There may be potential benefits for fish and bird populations due to the decreased likelihood of extreme salinities under BP2750, including migratory bird species covered under the Ramsar convention. Further investigation is needed to improve: (i) the understanding of salinity thresholds of target species, (ii) the modelling calculations underpinning the determination of the annual maximum salinity and its implications; and (iii) the importance of water levels to aquatic plant populations;
- Extreme low-water levels and salinities may still occur infrequently in the Lower Lakes under extended drought conditions, but are improved in the BP2750 Scenario compared to the Baseline. Thus, BP2750 could ameliorate habitat for threatened organisms in the region, including several native fish species;
- The trends between the Baseline and BP2750 scenarios modelled by the MDBA indicate that there is increased flow over the barrages under the BP2750 Scenario and possible improvements in connectivity between the Lower Lakes and the Coorong. This would improve habitat for congolli and a significant number of other native fish which migrate between the two systems to complete their life cycles;
- The BP2750 scenario is likely to improve the effective depth of the Murray Mouth, although the Murray Mouth will still likely require dredging in some droughts;
- A recovery period following drought conditions with subsequent elevated salinities should be factored into allocation of environmental water such that the CLLMM has the flows over a sustained period to enable the system to recover;
- Consideration of a minimum seasonal water level EWR to protect key indicator species (*Ruppia* spp.) is strongly recommended; and
- Overall, the ecological character of the CLLMM region as it is currently defined will almost certainly be lost under the Baseline Scenario, compromising its Ramsar status. Based on the available information, some indicator species and communities may still be impacted under BP2750.

3. *Provide advice on how ecological risks could be mitigated to enhance ecological outcomes from the proposed Basin Plan.*

Infrastructure

A range of local infrastructure is used to partially mitigate the negative environmental impacts of the current flow regime for the river in South Australia, such as groundwater interception schemes aiming to lower water tables in salinised floodplains and fishways to bypass weirs and barrages. Additional measures, such as environmental watering of floodplains using pumps and sprinklers, were also used during the recent drought to maintain local patches of healthier vegetation. However, while there may be some scope to further improve on the environmental benefits of the proposed Basin Plan using local infrastructure, the Panel believes that the greatest benefits of investing into infrastructure would be to alleviate the current channel capacity constraints upstream. This would enable a more flexible use of the recovered environmental water in South Australia. The river is already 'over-regulated' and adding more local infrastructure would continue the trend of fragmenting and isolating the different components of the riverine floodplain system, which is not in the 'spirit' of the proposed Basin Plan.

Rehabilitation

Once suitable environmental conditions are restored, it is possible that ecosystem recovery will be slowed or prevented by the low resilience associated with the current degraded state of some of the environmental assets. For example *Ruppia megacarpa*, a key indicator species for the North Lagoon, is currently absent, and *Ruppia tuberosa*, a key indicator species for the South Lagoon is greatly reduced in distribution and abundance. For both species the present seed bank is probably severely if not completed depleted through most of their former ranges. Thus, once suitable conditions are returned, reseeding of *Ruppia* from neighbouring populations could be considered. However, such interventions are only warranted if suitable environmental conditions are sustained in the longer-term.

Other ecological risk factors

There is a possibility that less environmental water may be available than foreseen in the future to maintain South Australian environmental assets. This is a complex topic beyond the scope of the Expert Panel review. Some key aspects that can contribute to the debate regarding achieving EWRs for South Australian assets include:

- ***Ensuring adequate environmental water for the CLLMM region***

In the modelling for the proposed Basin Plan, much of the environmental water for the CLLMM region is return flows from upstream environmental assets. There is considerable uncertainty in the "losses" of water in environmental watering of these assets and thus what the return flows are likely to be in reality. Greater transparency around the modelling assumptions made in determining these return flows is required, especially as these are important determinants of the modelled flows to the CLLMM region under the proposed Basin Plan. Similarly, in the future management of environmental water allocations, there will be considerable uncertainty in the flow volumes that reach the CLLMM regions after the watering of upstream environmental assets. To mitigate against additional risk for the CLLMM region, the Expert Panel believes a conservative approach should be taken – i.e. a bias towards over-estimating the upstream losses. In addition, the Expert Panel believes that some future modelling scenarios should be developed to perform a sensitivity analysis of the effect of the upstream losses on the water demands on the CLLMM.

- ***Reduced water availability due to climate change***

The proposed Basin Plan does not include provisions for climate change effects on sustainable diversions limit. The Panel understands that it is an MDBA policy decision to deal with possible impacts of climate change further into the implementation of the Basin Plan. However, it is not clear at present how the potential for reduced water availability under climate change would be dealt with in the implementation of the Basin Plan. While more frequent droughts would probably affect all environmental assets in the

MDB, being at the end of the Basin, the CLLMM assets could be especially at risk, as demonstrated during the 'Millennium Drought'.

- ***Proposed changes in groundwater allocation in the Murray Basin***

While one of the goals of the National Water Initiative is to treat groundwater and surface water as one resource, no attempt was made by the MDBA to relate proposed changes in groundwater allocation under the Draft Basin Plan to longer-term reductions in stream and river flows. Under the proposed Basin Plan, an increase of 2600 GL/year in groundwater use is proposed. Some of the proposed increases are for aquifers for which the connectivity with surface waters is poorly known. The risk for South Australia is that increased groundwater extraction upstream could lower river inflows – especially during low flow periods – and impact the volume of surface water available; this is likely to be most critical during extended droughts.

- ***Environmental water planning uncertainty***

As the water security of all water to be recovered is unknown and environmental watering plans are not yet defined, there is a degree of uncertainty regarding the availability of environmental water and the opportunity to implement multi-site events.

Conclusions

The Expert Panel only reviewed the South Australian Government's assessment of the MDBA modelling of the proposed Basin Plan and did not undertake any additional modelling but did contribute their significant experience, knowledge and understanding of the SA environmental assets to this evaluation.

While the Draft Basin Plan would bring some benefits to the South Australian environmental assets of the River Murray, few of the EWRs required to maintain the ecological character of the region are met. Moreover, these EWRs are conservative because they usually do not account for stressors other than a changed flow regime and therefore should not be relaxed without placing the desired environmental outcomes at greater risk. The current degraded state of the assets also imply that additional efforts might be required to restore their ecological character even if the EWR targets were to be met. The condition for some of the assets during extended drought periods remains problematic and could be a major factor in achieving desired ecological change.

It was not the mandate of the Expert Panel to evaluate alternative ecosystem states for which the assets could be managed for or whether ecological change is unavoidable. However, most South Australian River Murray environmental assets are gradually changing and have become more vulnerable to extreme events, such as droughts. Despite the current degraded state of the assets, they still have outstanding environmental value as exemplified by the extensive use of the CLLMM region by Murray-Darling Basin waterbirds during the recent 'Millennium Drought; (Kingsford and Porter, 2009). Unless there are early interventions, the desired ecological character might deteriorate prior to 2019 when full compliance with Sustainable Diversion Limits is expected, depending on climate and other stressors.

The Expert Panel believes that:

- Between now and 2015, it would be useful for a wider range of possible environmental water scenarios under the proposed Basin Plan to be evaluated, including scenarios with relaxed operational and physical channel-capacity constraints;
- Where feasible, interventions to rehabilitate currently degraded assets to reduce the risk that the desired ecological character will continue to deteriorate prior to 2019 when full compliance with Sustainable Diversion Limits is expected;
- Clarity is provided regarding the salinity metrics from the MDBA for the Lower Lakes and Coorong;

- The MDB Plan and associated Environmental Water Plans should pay attention to the aspect of drought recovery of degraded assets following prolonged periods of low flows.

Overall, there are important benefits identified under the BP2750 scenario that has been analysed, however, for much of the area of the floodplain environmental assets that require medium to high flows, the environmental water requirements are not met. Thus, the ecological character of the South Australian environmental assets, as defined in current water management plans, is unlikely to be maintained under the BP2750 scenario. Between now and 2015, a range of options should be explored that support management of the environmental assets such that their ecological function in the longer term is protected.

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Appendices

Table A1. Assessment of MDBA Riverland – Chowilla floodplain EWRs (from Bloss *et al*. 2012).
Green – EWR met; Orange – EWR partially met; Red – Negligible or no improvement relative to Baseline.

No.	Target	Environmental Water Requirement		Notes About Requirement		Baseline Frequency	Without Develop-ment Frequency	Target Frequency		BP2800 Scenario Frequency
		Flow (ML/d)	Duration (days)	Timing (season)	Min Duration (days)			Low Uncertainty	High Uncertainty	
MDBA 1	Freshes	20,000	60	-	Longest single continuous	46%	93%	80%	72%	77%
MDBA 2	Maintain 80% of the current extent of wetlands in good condition	40,000	30	Jun - Dec	7	37%	81%	70%	50%-60%	54%
MDBA 3	Maintain 80% of the current extent of red gum forest in good condition	40,000	90	Jun - Dec	7	23%	61%	50%	33%	33%
MDBA 4	Maintain 80% of the current extent of red gum forest in good condition	60,000	60	Jun - Dec	7	12%	43%	33%	25%	19%
MDBA 5	Maintain 80% of the current extent of red gum forest in good condition, maintain 80% of the current extent of red gum woodland in good condition	80,000	30	Pref. winter/spring but timing not constrained	7	10%	33%	25%	17%	11%
MDBA 6	Maintain 80% of the current extent of black box woodland in good condition	100,000	21	Pref. winter/spring but timing not constrained	1	6%	20%	17%	13%	5%
MDBA 7	Maintain 80% of the current extent of black box woodland in good condition	125,000	7	Pref. winter/spring but timing not constrained	1	4%	17%	13%	10%	4%

Table A2. Assessment of South Australian Riverland – Chowilla floodplain EWRs (from Bloss *et al*., 2012). Green – EWR met; Orange – EWR partially met; Red – negligible or no improvement relative to baseline.

Source and #	Target	Environmental Water Requirement			Baseline Frequency	Without Development Frequency	Target Frequency	BP2800 Scenario Frequency
		Flow (ML/d)	Duration (days)	Timing				
SA-a1 (BBr1)	Successful recruitment of cohorts of black box at lower elevations	85,000	20	Spring or early summer	11%	34%	10% (+ successive years[2])	11%
SA-a2 (BBr2)	Successful recruitment of cohorts of black box at higher elevations	>100,000	20	Spring or early summer	6%	20%	10% (+ successive years[3])	5%
SA-b (BB1)	Maintain and improve the health of 80% of the black box woodlands	>100,000	20	Spring or summer	6%	20%	17% (max interval 8 years)	5%
SA-c (BB2)	Maintain and improve the health of ~60% of the black box woodlands	100,000	20	Spring or summer	6%	20%	20% (max interval 8 years)	5%
SA-d (BB3)	Maintain and improve the health of ~50% of the black box woodlands	85,000	30	Spring or summer	9%	30%	20% (max interval 8 years)	11%
SA-e (RGr)	Successful recruitment of cohorts of river red gums	80,000	60	Aug – Oct	6%	20%	20%[4] (+ successive years)	6%
SA-f (RG)	Maintain and improve the health of 80% of the river red gum woodlands and forests (adult tree survival)	80,000 to 90,000	>30	Jun - Dec	10%	34%	25% to 30% (max interval 5 yrs)	11%

[2] EWR for black box and red gum recruitment includes the need for flooding in successive years, i.e. floods must occur in at least 2 consecutive years for successful recruitment. Successive year requirement is not addressed in this hydrological assessment.

[3] EWR for black box and red gum recruitment includes the need for flooding in successive years, i.e. floods must occur in at least 2 consecutive years for successful recruitment. Successive year requirement is not addressed in this hydrological assessment.

[4] EWR for red gum recruitment in DWLBC (2010) did not specify preferred frequency, however to enable analysis the frequency provided within Ecological Associates (2010) was used.

Source and #	Target	Environmental Water Requirement			Baseline Frequency	Without Development Frequency	Target Frequency	BP2800 Scenario Frequency
		Flow (ML/d)	Duration (days)	Timing				
SA-g (Lig1)	Maintain and improve the health of ~50% of the lignum shrubland	70,000	30	Spring or early summer	12%	43%	33% (max interval 5 years)	17%
SA-g (Lig2)	Maintain and improve the health of 80% of the lignum shrubland	80,000	30	Spring or early summer	10%	34%	20% (max interval 8 years)	11%
SA-h (Ligr)	Lignum shrubland recruitment - 66% of community maintained [5]	70,000	120	-	4%	10%	20%	4%
SA-i (Mos1)	Provide mosaic of habitats (i.e. larger proportions of various habitat types are inundated)	90,000	30	Spring or early summer	7%	25%	20% (max interval 6 years)	8%
SA-j (Mos2)	Provide mosaic of habitats (i.e. larger proportions of various habitat types are inundated)	80,000	>30	Spring or early summer	10%	34%	25% (max interval 5 years)	11%
SA-k (Mos3)	Provide mosaic of habitats (i.e. larger proportions of various habitat types are inundated)	70,000	60	Spring or early summer	7%	33%	25% (max interval 6 years)	8%
SA-l (Mos4)	Provide mosaic of habitats (i.e. larger proportions of various habitat types are inundated)	60,000	60	Spring or early summer	12%	43%	33% (max interval 4 years)	19%
SA-m (WB1)	Maintain lignum inundation for waterbird breeding events	70,000	60	Aug – Oct	7%	33%	25% (max interval 6 years)	8%

[5] An EWR for lignum recruitment was not provided in DWLBC (2010), however The Goyder Institute recommend the inclusion of a lignum recruitment target. This EWR has been developed from information provided in Ecological Associates (2010).

Source and #	Target	Environmental Water Requirement			Baseline Frequency	Without Development Frequency	Target Frequency	BP2800 Scenario Frequency
		Flow (ML/d)	Duration (days)	Timing				
SA-m (WB2)	Provide habitat (river red gum communities) for waterbird breeding events	70,000	60	Aug – Oct	7%	33%	25% (max interval 6 years)	8%
SA-n (FP)	Stimulate spawning, provide access to the floodplain and provide nutrients and resources	80,000	>30	Jun – Dec	10%	34%	25% (max interval 5 years)	11%
SA-o (TW1)	Inundation of (~80%) temporary wetlands for large scale bird and fish breeding events	80,000	>30	Jun – Dec	10%	34%	25% (max interval 5 years)	11%
SA-p (TW2)	Maintain and improve majority of lower elevation (~20%) temporary wetlands in healthy condition; and Inundation of lower elevation temporary wetlands for small scale bird and fish breeding events, and microbial decay/export of organic matter	40,000	90	Aug – Jan	23%	61%	50% (max interval 3 years)	33%
SA-q (FV)	Provide variability in flow regimes at lower flow levels	Pool to 40,000[6]	Variable		47%	84%	80% (max interval 2 years)	61%

[6] While specific flow is defined, this EWR has been assessed as the percentage of years in which 40,000 ML/day is reached with 1 day minimum duration

Table A3. Assessment of MDBA Environmental Water Requirements – Baseline Conditions vs 2750 GL Water recovery (Heneker and Higham, 2012; Higham, 2012)).

Target	Environmental Water Requirement	Notes	Without Development	Baseline	Target	2750 GL Scenario
Lower Lakes						
Salt export: Provide sufficient flows to enable export of salt and nutrients from the Basin through an open Murray Mouth	10 yr rolling average flow >3200 GL/yr in 100% of years	Flow target indicative of salt export target of 2 million tonnes per year	100%	78%	100%	99%
Provide a variable lake level regime to support a healthy and diverse riparian vegetation community and avoid acidification	Lake Albert and Lake Alexandrina water levels >0.0m AHD in 100% of years		100%	94%	100%	100%
Coorong & Murray Mouth						
Maintain a range of health estuarine, marine and hypersaline conditions in the Coorong, including health populations of keystone species such as Ruppia tuberosa in South Lagoon and Ruppia megacarpa in North Lagoon	Maximum salinity of 130 g/L in South Lagoon of the Coorong		67 g/L	291 g/L	130 g/L	122 g/L
	Maximum salinity in South Lagoon of Coorong < 100 g/L in 95% of years		100%	82%	95%	96%
	Maximum period of salinity > 130g/L in South Lagoon of the Coorong		0 days	323 days	0 days	0 days
	Maximum salinity of 50 g/L in North Lagoon of the Coorong		50 g/L	148 g/L	50 g/L	59 g/L
	Maximum period of salinity > 50g/L in North Lagoon of the Coorong salinity		0 days	148 days	0 days	91 days
	Barrage outflow: long-term annual average > 5100 GL/yr		11670 GL/yr	4860 GL/yr	5100 GL/yr	6830 GL/yr
	Barrage outflow: 3-yr rolling average >1000 GL/yr in 100% of years	Indicator of low flow conditions that may have extreme salinity risks for Coorong	100%	94%	100%	99%
	Barrage outflow: 3-yr rolling average >2000 GL/yr in 95% of years	Indicator of low flow conditions that may have salinity risk for Coorong	100%	79%	95%	98%

Legend

Legend
EWR met under scenario (green)
EWR improved but not met under scenario (orange)

*includes meeting high uncertainty targets

Table A4. Assessment of South Australian Environmental Water Requirements - Baseline Conditions vs 2750 GL Water Recovery (Heneker and Higham 2012).

Target	Environmental Water Requirement	Requirement Definition	Baseline	Target	2750 GL Scenario
Lower Lakes					
Maintain desired ecological character of Lower Lakes through managing water quality	Lake Alexandrina salinity <1000 EC for 95% of all years	Barrage outflow Greater of three targets: 1. 650 GL 2. 4000 GL – F_{X-1} 3. 6000 GL – F_{X-1} – F^*_{X-2} (where F^*_{X-2} is min (F_{X-2}, 2000 GL))	70%	95%	95%
	Lake Alexandrina salinity <1500 EC for all years	Barrage outflow Greater of three targets: 1. 650 GL 2. 4000 GL – F_{X-1} 3. 6000 GL – F_{X-1} – F^*_{X-2} (where F^*_{X-2} is min (F_{X-2}, 2000 GL))	95%	100%	98%
Coorong & Murray Mouth					
Maintain current frequency of ecosystem states associated with high flows	Barrage outflow 6,000 GL/yr, 1 in 3 years	6,000 GL/yr	27%	33%	48%
	Barrage outflow 10,000 GL/yr, 1 in 7 years	10,000 GL/yr	10%	14%	18%

Legend

EWR met under scenario

EWR improved but not met under scenario