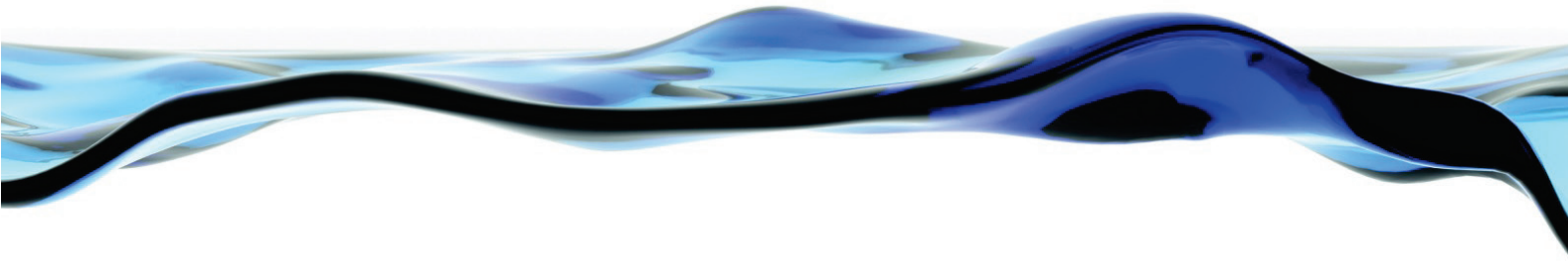
Synthesis review of the science underpinning the environmental water requirements of the Coorong, Lower Lakes, and Murray Mouth

Maltby E and Black D



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Preface

The *Water Act 2007* requires the Murray–Darling Basin Authority to prepare and implement a Basin Plan for the integrated and sustainable management of water resources in the Basin. The October 2010 release of the Guide to the proposed Basin Plan was a first step in this process and a major milestone for water management in Australia. Like all of the States that share management of the Murray-Darling Basin, South Australia has an interest in how the Plan is put together and how it will benefit its people.

Upon release of the Guide, the South Australian Government, through the Goyder Institute for Water Research, commissioned a science review of the Guide proposals in order to provide a South Australian perspective on the environmental and socioeconomic implications of the proposed sustainable diversion limits. Key findings are released in 'A science review of the implications for South Australia of the Guide to the proposed Basin Plan: synthesis'[1].

One component of the review was an independent and international review of the science underpinning the environmental water requirements of the Coorong, Lower Lakes, and Murray Mouth, as reported in:

- Lester RE, Fairweather PG and Higham JS (draft, 2010) Determining the Environmental Water Requirements for the Coorong, Lower Lakes and Murray Mouth region: Methods and Findings to date. A report prepared for the South Australian Department of Environment and Natural Resources. Flinders University, Adelaide, Australia. Version received 8 October 2010.
- Heneker TM (draft, 2010) Development of flow regimes to manage water quality in the Lower Lakes, South Australia. Department for Water, Government of South Australia. Version received 8 October 2010.

These reports were independently reviewed by Professor Ed Maltby of Liverpool University and Dr Dugald Black of CSIRO Land and Water respectively. This report is a compilation of these reviews and is thus divided into two parts.

- Part 1 – Professor Ed Maltby's review of Lester et al. (draft, 2010). This review is fit for the purpose of ensuring that the scientific basis for deriving environmental water requirements is both accurate and defensible.
- Part 2 – Dr Dugald Black's review of Heneker (draft, 2010), describing the hydrological modelling underpinning the Lester et al. (draft, 2010) report.

Subsequent to the reviews, the Lester et al. and Heneker reports have been amended in response to review comments, with publication planned for July 2011.

[1] CSIRO (2011) A science review of the implications for South Australia of the Guide to the proposed Basin Plan: synthesis. Goyder Institute for Water Research, Adelaide, Australia. < http://www.goyderinstitute.org/publications/2011/synthesis-science-review-Basin-plan.pdf>

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Synthesis review: environmental water requirements

1 Synthesis review: environmental water requirements

Objectives

As a component of the SA Basin Plan Review Project, CSIRO was required to sub-contract and manage the external review process for the report titled 'Determining the Environmental Water Requirements for the Coorong, Lower Lakes and Murray Mouth region: Methods and Findings to date'. Professor Ed Maltby of Liverpool University was nominated as the internationally recognised scientist to conduct the review.

The review needed to be 'fit-for-purpose' to ensure that the scientific basis for deriving environmental water requirements was above reproach. The impact will be in shaping the South Australian government response to the Basin Plan and ensuring the best possible outcome for South Australian water users and environmental assets.

Task activities

1. External reviewer (Prof. Ed Maltby, Liverpool University) sub-contracted by CSIRO to undertake a review of the report titled 'Determining the Environmental Water Requirements for the Coorong, Lower Lakes and Murray Mouth region: Methods and Findings to date'.
2. Prof Ed Maltby and Dr. Carmel Pollino (CSIRO) to discuss the outcomes of the review and any points of clarification.
3. Professor Ed Maltby to finalise the review and deliver to CSIRO by no later than 19 November 2010.
4. CSIRO to finalise the sub-contract and deliver the review to the funding body by no later than 29 November 2010.

Criteria of analysis

The foundation criteria for the review were:

1. Is the report presented in a form such that it fulfils its objectives?
2. Is the best available evidence used for deriving indicators and thresholds?
3. Are the modelling methodologies described (i.e. hydrodynamic modelling and ecosystem state modelling) appropriate and rigorously executed?
4. Are the recommendations and conclusions sound given the evidence-base?

The full set of assessment criteria are documented in Appendix A.

Deliverables

The project deliverable was to be a report which assessed the quality of the science that underpins the recommended environmental water requirements for the Coorong, Lower Lakes and Murray Mouth, guided by the review criteria. The content of this review is the report prepared by Prof. Ed Maltby.

1.1 Synthesis review for the report: Determining the Environmental Water Requirements for the Coorong, Lower Lakes and Murray Mouth Region: Methods and Findings to Date

Professor Edward Maltby
University of Liverpool

> "There is no simple figure that can be given for the environmental flow requirements of rivers and associated wetlands"
>
> "There is no single best method, approach or framework to determine an environmental flow"
>
> Acreman & King (2003)

Such statements still hold true today as they did over the last decade. The main reason is that the definition of required flows depends entirely on the specified desired character of the ecosystem(s) concerned, the actual capacity of the catchment and its environment to deliver the necessary hydrological regime and the limitations in our scientific understanding of complex and multiple ecological relationships. In addition there are often severe limitations in the quality and quantity of data available to support precise determinations of flow requirements.

Application to the Coorong, Lower Lakes and Murray Mouth (CLLMM) region is complicated by several overriding factors:

1. the inherent complexity and diversity of ecosystem types represented – this represents a significant increase in challenge beyond most cases;
2. the (unusual) level of drought which has impacted the ecosystem in recent years;
3. the level of degradation characterising the ecological condition of the ecosystem(s) already in 1985;
4. the lack of historic (and also frequently current) data for many species and certainly ecosystem processes.

1.1.1 Overview of the report

By any standards the body of the work represented by the report is exceptional and covers a wide range of studies / reviews at least comparable in quality and comprehensiveness to high profile assessments carried out elsewhere in the world (e.g. Everglades). The project team are to be congratulated on carrying out, reporting and integrating such a complex and wide-ranging set of investigations which is most certainly at the cutting edge of our present understanding. The authors are careful to document where possible the levels of uncertainty with their findings, assumptions in methodology and limitations associated with techniques especially in modelling as well as of data.

The methods and findings presented draw on or are paralleled by other studies found in a wide range of other reports which in their own right are detailed and comprehensive, as well as other sources in the literature. A synthesis of the findings is presented in a separate report. This organisation makes it more difficult to access the outcomes of the research than would be possible in a more integrated document, which could include for example:

- Executive summary
- Summary of key findings
- Main text (as is) with clear highlighted pathways in RH margin to other reports
- Use of boxes to indicate key finding(s), distilling the complexity and emphasising 'so what?'

The exact format of the report will depend on how the report is to be used and who will use it. It is advised to decide on the precise target audience(s) before finalising the shape of the document.

1.2 Presentation

1.2.1 Report organisation

The report summarises the methodologies used to provide guidance on the environmental water requirements for the CLLMM region.

A clear short executive summary using boxes to highlight the objectives (and methods) and bullet points to emphasise the key findings (conclusions) would have an immediate impact to the readership and help in navigation through the report. Clear pointers to other documents in the margin rather than the body of the text would help in making the important links to evidence / sources.

1.2.2 Objectives

A bold set of stated objectives would help set the tone for the report. A reminder of the impressive set of qualifying criteria under Ramsar would also be useful. It might be helpful to review the cautionary remarks regarding the constraints to the report (page 8). It is counter-intuitive to dismiss the need for recovery from the present degraded condition especially in the light of the 2005 revision of the definition of 'desired ecological character' under the Ramsar Convention to '..... at a given point'. Phillips and Muller (2006) discuss the views on the 'desired' condition including the position of the local indigenous people and long-term stakeholders which advocate an improvement of the 1985 situation existing at the time of Ramsar listing. This would be both logical and credible in ecological terms (assuming capability within the current / anticipated future hydrological envelope). It would be useful if the authors could indicate more positively how their work to date and /or future modifications could be used to define a different (improved) 'desired' ecological character.

1.2.3 Supporting evidence

There is a wealth of evidence to support the report but it is highly dispersed among numerous reports. It is not possible to integrate it all within the body of this report but essential to make the links easier to identify and follow if required. This could be more easily done by reference in boxes in the right-hand margin. It would be useful to comment more specifically on the level of uncertainty associated with data. This is particularly important where data are original empirical time or spatially limited or where inputs to a model may be outputs from another.

There is clear recognition of the need for further research especially in relation to the effects of climate change, interactions between inflows from the Murray with other sources and the effects of other management actions in relation to water diversion, the refinement of indicator sets and the setting of limits of acceptable change to enable assessment of success in meeting objectives.

1.2.4 Reference to other contributions in the field

Generally excellent reference is made throughout the supporting documentation to the directly relevant literature supporting the reviews and technical aspects of modelling. There is a gap in the referencing of other approach from the literature such as the Building Block Methodology developed in South Africa but also trialled in Australia (e.g. Arthington & Long, 1997; Arthington, 1998). A useful summary of different approaches, techniques and case study examples is given by Acreman & King in Dyson et al (2003). It would certainly strengthen the choice of approach adopted in the present work to develop a succinct synthesis table from international experiences which summarised the advantages and limitations of different approaches in relation to different management / flow

objectives to reinforce the logic of the framework adopted here. There is also considerable research expertise / experience in Australia on determination of environmental flows which could help set the context for the approach developed here, necessary because of the special conditions of CUMM.

1.2.5 Methodology

What is outlined on page 9 as a proposed methodology reads more like aims and the link to achieving the overall outcome of a 'healthy, resilient wetland of international importance' not sufficiently explicit. A wide range of individual techniques comprises the methodological framework for the study. The rationale behind the choice of method, analysis or interpretation is given comprehensively throughout the report and accompanying documentation. There may be other feasible approaches (which could be related to the review indicated in the previous section) but there is no reason to doubt the methodology actually used.

1.2.6 Indicator sets and tolerances

One of the features of the present study which takes it beyond most previous examples is that it is attempting to define flows for a complex mix of species, processes and conditions rather than, for example, a single species – often this might be a fish or a bird population. It breaks down the broad objective of a 'healthy, resilient wetland' into practical objective elements.

The criteria for inclusion of species (keystone, canary, threatened) are sound and the choice of characteristics (water quality, flow regime, connectivity, water level) permitted the identification of thresholds that could be related directly to the hydrological regime.

A figure would be beneficial in summarising more clearly the 5 process steps described from sections 3.2 to 3.7

There is a clear statement of species objectives, a substantiated rationale and indication of anticipated outcomes whilst all not necessarily always attainable are all nevertheless supported by reference to the literature.

1.2.7 Indicator sets

An impressive number of indicators have been assembled under different groups: vegetation, fish, macro-invertebrates as well as ecological processes. This is arguably the most comprehensive attempt to link hydrology to the 'whole' system as opposed to a specific component or limited combination of elements. Such a comprehensive list, however, undoubtedly masks considerable variation in the availability, quality and spatial extent of information.

This could be covered by either a general qualifying comment or some indication of the variation that could exist in the interpretation of ticks or other symbols in the summary outcomes table. The objectives, outcomes selected and indicators all appear reasonable. Most debate is likely to surround the strength of the evidence base from the individual ecological processes selected and commentary on this aspect could be usefully strengthened especially in relation to the specification of thresholds. It is perhaps surprising but certainly noteworthy for future considerations and infrastructure that the authors found vegetation indicators not to useful primary indicators. In the case of fish there are significant gaps in knowledge.

1.2.8 Critical thresholds

There is clear acknowledgement of the limited and variable information on thresholds and especially in relation to the potential (but generally unknown) effects of interaction of stresses causing significant variation in threshold levels. The tabular representation of tolerances associated with the indicators in table 5.5 – 5.7 are appropriate but it should be better explained how these work as 'trade-off' tables. It is impossible to judge whether the indicators and their tolerances have drawn on the best available data and knowledge without interrogating all

original sources. However, judging from the general quality of citation, interpretive and precautionary guidance given, there is no reason to doubt the integrity of the information used. This is explained generally in section 5.6 – 5.8 and the key limitations particularly well emphasised in 5.8.3

Tabulation of the specific relationships between macro-invertebrate indicator species and outcomes is also supported by a note of knowledge gaps. Categorisation across freshwater, estuarine / marine and hyper-saline habitats underlines the potential universality of using macro-invertebrates but the authors caution against their unqualified and non-discriminatory use because of limitations of the knowledge base.

The inclusion of ecological processes for consideration as indicators is ground-breaking. Their capacity to integrate responses across multiple species, relative ease of measurement and direct indication of change / impact are powerful arguments. Unfortunately there is still a lack of data-base and limited understanding of the links between process and outcome which restricts more general application. The limitation could be usefully addressed in further qualification of the 'ticked' boxes in table 7.23 (though the more detailed text following, broadly covers this). Inclusion of colonisation by invasive species is significant and underlines the potential for major (and often unforeseen) switches in ecological character.

1.2.9 Hydrodynamic model

The fundamental features of the modelling is summarised and reference made to the greater detail shown elsewhere. Its spatial structure is given, connectedness and drivers explained. Explanation is given of model calibration against the continuously-changing elevation of the bed of the Murray Mouth channel and other fixed parameters. The experience of calibration and model testing is used to indicate the high credibility of the model in simulating the response of the system in both salinity and water level. The authors are careful, however, to indicate potential sources of error and uncertainty. It would be useful to indicate the overall assumptions and limitations of the model more precisely and specifically e.g. in a box. The spatial scale of analysis is clear but the temporal scale needs to be made more specific.

1.2.10 Application

The conceptual basis of the model takes account of the special configuration of the Coorong (e.g. as an 'inverse' estuary) and including, also, water control structures.

The 19 scenarios selected covered a range of flow and climate conditions which would seem reasonable in the context of the report's objectives. The scenarios are dependent on the output from climate change projections made from other sources. There is a risk that the resulting forecasts may prove wide of the mark. It is not possible for the reviewer to comment on the likelihood or not of this but it would be useful to include a brief commentary on the possible implications of the hydrodynamic model prediction if the possible climates selected should prove inappropriate or inaccurately determined. The authors could strengthen their position by indicating more precisely the rationale for the particular range of scenarios and the data / climate model outputs from other sources that determined their choice. Readers external to Australia would benefit from explanation of the 114 year run period.

The actual scenario descriptions and underlying assumptions are clear. The results are described with the help of diagrams. Interpretation deals with numerous interactions and comparisons between scenarios. It would enhance the impact of the report if the most salient points emerging from the results could be highlighted as a set of bold statements. This would also be useful for the analyses relating to the effects of adjusting timing of flow delivery and climate change; effect of constant environmental flow delivery; effects of rules-based environmental flow delivery (and under climate change). There is a technically sound discussion of the outcomes but an orientated summary of the question 'so what?' could help in the evaluation of the strength of the science / evidence-base.

1.2.11 Ecosystem state model

Determination of the most probable mix of ecosystem states that will be supported by a particular flow regime is arguably the most important and technically challenging part of the work. This stems at least in part because of the non-linear relationships in the ecosystem but also because of imperfect or unavailable knowledge. Because of this the decision to develop a statistical model is entirely reasonable. Limited detail of the actual model is given but reference is provided to its source. It would strengthen the credibility of this section if a box was inserted which distilled the model's foundation, assumptions and limitations. The authors explain the particular issue of the model's inability to correctly predict recovery of the ecosystem, constrained by its development using 1999 – 2007 data (when the system was deteriorating). A more positive message could be given that indicated how the model could be used with the benefit of new data in response to the flow changes resulting from the break of the recent drought period and / or the effects of a new environmental flow regime. In the descriptions of the results it would be useful to identify summary key points (for example in the right hand margin). These would be picked up in the following discussions. For example confirmation of the links between hydrodynamics and ecology is certainly re-assuring (and fundamental to the rationale of the whole overarching objective) but to what extent could this be the result of interaction with the data sets rather than of independently determined variables?

The description of actual states is found in a separate report. Whilst this is referenced it would be helpful to have a box here which summarised the individual categories indicating in particular the basis on which they were considered unhealthy or healthy.

1.2.12 Conclusions / Recommendations

The conclusions relate specifically to the Coorong, but acknowledging the links to conditions in the Lakes. Rather than a simple reference to the reports of Muller and Heneker it would help for completeness to distil key relevant points from those reports in a marginal box for example.

Objectives are identified which are not explicitly identified at the outset or the report viz:

1. avoiding ecological degradation in the Coorong and ensuring sufficient flow to maintain an open Murray Mouth without the need for dredging (in 95% of years);
2. achieving high-flow conditions critical for the long-term health of an estuarine system.

These are surely better expressed as 'target conditions'. In any case they should refer back to the context of 'desired' ecological character and assess specifically in relation to the important debate as to whether this should be the 1985 or some other condition.

Two methods were used to determine the minimum flow requirements of the Coorong – one which linked the proportion of the degraded ecosystem states to different flow volumes (based on the alternative ecosystem states model) and a second based on models of future degraded ecosystem states (based on the original ecosystem states model).

In the first case the authors caution that their analysis will likely underestimate the proportion of degraded ecosystem and that there is further work required to correct for this in the determination of the recorded minimum flows. Their estimates are based on the likely percentage of the Coorong falling into degraded ecosystem states. This provides a useful basis for decision-making based on the level / degree of desired outcome.

The summary flow requirements are clearly stated (and substantiated from the previous evidence / linked reports cited) for an historical flow-delivery and a modified flow-delivery pattern both under any climate. The recommendations specify temporal as well volume considerations. The report emphasises further the important effects that can result from the actual timing and distribution of flow delivery. The summary findings for minimum flow requirement and linkage to the minimum requirements to maintain a maximum salinity in Lake Alexandria appear reasonable and evidence-based.

Slightly different requirements result from the second approach assuming that flow delivery can be optimised and based on a model threshold for average south lagoon salinity. The resulting overall recommendations are strengthened by the dual approach and the cautionary remarks qualifying their use.

The authors urge the need for further analysis to improve the reliability of flow requirements. This will always be true but in this case is particularly relevant. The region has just experienced a major break in drought conditions and the likelihood is that the previously degraded ecosystems of the CLLMM may now experience a new trajectory of ecological recovery. This emphasises the need for new monitoring and assessment data to feed into the modelling work to continue the refinement of the estimated environmental flow requirements.

References

Acreman MA and King J (2003) Defining Water Requirements, in Dyson M, Berkamp & Scanlon J. (Eds.) Flow. The Essentials of Environmental Flows. IUCN Gland, Switzerland & Cambridge, UK. xiv + 118pp.

Arthington AH and Long GC (eds) (1997) Logan River Trial of the Building Block Methodology for Assessing Environmental Flow Requirements: Background Papers, Centre for Catchment and In-stream Research and Dept. Natural Resources, Queensland. (Also Workshop Report (1998).

Arthington AH (1998) Comparative Evaluation of Environmental Flow Assessment Techniques: review of holistic methodologies. Occ. Paper 26/28. Land & Water Resources Developement Corp. Canberra.

Phillips B and Muller K (2006) Ecological Character of the Coorong, Lakes Alexandrina & Albert Wetland of International Importance. South Australian Department for Environment and Heritage.

Appendix A Report assessment criteria

Overall

- Is the rationale and approach used in deriving the environmental water requirements for the Coorong Lower Lakes and Murray Mouth robust and valid?
- How do you rate the quality of the science presented in the report?

Presentation

- Is the report well organized?
    - Are the objectives, analysis and conclusions in the report clear and understandable?
    - Are there any gaps in the sequence logic presented (i.e objectives > analysis > conclusions)?
    - Is the supporting evidence provided with the report adequate?
    - Has adequate reference and synthesis been given for previous (inc. recent) contributions in this area?

Methodology

- Are the ecological objectives and proposed outcomes for the study well described?
- Is the methodology used for deriving environmental water requirements for the Coorong, Lower Lakes and Murray Mouth sound?

Indicator sets and tolerances

- Are the indicators selected for deriving environmental water requirements appropriate?
    - Ecological process indicators
    - Species indicators
    - Hydrodynamic/hydrology indicators (e.g. lake water level indicators)
    - Water quality indicators
- Are the outcomes selected for each indicator appropriate?
- Are the objectives set per outcome sensible?
- Do the process indicators accurately represent the objectives described?
- Are the critical thresholds (presented in trade-off tables) that have been selected for assessing environmental water requirements appropriate?
- Are the thresholds used consistent with the indicators, objectives and outcomes presented?
- Has the best available data and knowledge been used to derive indicators and describe their tolerances?

Hydrodynamic model

- Is the foundation of the modelling documented or referenced in sufficient detail?
    - Is there sufficient reporting of the model against data?
- Are the assumptions and limitations of the models described in sufficient detail?
- Is the scale (temporal and spatial) of analysis considered appropriate?
- Are the scenarios (i.e. climate, flow allocations) considered in the analysis appropriate and consistent with the described objectives in the report?
- Has the best available data and knowledge been used to develop the model?

- Is the description of the model results sufficient and credible?

Ecosystem state model

- Is the foundation of the modelling documented or referenced in sufficient detail?
    - Is there sufficient reporting of the model against data?
- Are the assumptions and limitations of the models described in sufficient detail?
- Is the scale (temporal and spatial) of analysis considered appropriate?
- Are the scenarios (i.e. climate, flow allocations) considered in the analysis appropriate and consistent with the described objectives in the report?
- Has the best available data and knowledge been used to develop the model?
- Is the description of the model results sufficient and credible?

Conclusions/Recommendations

- Are the recommended environmental water requirements defined sound and consistent with the evidence presented?
- Do the recommended environmental water requirements fulfil the stated ecological objectives?
- Are the recommended environmental water requirements presented in a way that they can be implemented to fulfil policy and management requirements?

Synthesis review: hydrological modelling

2 Synthesis review: hydrological modelling

2.1 Summary

Results of an investigation into the development of the inflow and outflow regimes required for the Lower Lakes have been reviewed using information in the report prepared by Heneker (2010) and relevant criteria provided by the Department for Water. From the information in the report the review criteria are largely satisfied, although there are some specific areas where information could beneficially be clarified or expanded. In particular, results and conclusions could be sensitive to the flow-salinity regression relationship adopted, and to the sequencing of the historical data used as model input for many of the analyses, and further consideration of sensitivity may be warranted.

2.2 Review criteria

The criteria used in the review were provided by the Department for Water (DfW), relevant to the scope of work to be reviewed. They were as follows:

- Is the modelling described credible?
- Is the foundation of the modelling documented or referenced in sufficient detail?
- Is there sufficient reporting against data?
- Are the assumptions described in sufficient detail?
- Is the scale (temporal and spatial) of analysis considered appropriate?
- Are the scenarios (i.e. climate, flow allocations) considered in the analysis appropriate and consistent with the described objectives in the report?
- Has the best available data and knowledge been used?
- Is the description of the results sufficient and credible?

As required by DfW, only the functions of the various models and their outputs were assessed, not the actual models themselves.

2.3 Review comments

This review is based on the information in the report by Heneker (2010) on the results of an investigation into the development of the inflow and outflow regimes required for the Lower Lakes. From Heneker (2010), the primary objectives and required outcomes from the investigation reported were to:

1. determine the flow regimes required to maintain salinity within Lake Alexandrina below 700, 1000 and 1500 EC thresholds, including the consideration of one, two and three-year flow sequences, in a form suitable for an operational model.
2. consider the required flow regimes in the context of historical inflows to Lake Alexandrina.
3. consider the required flow regimes in the context of inflows to Lake Alexandrina under a number of potential climate change scenarios, assuming the current water sharing arrangements as defined under the Murray-Darling Basin Agreement.

Review comments are discussed below.

Is the modelling described credible?

Based on the information in the report, overall the modelling is credible.

Is the foundation of the modelling documented or referenced in sufficient detail?

The foundation of the modelling discussed in Sections 3.1, 3.2 and 3.3 is documented or referenced in sufficient detail.

Is there sufficient reporting against data?

The evaluation of model performance by comparing model results with observed data is generally sufficient. Reporting on testing of modified flow patterns is also sufficient. However, as discussed further below, the potential sensitivity of the overall results obtained to the use of the adopted flow-salinity regression relationship, and also to the sequencing of the historical data, may warrant further consideration.

Are the assumptions described in sufficient detail?

In general, the assumptions and methodology are described sufficiently. However, there are some specific instances where clarification or additional information would be beneficial. For example:

- Bottom of page 10: “As flows are set at Lock 1, the desired inflows to Lake Alexandrina are increased by the average daily loss for each month, as will be applied in the model.” Should this refer to a decrease in flows between Lock 1 and the lake rather than an increase?
- Top of page 12: “For the main river channel between Lock 1 and Wellington, which includes the major pumping stations, no water supply, irrigation or other stock and domestic diversions were applied.” Would ignoring these not introduce an error into the modelled volumes of inflows to Lake Alexandrina?
- Top of page 12: “While these extractions affect the total salt load reaching the lower lakes, the salinity of lake inflows is reset at Wellington using the relationship defined in Section 3.4.4.” This comment implies the relationship was used in all salinity modelling, including the work reported in Sections 4.1 and 4.2, and the actual situation could beneficially be clarified.
- Figures 11 and 12: it is not obvious whether these refer to only groundwater salt loads or to total salt loads (from the magnitude of the numbers, it appears they refer to groundwater salt loads).
- Middle of page 13: “An analysis of the salinity of inflows to Lake Alexandrina from the current conditions model run was undertaken to develop [an] inflow-salinity relationship that could be applied to all inflows at Wellington, thereby preserving the characteristics of salt inflows and removing the influence of any extractions between Lock 1 and Wellington.” While the mean may have been preserved, the standard deviation and other characteristics almost certainly will not have been, which may have implications for dependent results and conclusions.
- The variability in the actual flow salinity relationship (Figure 13) is a reflection of where in the Murray-Darling system the water is coming from. For example, during extended low flow periods, inflows are likely to be predominantly very low salinity water originating from Hume and/or Dartmouth Dams whereas during short low flow periods inflows could come from a range of sources with higher salinities, including the Darling River, depending on time of year and other factors. Thus, the use of this regression relationship with extended low flow periods might lead to adverse salinity impacts in the lakes being overstated. Likewise, the benefits of high flows may be understated. However, supporting information did not seem to be available to assess this, such as comparing statistics from applying the regression relationship to an independent period where data is available with the statistics of the available data.
- Further, transforming the data may give a different result, perhaps one that is more robust. Use of multiple variables, such as including lagged inflows or lake levels (as a means of capturing recent flow regime history), may also lead to more robust results.
- Top of page 17 should clearly state whether it is the “Averaged distribution of Lake Alexandrina inflows” or the “Alternative distribution for Lake Alexandrina inflows” which has been adopted, and terminology could beneficially be standardised between the text, Figure 19 and Figures 20-22 to minimise confusion.
- Sections 4.1 and 4.2: notwithstanding the comments in Section 3.4.4 about resetting the salinity of lake inflows, it appears the analyses in these sections use salinity values taken from standard BigMod results; this could beneficially be clarified.
- Section 4.2: in common with other storages, the salinity “memory” in Lake Alexandrina should be a function of throughflow as a proportion of the storage capacity of the lake (or, in other words, the residence time of the water). If the throughflow rate is large relative to the storage capacity of the lake then the “memory” will be short; if the throughflow rate is small relative to the storage capacity of the lake then the “memory” will be long. The persistence of short and long memory phases will depend on the sequencing of the inflows. In this investigation, the results could be sensitive to the sequencing of the historical data. While the concept of using a multi-year

period for management is a good one, it is not immediately obvious why an upper limit of 3 years was chosen, as distinct from, say, 2 years or 4 years (apart from the requirements in the objectives, but where did these come from?).

- At the end of Section 4.2 it is stated that “it is not appropriate to manage salinity based on a long-term average outflow” and then this is immediately followed by Section 4.3 which is headed “Average annual inflow and barrage outflow requirements”. The rationale for including the step described in Section 4.3, in the face of the comment stating the approach is inappropriate, could beneficially be made clearer.
- In Section 4.3 it is not certain but it appears, from looking at Figures 36-41 and comments in Section 4.4, that in each case investigated a fixed inflow pattern was applied to each year of modelling using one or other of the average patterns adopted on page 17, scaled so that the annual total equalled the required average each year. Historical dates should not be assigned to these results as doing this is misleading. Also, the salinity results would be an artefact of the flow pattern (especially the maximum and minimum) and with a different pattern a different conclusion might be reached. In addition, as Figures 36-41 show time series results and there is presumably some importance attached to these, the rationale for the starting conditions adopted and the influence these might have on the modelled time to equilibrium is not clear. The situation with these points could beneficially be clarified.
- In Figures 43 and 44, as the time series used are artificial constructs, historical dates should not be assigned to these results as doing this is misleading.
- The work reported in Section 4.5 is a valuable contribution to achieving the objective of delivering flow sequences in a form suitable for an operational model. It should be noted though, that the results could be sensitive to the choice of flow-salinity relationship and the sequencing of the historical data. Also, as there is always the likelihood that the additional water will not be available when it is wanted (discussed in Section 5), comments such as at the bottom of page 62 in relation to Figure 83 that it “shows … the threshold rules applied in this instance have been successful in managing salinities within the 1200 to 1400 EC range” need qualifying so as not to unreasonably raise expectations.
- In Section 4.6.1 it could usefully be clarified whether the salinity data used in obtaining all results reported in this section comes exclusively from the regression relationship or otherwise.
- Also in Section 4.6.1 the rationale for forcing lake inflows to never fall below 350 GL/y in the Cmid and Cdry scenarios is not obvious. As this is an artificial construct, it could beneficially be made clear that in reality annual inflows could well fall below this value and this eventuality should be managed for. It is uncertain what implications, if any, this might have for the discussion in Section 5 and the conclusions in Section 6.

Is the scale (temporal and spatial) of the analysis considered appropriate?

The temporal and spatial scales of analysis are considered appropriate.

Are the scenarios (i.e. climate, flow allocations) considered in the analysis appropriate and consistent with the described objectives in the report?

The climate and water sharing scenarios considered in the analysis are seen to be appropriate for the objectives of the investigation.

Has the best available data and knowledge been used?

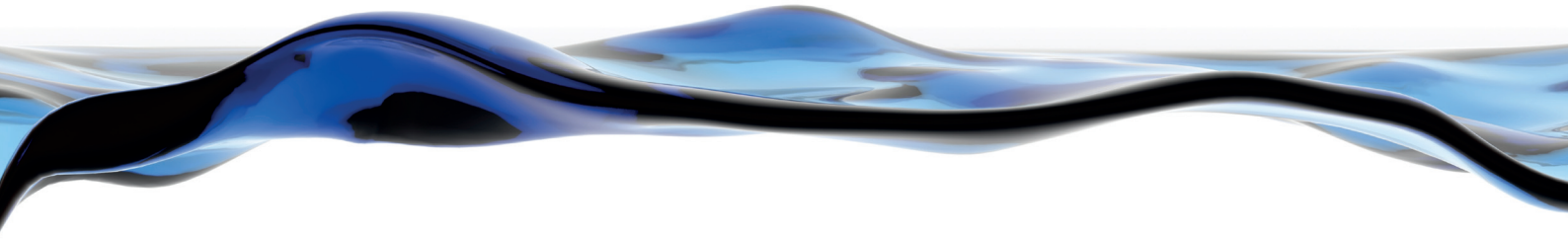
The modelling approach and the data and knowledge underpinning the model are either the same as, or consistent with, that used to underpin implementation of the Basin Salinity Management Strategy and the salinity registers in the Murray River. As such they would represent the best available at the time the work was done (noting that MDBA are continually updating their modelling). The approach adopted for representing climate change scenarios is also the best currently available that is suited to the purposes of this investigation.

Is the description of the results sufficient and credible?

Subject to the points raised above, the description of the results is sufficient and credible. In particular, the discussion in Section 5 and the conclusions in Section 6 appear sensible based on the information in the report.

References

Heneker TM (2010) Development of flow regimes to manage water quality in the Lower Lakes, South Australia. Department for Water, Government of South Australia.



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