Ecological Assessment of Environmental Flow Reference Points for the River Murray System

Interim Report

prepared by

the Scientific Reference Panel for

the Murray-Darling Basin Commission, Living Murray Initiative.

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COOPERATIVE RESEARCH CENTRE FOR
FRESHWATER ECOLOGY

Cooperative Research Centre for Freshwater Ecology

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Disclaimer

The results presented in this Interim Report are based on analyses of available data and the expert opinions and best judgment of the Scientific Reference Panel (SRP). The SRP Interim report was informed by the Regional Evaluation Group (REG) assessments completed for each zone of the Murray system under direction from the SRP . The REG reports form separate accompanying documents to this SRP report, and are provided for information. The opinions and content of the REG reports may not reflect the opinion of the SRP.

The MFAT decision support system indices in the Interim Report and accompanying (REG) reports are provided to inform discussion and scientific evaluation. They are not specific or independent forecasts of future ecological condition under any management option or scenario. No member of the SRP, REGs, CRC for Freshwater Ecology or CSIRO accepts any liability for any management decisions made on the basis of this report.

Scientific Reference Panel

The Scientific Reference Panel (SRP) comprises the following members:

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- MDBC staff – Sarah Cartwright, Julianne Martin and Lindsay White
- MFAT development team from CSIRO Land & Water – Bill Young, Susan Cuddy, Felix Andrews and John Coleman.

FOREWORD

The Cooperative Research Centre for Freshwater Ecology (CRCFE) was contracted by the Murray-Darling Basin Commission (MDBC) to establish a Scientific Reference Panel (SRP) to provide independent scientific advice on the ecological benefits or impacts associated with the three reference points for analysing the recovery of water for the River Murray.

This is an interim report and provides initial guidance on the potential ecological benefits that come from additional flow and improved management of the River Murray system, through changed river operations and better use of structures.

The MDBC wants to see the report widely distributed and easily accessed to assist discussion and review of its findings amongst communities, scientists and government officials. The final report is due for submission to the MDBC in mid-2004.

The information contained in this report is an important input to the Murray-Darling Basin Ministerial Council's consideration of The Living Murray initiative.

The SRP has done an excellent job in drawing together a large amount of knowledge in a short space of time. In the words of the two scientific reviewers of this report, "the analysis achieved to date, and the level of consensus represents a major first achievement in the integration of science within a large-scale water resource management in Australia." The Commission is pleased to release the interim report – *Ecological Assessment of Environmental Flow Reference Points for the River Murray System* – and congratulates the SRP on a job well done.

At its April 2002 meeting at Corowa, the Council directed the MDBC to use 350GL, 750GL and 1500GL of water returned to the River Murray as reference points for analysis of outcomes for river health . This work will identify local and system-wide problems and benefits with particular reference to the Murray Mouth, Coorong and Lower Lakes, Chowilla Floodplain (including Lindsay-Wallpolla), Gunbower and Koondrook-Perricoota Forests, Barmah-Millewa Forest areas and Murray Cod populations.

The reference points are points for analysis to help understand the economic, social and ecological outcomes of returning varying amounts of water to the River Murray. They were not intended to be options from which the Ministerial Council would choose. The volume needed to implement the Ministerial Council's decisions may differ from these points.

Since this report was first commissioned following the Corowa meeting, two major decisions have been taken. First, in May 2003 the Murray-Darling Basin Ministerial Council indicated its intent to consider a proposal from the MDBC for a first step decision in November this year, provided that the proposal delivers measurable and integrated ecological, social and economic outcomes. This will be based on the scientific and socio-economic evidence to be presented before the meeting and the estimated costs and benefits of the options considered. This would be the first step in the process of restoring the River Murray to a healthy working river.

Second, the Council of Australian Governments' (COAG) decision on 29 August 2003 to refresh the water reform agenda and develop a National Water Initiative has profound implications for The Living Murray. Governments within the Basin (with the exception of

Queensland) have indicated they are prepared to invest $500m to address water over allocation in the Basin. Targeting and management of these funds will be settled through intergovernmental agreement.

Using Murray Flow Assessment Tool (MFAT) developed by the SRP specifically for this purpose, the interim report is able to estimate how native fish, waterbirds, wetlands, floodplain vegetation and algal blooms will respond to different flow scenarios, smarter operational rules, more focus on flow variability and connecting floodplains to the river, and to works that make best use of the water available.

More recently the MDBC has asked the SRP to look more closely at ecological responses at five significant ecological assets - Barmah-Millewa Forest, Gunbower, Koondrook-Perricoota Forests, Chowilla Floodplain (including Lindsay-Wallpolla), the Murray Mouth, Coorong and the Lower Lakes, and the River Murray channel. The MDBC has proposed that the first step decision should focus on the outcomes for these assets and that the proposal should be developed within the longer term framework to capture system-wide ecological, economic, cultural and social outcomes that achieve a healthy working river.

In the short term, the interim report provides confidence that flows targeted at these significant ecological assets will provide local benefits. For the longer term the scientific reviewers have been clear in saying that while the MFAT is a valid decision-support tool, there is more developmental work before we can have an ecological model for river management.

The Ministerial Council and the MDBC are committed to consulting with the community on refinement of initiatives for The Living Murray. The public release of this interim report is highly significant for the journey to sustainable outcomes for the River Murray and its communities, which is the agreed overriding vision for The Living Murray.

ROY GREEN
President
Murray-Darling Basin Commission

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1. EXECUTIVE SUMMARY

Prepared by Professor Gary Jones, Chair of the Scientific Reference Panel

Background

1. There is considerable evidence that the overall health of the River Murray system is in decline and no longer in a sustainable condition. While the effects of such decline are more immediately obvious in some parts of the river system than others, the scientific evidence for overall loss of river health is strong.

2. There are multiple threats to the health of the River Murray system. These include changes to flow regime, habitat destruction, increased salt and sediment load, loss of connectivity due to structural alterations, unsustainable floodplain management, and introduction of exotic pests. Of these threats, changes to flow regime are critical and require immediate attention if the River Murray is to be returned to a 'healthy working river' condition, and maintained that way for future generations. Other threats are being addressed by the MDBC under related programs covered by the Living Murray process, and the MDBC Integrated Catchment Management strategy.

3. Following earlier investigations, in April 2002, the Murray-Darling Basin Ministerial Council called for a comprehensive assessment of the costs and benefits to the environment, industries and communities of returning additional water to the River Murray as environmental flows. The Ministerial Council chose three environmental flow 'reference points' for analysis; 350, 750 and 1500 GL/yr. Proposed structural and operational modifications were also to be assessed. An independent Scientific Reference Panel (SRP) was contracted by the MDBC in October 2003 under the chair of Professor Gary Jones, Chief Executive, Cooperative Research Centre for Freshwater Ecology to advise the MDBC and Ministerial Council on potential ecological benefits.

4. The MDBC provided the SRP with three different operational scenarios to be assessed for each of the flow 'reference points'. These scenarios were not proposed water recovery or management options, rather, examples of what may be achievable through improved river operations. For each of the 350, 750 and 1500 GL options a 'Cap', 'b' and 'c' operational scenario was assessed. The 'Cap' option provided an environmental flow regime based on current river operational rules. The 'b' and 'c' options were based on modelled flows targeting various ecosystem locations and specific ecological indicators.

5. This report presents the interim results of the ecological assessment undertaken by the SRP up to August 2003, with minor modifications made in October 2003 in response to international peer reviewers' comments. It provides estimates of 'ecological potential' for the reference points under consideration. It is designed to serve as a basis for discussion and review amongst scientists, government officials and the broad community. It is not the definitive or final statement of the SRP on ecological benefits potentially arising from the flow volume reference points. The final report is due for submission to MDBC in mid-2004.

The Assessment Process

6. Under direction from the Ministerial Council, the SRP was to provide independent, expert scientific advice on the potential ecological benefits associated with the three reference

points and structural & operational options - relative to 1993/94 Cap reference condition. The assessments were to be undertaken at local, regional and system-wide scales with separate assessments for ecologically important 'icon' floodplain forests and wetlands (see below) and species (Murray Cod populations and River Red Gum forests).

7. Under the guidance of the SRP, and to inform its deliberations, 10 Regional Evaluation Groups (REGs) were formed to undertake local and regional scale ecological assessments of the three environmental flow reference points and potential structural/operational options. Each REG was comprised of scientific experts with specific local and regional ecological knowledge. To ensure consistency in approach across regional groups, the SRP provided an assessment framework and guidance for each of the 10 river zone assessments undertaken (one by each REG). The SRP then assessed, reviewed and combined the results from each of the REGs to form a system-wide assessment of the River Murray.

8. The SRP required a structured knowledge based assessment tool to assist with the assessment of the three environmental flow reference points. This tool would be structured as a Decision Support System (DSS) that estimated ecological responses to specified flow regimes for riverine environments at a range of spatial scales. A DSS would ensure that the assessments by each REG would be consistent, repeatable and transparent, using the same set of ecological knowledge. A 'decision support system' is software that integrates models, databases, expert knowledge and/or other decision aids, and packages them in a way that decision makers can readily use.

9. There were a number of existing tools or frameworks available nationally and internationally for environmental flow assessments, and several of these were considered by the SRP. The SRP was mindful that the very tight deadlines imposed on the assessment process, meant that a suitable assessment tool had to be ready for use within a 3 month timeframe. In Appendix 1, each tool considered is described in further detail, with particular reference to four essential selection criteria.

10. Based on this analysis, the SRP concluded that the Environmental Flows Decision Support System (EFDSS), developed by CSIRO in the late 1990's, was the only option that met all selection criteria. The SRP considered that modifications must be made to the EFDSS to tailor it to the River Murray system and the specific requirements of The Living Murray project, as well as incorporate updates in ecological knowledge since the late 1990's. This modified and updated assessment system became known as the Murray Flow Assessment Tool (MFAT).

11. MFAT was used to assess the ecological impact of different flow scenarios at various localities along the River Murray, both in-channel and on the surrounding floodplains and wetlands. For in-channel localities, the daily river flows were used directly to estimate the response of native fish and impacts on algal growth. For floodplain and wetland localities, a floodplain configuration was set up which uses the daily river flows to estimate the timing and quantity of water reaching each floodplain or wetland. These results are then used to estimate the response of floodplain vegetation, wetland vegetation and waterbirds. The outputs from the ecological models were in the form of annual indices ranging from zero (intolerable conditions) to one.(ideal conditions). After setting up appropriate model and geographic weightings (if required), statistical analyses of the results (annual indices) were undertaken to provide integrated assessments across river zones, and across the entire river system.

12. For the Final Report, all agreed structural and operational improvements will be run together in a single MFAT model run for each flow scenario. For this Interim Report the structural modifications have been only partly analysed, based on potential impacts on MFAT scores and two case studies. These were; installation of floodplain regulators, and thermal pollution reduction.

13. In addition to these ecological index assessments, MFAT captures statements of the evidence supporting every individual component of the ecological models. These are available for consideration and analysis by the user. It also captures a semi-quantitative measure of confidence in that scientific evidence, as determined by the REG or SRP member entering the data. In the Final SRP Report (2004), the MFAT will be used to propagate overall levels of confidence for each assessment model and for the whole of river assessment. For this Interim Report, levels of confidence are recorded for individual evidence fields only.

14. In 'populating' and applying the MFAT, the first task of each REG was to select a small set of key localities within their river zone for evaluation with the Murray Flow Assessment Tool (MFAT). A set of guidelines was developed by the SRP to assist the REGs in the selection of these localities. REG groups subsequently undertook a series of tasks prior to 'running' the MFAT analysis. These were: design of a simple representation for each floodplain configuration; calibration of the floodplain configuration; set-up and calibration of the ecological models

15. Key floodplain localities included those specified by the Ministerial Council, Ramsar sites and Ramsar nominated sites. The localities nominated by Ministerial Council were; Barmah-Millewa, Gunbower, Koondrook-Pericoota, Chowilla, the Murray Mouth, and the Coorong. Although not nominated by Ministerial Council, Hattah Lakes was also regarded as an important locality for assessment.

16. There were a number of issues that the MFAT does not address and needed to be assessed 'manually' by the REGs. These included issues such as salinity, water quality, the impact of exotic species, and grazing of floodplain or wetland vegetation by stock. Some of these issues constrain the ability of a system to respond to improved water management, and hence limit the 'ecological potential' indicated by MFAT index scores.

17. MFAT is best considered as providing 'estimates of potential ecological benefits' arising from a flow management scenario, not specific predictions of ecological response. It should be seen as a 'work in progress', being based on our current best knowledge of the system and of how to represent that knowledge in a decision support system. Its structure and the ecological knowledge embedded therein, is constantly under analysis and review by the scientists involved. It is the product of consensus, rather than unanimous scientific opinion.

18. The MFAT is not suitable for the hydrological conditions experienced in estuarine lakes such as the Lower Lakes and Coorong adjacent to the Murray mouth (Zone H). The team of scientists in REG H designed a similar assessment tool using the same principle of evaluating a habitat condition index from a set of mathematical equations and indices. The relationship between these ecological indices and the hydrology was determined by using a set of preference curves similar to those used in the MFAT but customized for the estuarine plant and animal communities in this zone. With caution, index outputs from the

REG H approach can be compared, at least in part, against those for other Zones upstream produced by MFAT.

19. The SRP reviewed the draft floodplain configurations and draft reports from each REG and recommended improvements or modifications. The final REG reports were also reviewed and this resulted in some minor modifications being implemented. These were considered and agreed to by the REG coordinators, and the MFAT was re-run with the modifications implemented. All MFAT outputs in this Interim SRP Report are based on these checked and modified (as agreed) analyses. Outputs in the appended REG reports are as originally supplied to the SRP.

20. The following results are presented and have been used by the SRP in reaching their Interim Assessments:

    - A summary of MFAT ecological (habitat condition) index statistics – for fish, waterbirds, floodplain and wetland vegetation, toxic blue-green algae and combined assessment (not including algae) – by river zone and at the 'whole of river' scale. Results for each flow reference point scenario and operational option were compared to a 'reference scenario' - 1993/1994 Cap conditions – which was used as a benchmark. Detailed results of regional (river zone) assessments are contained in the accompanying REG reports.
    - A qualitative assessment of the potential benefits offered by structural or operational improvements. Time has precluded a full quantitative assessment of these options using MFAT. This will be undertaken in the post-interim report phase prior to submission of the final SRP report in mid-2004.
    - Assessment of potential benefits provided for icon species at the whole of river scale, and icon sites (as specified by the MDB Ministerial Council).
    - Effects of flow scenarios on river salinity
    - Key findings of the MFAT model sensitivity analysis (undertaken independently by Charles Sturt University on behalf of the SRP and MDBC)

Key Results from MFAT analysis

21. For the majority of zones, the MFAT ecological (habitat condition) index scores progressively improve with increasing allocation of water from 350 to 1500 GL per annum (long term average).

22. Across all zones, substantial overall improvement (combined analysis) – defined as >50% improvement in index score for any year in the 108 years of modelled data - is achieved under the 1500GL scenarios. Some zones show substantial response to the 750 'b' and/or 'c' options.

23. Not surprisingly, the distribution of potential ecological benefits is not uniform along the river. The number of years showing a substantial improvement relative to the reference scenario varies from river zone to zone. For example, 750 GL could provide substantial improvements for floodplain vegetation in the Barmah-Millewa forest in up to 17% of years, but in only 3% of years for the SA Riverland (including Chowilla).

24. The ‘Cap’, ‘b’ and ‘c’ operational scenarios (for each flow reference point) varied in their effect depending on which zone was being assessed. Generally, zones in the upper Murray responded best to the ‘b’ scenarios while zone E responded best to the ‘Cap’ scenarios. Zones F and G responded best to the ‘c’ scenarios. This is broadly consistent with the operational rules of the ‘b’ and ‘c’ scenarios. The ‘b’ scenarios target environmental outcomes in; the upper Murray, wetlands downstream of Hume, Barmah-Millewa Forest, and the Murray Mouth. The ‘c’ scenarios additionally target environmental the Lower Darling (Zone F) and result in increased flows reaching the lower Darling and lower Murray zones (Zones F and G).

25. On their own (ie. without structural and operational improvements), all flow reference points and operational scenarios provide very little, or no, improvement in ‘aggregated’ MFAT Fish index scores (ie. all fish assessed), whether at a zone or whole of river scale. However, individual ‘flow sensitive’ fish species such as Golden Perch do show progressive improvement across the flow reference point range.

26. For Waterbirds, the greatest improvement in MFAT index scores were analysed for the 1500 GL options, and in particular the 1500c scenario, which shows ‘some improvement’ in up to 60% of years and ‘substantial improvement’ in over 10% of years. The 750 and 350 GL scenarios provide ‘some’ improvement in 25-40% and 10-20% of years respectively.

27. The MFAT Floodplain Vegetation indices show a greater response to the flow reference points than for any of the other ecological models. The 350Cap and 750Cap scenarios provide the least benefit, with ‘some improvement’ in only 10-30% of years. The 1500b and 1500c scenarios provide the most benefits with ‘some improvement’ in over 70% of years and ‘substantial improvement’ in about 15% of years.

28. For Wetland Vegetation, the 350 GL options show the least benefit and the 1500 GL options show the greatest benefit. The best scenario, the 1500c, shows ‘some improvement’ in 60% of years and ‘substantial improvement’ in over 10% of years.

29. For toxic and malodorous Blue-Green Algal blooms, the 1500c, 1500b and 750c provide substantial reduction in bloom risk (by up to 50% compared with reference conditions). The other reference points, including current, provide little or no significant reduction in algal bloom risk compared with 93/94 reference. The exception is for Zone J - lower Murrumbidgee – where the current flow scenario is providing a reasonable reduction in bloom risk (by almost 20% compared with reference conditions).

30. The modelled salinity concentrations at Morgan are reported in MFAT directly as supplied from MSM-Bigmod. The 350 GL and 750GL reference points show an improvement of around 20-30 EC, whilst the 1500GL scenarios substantially reduce EC, by up to 90 EC relative to an absolute Reference condition of 594 EC.

31. None of the flow reference points, on their own, provide substantial improvement in MFAT index scores for the icon species, Murray Cod. This is not surprising as Murray Cod would not be expected to respond significantly to flows within the reference point range (and as operationalised in the ‘cap’, ‘b’ or ‘c’ scenarios).

32. For River Red Gum forests and woodlands at the ‘whole-of-river’ scale, the 1500c scenario provides the greatest benefit with 35% of years showing a substantial

improvement. Of the 750 GL options, the greatest benefit is derived from the 750c scenario which provides substantial improvement in 20% of years. The 350 GL options provide the least benefit, with the 350C scenario providing substantial improvement in only 12% of years.

33. MFAT index scores for the following icon sites (as directed by MDB Ministerial Council) are reported; Barmah-Millewa Forest, Gunbower Forest, Koondrook-Pericoota Forest, Hattah Lakes, Riverland (Chowilla), Murray Mouth and Coorong. These sites showed similar responses to those recorded at the whole of river scale. Under 1500 GL reference point scenarios, floodplain vegetation showed a substantial improvement in condition in 8 to 18% of years and waterbird habitat showed substantial improvement in approx. 20% of years. The results also varied in response to the particular scenario with best results at Barmah-Millewa under the 1500c scenario and Gunbower, Chowilla and Hattah under the 1500b scenario. The assessment of the Coorong and Murray Mouth indicate that environmental conditions in the Coorong and the extent to which the Murray Mouth remains open, increase with more water. The level of increase, however, is small for the lower volumes of water (350 GL, 750 GL) compared with 1500 GL. The 1500b and 1500c scenarios provide the best outcome as far as securing an open Murray Mouth although it is still five time more likely to close then under natural conditions.

34. The extent to which environmental flows can provide respite for the Coorong and Murray Mouth is also dependent on the pattern of release of water over the barrages. Irrespective of the volume of water, changes to barrage operation can maximize the potential environmental benefits.

Summary Interim Assessments by SRP

35. In reaching the Interim Assessments provided in this report, the SRP have drawn significantly, though not exclusively, on the MFAT outputs summarised above and reported in Chapter 8. MFAT is a decision support system (not an ecological predictive model) and, hence, can only ever inform a decision process. It cannot and should not be the decision making tool on its own.

36. MFAT ecological model outputs are best suited for comparing the ecological benefits (or disbenefits) of a flow management scenario relative to a benchmark flow regime. For the purposes of the SRP report and the Living Murray process more broadly, that benchmark is the 1993/94 Cap condition (so called ‘reference’ condition). In addition to providing assessments of relative ecological benefits, the MDBC has asked the SRP to assess whether any of the flow reference points, combined with planned structural and operational improvements, can provide a ‘healthy working’ River Murray system. To do this, the SRP must compare the various flow reference points with the modelled natural flow regime. Our knowledge of riverine ecological structure and functional processes is simply not detailed enough to ‘build’ a desired or target condition from the ‘ground up’. In the absence of such knowledge, and supporting predictive models, deviation from modelled natural is the best yardstick available for assessing likelihood of absolute ecological condition. This quite categorically does not mean that ‘modelled natural’ is the target condition - it clearly is not for a working river like the Murray. Simply, it is a benchmark against which ecologists can make assessments of potential or actual ecological condition. Readers should form their own judgements as to the applicability of both assessment types for informing the Living Murray process.

37. Based on the MFAT analyses of ecological habitat condition (relative to the 93/94 reference condition) it can be concluded that the River Murray is likely to progressively improve as additional water is allocated to the environment (from 350 to 1500 GL). However, specific benefits will vary according to biological group (whether fish or birds or trees, etc) and location along the river or across the floodplain.

38. A further 350 GL environmental allocation, however operationalised, will provide little 'whole of river' ecological benefit. This assessment is strongly supported by the reported MFAT analyses – none of the 350 GL options provide any 'substantial' improvement in combined MFAT index scores. Targeting flows to selected high conservation floodplain areas may provide some localised benefits.

39. If fully optimised from an operational perspective, a further 750 GL may provide some whole of river ecological benefits. Comparison of the MFAT index scores with reference condition, and of the 750 'c' option with the other 750 GL options, provides support for this assessment. Substantial improvement in MFAT scores mostly occurs with the 750 'c' option.

40. A further 1500 GL can provide considerable whole of river and local ecological habitat benefits. The MFAT index scores for all options support this proposition. Substantial improvement in MFAT index scores is predicted in 10-20% of years in all assessed biological components except fish (blue-green algae risk is reduced by more than 40% for the 1500 'b' and 'c' options).

41. In spite of the apparent weak fish response to flows, successful fish recruitment (the full path from spawning through to adulthood) is known to be influenced by large over-bank floods. Few of these are provided by the reference point flow volumes. Large floods probably promote successful recruitment through indirect beneficial effects on river productivity, rather than through direct habitat effects as considered in MFAT. Further improvements in operational rules may allow more overbank flows and hence a stronger fish response across the flow reference point range.

42. Some components respond well to flow management across the reference point range (eg. floodplain and wetland vegetation) others do not. The non-flow constraints to recovery are very influential for some plants and animals (especially fish), and these must be considered in any assessment of future ecological condition and management.

43. Each operational scenario has a different set of operating rules and some of these rules tend to favour one river zone over another. This variation reinforces the need to consider the modelled flow scenarios as examples of the potential benefits from better environmental flow operations rather than as final management options. Considerable work is still required to finalise operational scenarios that maximise the environmental benefit for any allocation or across the entire Murray. The benefit of the zone-based MFAT analyses is that the trade-offs and 'ecological equity' can be considered in a transparent manner and evaluated by government and community.

44. Based on a combination of MFAT analyses and scientific knowledge and experience, it is the considered opinion of the SRP that at the whole of river scale, the 1500 GL flow options alone (ie. without structural, operational and water quality improvements) will deliver at best, a moderate improvement for the plant and animal communities assessed.

45. However, combined with improved structural, operational and water quality management – including all options currently being assessed by the MDBC – there is a possibility that a further 1500 GL of environmental flow allocation, could deliver a healthy working River Murray system. Whether or not this ultimately proved to be the case would depend on the setting of realistic ecological condition targets and objectives, plus a commitment to on-going and well funded river operations and monitoring in an active environmental management context.

46. It is critical to recognise that non-flow management options cannot be traded-off against environmental flow allocations. Both flow and non-flow resource allocations are required if the Murray is to return to a state that all can consider to be a healthy working river.

47. The health of the River Murray system has been impacted by many factors other than changed flow regime. These include water quality problems (such as salinity, thermal pollution and turbidity), dryland salinity across the floodplain, construction of barriers across the river channel, snag removal, bank erosion, over-grazing of the floodplain and wetland vegetation, logging of forests, construction of levees, the spread of exotic species, and over-fishing in some areas. The full benefits that can potentially be derived from a recovery in water for the environment cannot be realised unless these other impacts are also addressed.

48. If a first-step decision is to allocate volumes of water that will not have substantial system wide effects, the community may wish to consider the relative merits of allocating water to achieve specific local or regional benefits. Further, consideration should be given to the development of a year to year roster for the allocation of water to particular locations along the Murray to achieve longer term ecological outcomes. The ecological need for both drier and wetter years needs also to be recognised in the year to year allocations.

49. The SRP is available to work with the MDBC and local experts to continue the quantitative analysis of benefits that may be provided by structural and operational improvements. In many zones and locations, these will be significant and significant resources should continue to be directed to these discussions and analyses.

50. The decline in health of the riverine ecosystems along the River Murray has occurred gradually over more than 50-100 years. Likewise, any recovery in health will also occur over many decades, and might not be noticeable for many years after any allocation of extra water for the environment has been introduced.

51. The SRP and REGs have developed a detailed review and critique of the assessment processes used, including the MFAT. The Murray Flow Assessment Tool (MFAT) is a 'decision support system' designed to help demonstrate in a reproducible and transparent manner the potential benefits of increased environmental flows. It focuses on changes to habitat condition, rather than population dynamics or recruitment. It is developmental, and outputs should be seen as indicative rather than prescriptive. Assessments made using the MFAT are a synthesis of opinion, in that the performance of the model is weighed against expert opinion (the process is circular in that regard).

52. It is in the nature of science that there are points of doubt or contention. The SRP does not represent the information and assessments in this report as being without uncertainty. Assessments are the result of scientific consensus in the time available rather than unanimity. Indeed, we are conscious that there is not unanimous agreement by scientists

on every element of the MFAT decision tool. We will continue to work with all interested scientists, local experts and community stakeholders to improve the assessment process, including the MFAT, up to the final report submission in mid-2004. This element of scientific uncertainty should be borne in mind by any person considering the information and assessments contained in this report.

53. Statements and levels of confidence in all ecological knowledge has been documented in the populated zone-based MFAT models by the REGs and SRP. A formal analysis of overall confidence in the assessments reported herein has not been possible in time for submission of this Interim Report. The SRP sees this as a priority for further research and analysis in the period up to submission of the Final SRP report in mid-2004.

54. This report and the results and assessments contained therein are 'interim' in nature. They should be seen as providing initial guidance on the potential ecological benefits that may be provided by improved flow and non-flow management of the River Murray system, as well as informing a possible 'first-step' decision. There is much work, discussion and review that must occur before the Final SRP Report is submitted in mid-2004.

2. INTRODUCTION

In April 2002, the Murray-Darling Basin Ministerial Council called for a comprehensive assessment of the costs and benefits to the environment, industries and communities of returning additional water to the River Murray as environmental flows. The Ministerial Council chose three environmental flow 'reference points' for analysis, 350, 750 and 1500 GL/yr. An independent Scientific Reference Panel (SRP) was set up to assess the ecological outcomes by considering the potential effect of flow changes on physical habitat condition for native fish, waterbirds, floodplain vegetation and wetland vegetation, as well as the occurrence of algal blooms. This report presents the interim results of the ecological assessment undertaken by the SRP.

2.1 Setting the scene

The health of the River Murray ecosystem has been in decline for over 100 years and is no longer in a sustainable condition. In the early 1900's diversions were low compared with now, but water quality impacts would have commenced as a result of catchment clearing. Increasing flow regulation, associated with construction of Hume Dam near Albury and weirs on the lower Murray, accelerated the decline, and the process was further promoted by the rapid expansion in water abstraction for irrigation from the mid-1950s onwards. The first Murray-Darling Basin Snapshot Assessment of River Health (Norris *et al.* 2001) described the Murray as 'unhealthy'. The principal ecological threats to the health of the River Murray System have been identified on a regional basis by three Expert Panel reports (Thoms *et al.* 2000, Jensen *et al.* 2000, Roberts *et al.* 2001). These ecological threats are:

- Altered flow regime
- Reduced in-channel and floodplain connectivity
- Degradation and loss of physical habitat
- Catchment and floodplain management damaging to river ecosystem
- Degraded water quality (including salinity)
- Exotic and invasive plants and animals

The future condition of the River Murray system is clearly dependent on our actions now and over coming years. The ecological condition of the river system continues to degrade under the present Cap and current river operations. Even if there was no increases to water abstraction, no more dams, no worsening of water quality and no further spread of exotic pests, ecological condition will continue to decline before reaching a new quasi-equilibrium from which recovery to a healthy condition will be more difficult, and probably impossible.

Returning the River Murray system to a healthy working condition will require major improvements to river management. In March 2001 the Murray-Darling Basin Ministerial Council adopted a vision for the River Murray system. This included river health, environmental flow, water quality and social and cultural objectives.

2.2 Recommendations of the Expert Reference Panel

In 2001 an Expert Reference Panel (ERP) was convened by the MDBC to provide scientific advice on the environmental flow requirements of the River Murray. Prof. Gary Jones, CEO of the CRC for Freshwater Ecology, was appointed as Chair (Jones *et al.* 2002). Members were appointed based on their knowledge and experience of the Murray-Darling Basin.

The ERP adopted a system level (ie. whole-of-river) approach to assess the potential ecological benefits offered by five hypothetical flow management packages. This meant that the net ecological benefits were considered across the entire length of the river system and its floodplains. The ecological assessments did not specifically address the management of individual river reaches, or floodplain wetlands and forests. Because of the lack of precise knowledge linking river flows to ecological condition, a semi-quantitative risk-based assessment framework was adopted for setting specific targets for river management actions.

This assessment was based around the opinion of the ERP that there was a high risk that the River Murray will not be in a healthy state when annual discharge is reduced below about two-thirds of the natural level. Based on this 'risk guidance value' the ERP derived probability categories for successful environmental flows restoration. Assuming suitable habitat and water quality condition, when key flow attributes are greater than two/thirds of their natural level, there is a high probability or likelihood of achieving a healthy river (Table 2.1). When the same flow attributes are greater than half of their natural level, there is a moderate probability of achieving a healthy river. Below half of the natural level, the probability of having a healthy river is low.

Table 2.1. Expert Reference Panel's (2001) estimate of flow requirements for a healthy working River Murray

Key system level hydrological attributes (fraction of natural)	Probability of having a healthy working River Murray
≥ two-thirds	HIGH
≥ half	MODERATE
< half	LOW

Caveat: The 'two/thirds natural' guidance level is focussed on the River Murray, and is not a level for 'acceptable degradation' or 'sustainable diversion' of minimally impacted or wild rivers.

Caveat: The full benefits of environmental flow restoration will only be realised if water quality, floodplain habitat and riverine habitat are also rehabilitated or protected.

The risk categories described above were used to analyse the likelihood that the flow option packages provided by the MDBC project team would deliver a healthy working River Murray System. The summary results of this analysis are outlined in Table 2.2 below.

Table 2.2. ERP risk-based assessment of flow option packages (Jones *et al.* 2002)

Management Options	Probability of having a healthy working River Murray System
Do nothing more (Current operations).	LOW
A. Improved operations.	LOW[1]
B. Improved operations plus 340 GL/yr new environmental flows (Murray source)	LOW[1]
C. Improved operations plus 750 GL/yr new environmental flows (Basin-wide source)	LOW-MODERATE
D. Improved operations plus 1630 GL/yr new environmental flows (Basin-wide source)	MODERATE
E. Improved operations plus 3350L new environmental flows (Basin-wide source)	HIGH

[1] Some localised ecological benefits are delivered by these options ie. for specific wetlands, floodplain forests or river reaches, but the overall system level impact was insufficient to improve the probability category.

The key outcomes were that there would be a high probability of achieving a healthy working River Murray system with 3350 GL/yr of new environmental flow allocations, combined with a set of the operational improvements. The same operational improvements combined with 1630 GL/yr of new environmental flow allocations would lead to a moderate likelihood of achieving a healthy system. Other flow option packages examined provided little confidence that a system-wide, healthy working river would be achieved in the future. Some localised ecological benefits would be delivered by options A & B - for specific wetlands, floodplain forests or river reaches - but the overall system level effect was insufficient to improve the probability category.

2.3 Assessment of 350, 750 and 1500 GL/yr reference points

Based on the recommendations of the ERP and other advice, at its meeting in April 2002, the Ministerial Council directed the MDBC to undertake comprehensive analysis of the environmental, social and economic costs and benefits associated with returning water to the River Murray system, using three environmental flow reference points for analysis (an additional average 350, 750 and 1,500GL/year available to the River Murray system). This project has been named '*The Living Murray'* Initiative (for more information see www.thelivingmurray.mdbc.gov.au). The Ministerial Council also recognised the need for a program of structural and operational measures which would make better use of the water currently available, and optimise the benefit of any future environmental water allocations. An assessment of the potential ecological benefits for a range of proposed structural and operational improvements, was also required.

2.4 Formation and aims of the Scientific Reference Panel

The former ERP was reconvened, with some changes in membership, as the Scientific Reference Panel (SRP) for the current phase of project work (September 2002 – October 2003). The primary aim of the SRP was to provide independent, scientific advice on the ecological benefits (or impacts) associated with the three reference points for the recovery of water for the River Murray (350, 750 and 1500 GL/yr), relative to a reference scenario nominated by the MDBC (the 1993/94 Cap). In addition, the benefits (or impacts) of a suite of proposed structural and operational improvements would be assessed. The assessments were to be undertaken at both local, regional and system-wide scales. Particular reference would be given to ecologically important forests and wetlands (icon sites) such as the Barmah-Millewa forest, Gunbower forest, Koondrook-Pericoota forest, Hattah Lakes, the Riverland wetland complex (including Chowilla), Murray Mouth, and the Coorong, as well as Murray Cod populations and River Red Gum forests (icon species). Other panels were convened to undertake social and economic assessments.

2.5 Formation of Regional Evaluation Groups

Under the guidance of the SRP, ten Regional Evaluation Groups (REGs) were formed to undertake local and regional scale ecological assessments of the three environmental flow reference points, and also assess potential structural/operational improvements. Each REG was comprised of scientists with specific local and regional knowledge. The SRP provided the assessment framework (which included the MFAT) as well as quality assurance for each of the river zone assessments undertaken by the REGs. The SRP then reviewed and combined the results from each of the REGs to form a system-wide assessment of the response of the River Murray to the 3 environmental flow reference points (see section 5 for details).

3. DEVELOPMENT OF A MURRAY FLOW ASSESSMENT TOOL

3.1 The need for a flow assessment tool

The SRP required a tool to assist with the assessment of the three environmental flow reference points. This tool would be structured as a Decision Support System (DSS) that estimates ecological responses to specified flow regimes for riverine environments at a range of spatial scales. A DSS would ensure that the assessments by each REG would be consistent, repeatable and transparent, using the same ecological knowledge. A 'decision support system' is software that integrates models, databases or other decision aids, and packages them in a way that decision makers can readily use. This assessment tool was called the 'Murray Flow Assessment Tool (MFAT).

3.2 The choice of a suitable tool

The following essential criteria were used to define an appropriate assessment tool. It should be:

1. Structured as a Decision Support System that estimates ecological responses to specified flow regimes for riverine environments. A DSS would ensure that the assessments by each REG would be consistent, repeatable and use the same broad range of ecological knowledge.
2. Directly applicable to the River Murray system, or adaptable within 2-3 months. It should include ready-to-use tools that model the key elements of the channel and adjacent floodplain, as well as any major wetland complexes connected to the river.
3. Effective using existing, available data or make best use of structured expert opinion, since there would be very little time for the collection of new field data in this phase of the Living Murray Project.
4. Applicable to local, regional and system-wide assessments.

There are a number of existing tools or frameworks available for environmental flow assessments (Arthington 1998, Arthington and Zalucki 1998, Tharme 2003) and several of these were considered by the SRP. These included:

- The Flow Events Method (FEM)
- FLOWS
- Downstream Response to Imposed Flow Transformations (DRIFT)
- Instream Flow Incremental Methodology (IFIM)
- Environmental Flows Decision Support System (EFDSS).

When assessing these tools, the SRP had to be mindful that the very tight deadlines imposed on the assessment process meant that a suitable assessment tool had to produce useful outputs within a 2-3 month timeframe. Each tool is described in further detail in Appendix 1, with particular reference to the four essential selection criteria listed above.

Based on this analysis (Appendix 1), the SRP concluded that the EFDSS was the option that best met the selection criteria. The EFDSS is a decision support system that provides quantitative predictions of ecological response to specified flow regimes and to some other non-flow related habitat features. It is applicable to a lowland river floodplain system, such as the Murray. The basic data input requirements are relatively low and could be met within 6-8 weeks. The EFDSS provides a structured, transparent and repeatable method for assessment for each river zone by the Regional Evaluation Groups and also provides for a system-wide level of analysis. It was the opinion of the SRP that within the very limited time available, and in the context of an Australian lowland river floodplain system, the EFDSS would be the most appropriate basis from which to develop the MFAT.

3.3 Development of the MFAT

The EFDSS was originally developed and tested for the Border Rivers in the north of the Murray-Darling Basin (Young *et al* 1999). The SRP considered that some modifications to the EFDSS were needed to tailor it to the River Murray system and the specific requirements of The Living Murray Initiative, as well as incorporating the current state of ecological knowledge since the late 1990s. CSIRO Land & Water (the original EFDSS developer) was commissioned to undertake the modifications between late November 2002 and late January 2003. The limited amount of time available determined the exact nature of modifications to the EFDSS. Some of the more significant modifications included;

- Updates to four existing ecological models (native fish, waterbird, wetland vegetation and floodplain vegetation) to reflect recent advances in understanding of lowland river ecology;
- The input, storage and use of daily flow data from the Murray Simulation Model (MSM-Bigmod);
- The improvement of the technical user interface (TUI) module for comparison, summarising and integration of model results; and
- Modifications to the floodplain hydrology model, including the representation of area-volume relationships.

With the incorporation of these modifications, the EFDSS formed the basis of the MFAT as a Decision Support System to under-pin the assessment of the three reference points (350, 750 and 1500 GL) by the REGs, as well as the system-wide assessment by the SRP.

3.4 A short overview of the MFAT

The MFAT is a modified and extended version of the Environmental Flows Decision Support System (EFDSS) developed by CSIRO Land and Water (Young *et al* 1999). It can be used to assess the ecological response under different flow scenarios at various localities along the River Murray, both in-channel and on the surrounding floodplains and wetlands. For in-channel localities, the daily river flows are used directly to assess the habitat condition for native fish and also the response of algal growth. For floodplain and wetland localities, a floodplain configuration is set up which uses the daily river flows to estimate the timing and quantity of water reaching each floodplain or wetland. These results are then used to predict habitat condition for floodplain vegetation, wetland vegetation and waterbirds.

After setting up appropriate weightings, the Explore Tool can be used to provide statistical analysis of the results or to undertake integrated assessments across river zones, or across the entire river system. Figure 3.1 shows the basic framework of the MFAT.

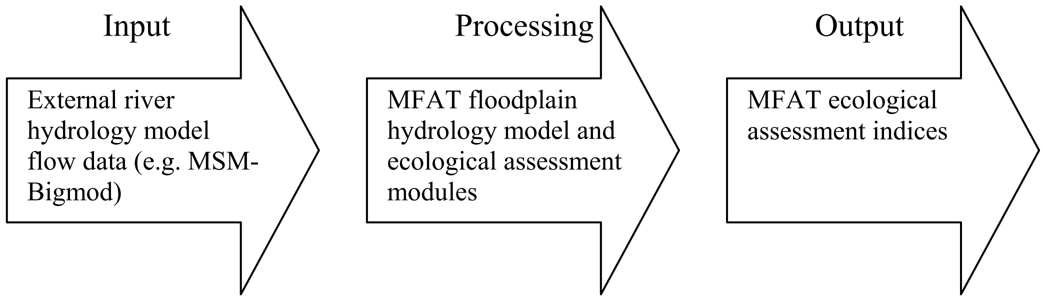

Figure 3.1; Basic framework of the MFAT

Ecological assessments are divided into two categories;

- The habitat condition assessment which includes native fish habitat, floodplain vegetation habitat, wetland vegetation habitat and waterbird habitat.
- The nuisance assessment which currently only includes assessment of blue-green algal bloom occurrence.

These can be assessed at a total of 6 different locality types, as described in Table 3.1.

Hydrology data are associated with localities, and simulation models can only be run at these localities. The in-river localities are described by hydrology data imported from an external hydrology simulation model, MSM-Bigmod (or similar hydrology models for the tributaries). Off-river localities are described by hydrology data from the MFAT floodplain hydrology model. These hydrology data drive the ecological assessment models which are run at the different localities.

In summary, the key advantages of using the MFAT would be to;

- capture and use the best available scientific knowledge (ecological and hydrological),
- provide consistent, automated and repeatable assessments of the 'likely' ecological outcomes of different flow scenarios,
- provide quantitative output indices representing ecological response,
- integrate ecological assessments from local and regional scales to whole-of-river scales, and
- provide documentation of the source and reliability of supporting ecological evidence in a transparent way.

Table 3.1. Association between ecological models, locality types and hydrology data in MFAT.

Ecological Model	MFAT Locality Type	Hydrology Data
Native Fish Habitat Condition	'River Sections'	Daily river flow data from MSM-Bigmod
Floodplain Vegetation Habitat Condition	'Floodplains'	Volume, area and depth of inundation are calculated in the MFAT floodplain hydrology model, which is linked to daily river flow data from MSM-Bigmod.
Wetland Vegetation Habitat Condition	'Riverine lakes', or 'Billabongs/lagoons'	Volume, area and depth of inundation are calculated in the MFAT floodplain hydrology model, which is linked to daily river flow data from MSM-Bigmod.
Waterbird Habitat Condition	'Waterbird habitat complex'	Volume, area and depth of inundation are calculated in the MFAT floodplain hydrology model, which is linked to daily river flow data from MSM-Bigmod.
Algal Growth Model	'Weir Pools'	Each MFAT 'weir pool' locality is linked to a river node from MDBC's river hydrology model, MSM-Bigmod, to provide daily flow and stage height data.

In the following sections a brief description of each of the major components of the MFAT is presented. More detailed descriptions are provided in a separate document (Young *et al* 2003, in prep)

3.5 The MFAT floodplain hydrology model

MFAT includes a model for configuring and running simulations of floodplain hydrology. The model represents the floodplain system as a network of storages and pipes (in a mathematical sense). The floodplain is linked to one or more river hydrology model nodes that provide the daily flow data that drive the floodplain hydrology simulation. The outputs are daily values for inundated volume and area for each modelled floodplain and wetland over the108 year period of flow records.

The model allows very simple or very complex configurations to be defined. The level of complexity should reflect both the actual complexity of the floodplain system, and also the extent of data available to accurately parameterise the model.

3.6 The floodplain vegetation habitat condition model

The floodplain vegetation habitat condition (FVHC) model enables simulation of floodplain vegetation habitat (primarily flow-related habitat) on the floodplains of the River Murray system under different river flow scenarios. Explicit consideration is made of adult and recruitment (specifically germination and seedling establishment) habitat preferences, with habitat condition indices calculated for each life stage. Separate assessments are made for the following vegetation groups:

- River Red Gum forest
- River Red Gum woodland
- Black Box woodland
- Lignum shrubland
- Rats Tail Couch grassland

3.7 The wetland vegetation habitat condition model

The wetland vegetation habitat condition (WVHC) model enables simulation of wetland vegetation habitat (primarily flow-related habitat) in the wetlands of the River Murray system under different river flow scenarios. Explicit consideration is made of adult and recruitment habitat preferences, with habitat condition indices calculated for each life stage. Two major wetland vegetation types are considered in the model: 'edge plants' and 'open water plants'. The following edge plant communities are available in the WVHC model:

- Cumbungi (*Typha*) rushlands
- *Phragmites australis* reedlands
- Spiny mudgrass (Moira grass) grasslands
- Giant rush rushlands

The only open water plant type available in the WVHC model is Ribbonweed (*Vallisneria americana*) herblands.

3.8 The waterbird habitat condition model

The waterbird habitat condition (WBHC) model enables simulation of waterbird habitat (primarily flow-related habitat) on the floodplains of the River Murray system under different river flow scenarios. The model is run for 'waterbird habitat complexes' which are described by multiple 'floodplain elements' (storages in the MFAT floodplain hydrology model). These 'floodplain elements' include 'floodplains', 'riverine lakes' and billabongs/lagoons. Explicit consideration is made of recruitment and foraging habitat preferences, with habitat condition indices calculated for each aspect. Separate assessments of recruitment habitat condition are made for two waterbird groups:

- colonial nesting waterbirds (which includes ibis, egrets, herons and spoonbills);
- waterfowl and grebes (which includes flood dependent species such as grey teal, pink-eared duck, freckled duck, Australasian shoveler, great-crested grebe, hoary-headed grebe).

A single assessment of foraging habitat is made, as there are no major differences in habitat preferences between the two groups.

The WBHC model is constructed on the premise that waterbird habitat condition is most sensibly considered at a large spatial scale, hence "waterbird habitat complexes" are assemblages of floodplain elements within a lowland floodplain region, which in reality represent a wide range of different waterbird habitats. Waterbird habitat complexes are expected to be of the order of 10s to 100s of square kilometres. The WBHC model is also constructed on the premise that waterbird recruitment occurs mainly on inundated floodplain elements, while waterbird foraging occurs mainly in the more permanent 'wetland' environments including "billabongs/lagoons" and "riverine lakes". The WBHC model therefore only considers "floodplain" elements in the assessment of recruitment habitat condition, and only considers "billabongs/lagoons" and "riverine lakes" in the assessment of foraging habitat condition.

3.9 The native fish habitat condition model

The native fish habitat condition (NFHC) model enables simulation of the likely condition of native fish habitat (primarily flow-related habitat) in the River Murray system under different river flow scenarios. The model is run for "river sections" for which the primary input data are simulated daily river flow volumes. Other input data include:

- A stage-discharge relationship,
- Several habitat preference curves that relate aspects of habitat condition to hydrologic or hydraulic variables, and
- Qualitative time-invariant descriptions of other aspects of habitat such as woody debris, thermal pollution, riparian condition, channel condition.

Explicit consideration is made of adult, spawning, and larval-juvenile habitat preferences, with habitat condition indices calculated for each life stage. Separate assessments are made either for individual species, or for groups of species with similar habitat preferences, with species found in more than one habitat type appearing in more than one group.

The following groupings are used in MFAT:

- <u>Flood spawners:</u> Golden perch, Silver perch (Spawn and recruit following flow rises. Major spawning occurs during periods of floodplain inundation).
- <u>Macquarie perch</u> (Require clean gravel substrate. Floodplain inundation not required, but spawning probably enhanced by rising flows).
- <u>Wetland specialists</u>: Australian smelt, Bony herring, Carp gudgeons, Southern pygmy perch, Hardyheads, *Galaxias rostratus.* (Spawn and recruit in floodplain wetlands and lakes, anabranches and billabongs during in-channel flows).
- <u>Freshwater catfish</u> (Spawn in coarse sediment beds (usually sand or gravel) during any flow conditions).
- <u>Main channel generalists</u>: Australian smelt, Bony herring, Flathead gudgeons (Spawn and recruit in high or low flow in the main channel).
- <u>Main channel specialists</u>: Murray Cod, Trout cod, River blackfish, Two-spined blackfish (Spawn and recruit under high or low flow in the main channel. Woody debris important habitat attribute).
- <u>Low-flow specialists</u>: Crimson-spotted rainbow fish, Carp gudgeons (Only spawn and recruit during low flow (channel or floodplain habitats).

3.10 The algal growth model

The Algal growth model enables simulation of the likely cyanobacterial (blue-green algal) populations in weir pools under different river flow scenarios. This is the only model in MFAT which is mechanistic (in part). It is based on a scientific understanding of the relationship between stratification and the likelihood of cyanobacterial growth. Stratification is predicted mechanistically from river discharge, water turbidity and meteorological data. The model undertakes an hourly energy balance (considering net surface heat flux, net downward shortwave radiation, net upward long wave radiation, net sensible heat flux, and the heat flux due to evaporation) and compares this to the kinetic energy of the river flow to determine whether the water column stratifies on any given day. While the water column is stratified, the algal population grows (up to a maximum), and while unstratified the population decays (down to a minimum). The annual algal index is the arithmetic mean of the daily values for the months September to April (ie. the warmer months).

3.11 Preference curves

The first four ecological models (native fish, waterbirds, floodplain vegetation, and wetland vegetation) all contain user-defined 'preference curves' to determine the daily 'output indices'. A preference curve has as its x axis, (or input parameter), a variable that is usually a function of the flow regime (a hydrologic or hydraulic variable) or a function of time (such as calendar month, or time duration – usually days or months). The y axis (or output) is a non-dimensional index with a range from 0 to 1. Zero (0) is used to indicate habitat conditions unsuitable for growth or reproduction (on an annual basis), and 1 is used to indicate 'ideal' habitat conditions. The index value of one (1) is not necessarily equivalent to 'natural' flow conditions. While natural flows could be considered ecologically optimal for the entire system, the natural flow condition does not provide ideal habitat for all biota at all times. Nor was every year under natural conditions always ideal – poor flow-related habitat years clearly occurred under 'natural' conditions. A critical factor, though, is the relative return frequency and history of good versus bad years and how this has changed in response to river regulation.

For most preference curves, a default curve (labelled the SRP default) was determined by the SRP. These default curves were developed based on published scientific knowledge, and after taking advice from specialists within the REGs. Default curves were used where the relationship between the hydrology and ecology was considered to be constant across the length of the River Murray. The default curves provided for consistency in the use of current ecological knowledge across all REG assessments. For preference curves which were locality specific (such as flood magnitude) adjustments were made by the REGs to suit each locality.

3.12 Calculation of daily and annual indices

The ecological models use the preference curves and a set of mathematical equations to calculate either a daily or event-based index. These are calculated for an entire year and then converted into an annual index based on a set of ecological rules. Depending on the model, the annual index might be the maximum daily index, or the mean or median value for the year. Annual indices are calculated for every year of the 108 year flow scenarios.

Within each of the ecological models (except algae), the annual habitat condition index is a weighted sum of an adult habitat condition index (*AHC*) and a recruitment habitat condition index (*RHC*).

3.13 Weightings

The native fish, waterbird, wetland vegetation and floodplain vegetation models each contain various weightings. Weights are specified by the user to indicate the relative importance of different components of the ecological models or of different localities. For example, this might include the relative importance of:

- Recruitment habitat and adult habitat to overall habitat condition,
- Different components within the adult or recruitment habitat models
- Spawning habitat and larval-juvenile habitat for native fish
- Breeding habitat and foraging habitat to overall waterbird habitat condition
- Different native fish species to the overall native fish community
- Different localities within a zone (perhaps according to relative size or ecological importance)
- Different zones along the river

Weights may reflect some or all of the following factors:

- Amount or quality of information underpinning each component of the assessment.
- Relative extent (length or area) represented by the locality.
- Ecological importance of the species group or locality to the overall community structure.
- Conservation status or iconic status of the particular species, group or locality.

In most instances, the default weighting of 1 was used, unless satisfactory evidence for making adjustments could be provided. The justification for any changes was recorded in the appropriate 'Evidence' fields of the MFAT by the REGs or the SRP.

3.14 Recording evidence

MFAT provides a simple mechanism for recording the quality and source of ecological data that is used to assign preference curves and weightings. Four pieces of 'evidence' are recorded:

- author
- date of entry
- confidence level
- statement of evidence and sources of information

In the case of preference curves, two sets of evidence are recorded and available for viewing. One is associated with the default values provided by the Scientific Reference Panel (SRP), and the other provides evidence for any user-defined changes to these default values.

The recording of evidence allows for the critical review of the sources of data being used to develop preference curves and assign weightings.

4. DEVELOPMENT OF FLOW SCENARIOS FOR ASSESSMENT

4.1 Introduction

Within MFAT, a flow scenario is a set of daily flow records for selected river locations. Along the River Murray, the flow scenarios were generated by the MDBC's river hydrology model, MSM-Bigmod. Similar models are used for the Murrumbidgee River (IQQM), and for the Goulburn River (REALM). The following summary focuses on the modelling that has been undertaken using MSM-Bigmod, for the three flow reference points. Further details are presented in Appendix 3 and also in various reports by the MDBC (eg. MDBC, 2002 and Martin, 2003).

MSM-Bigmod simulates as closely as possible the operation of the River Murray System under any given set of conditions, through the historic sequence of climate for which information is available (108 years, from 1891 – 1999). Each 'model run' operates the river under a fully described set of conditions to simulate what would have happened through the historic sequence. In line with the Ministerial Council's direction, the overall aim of the modelling was to develop flow scenarios around the three reference points (350, 750 and 1500 GL/yr) that would optimise environmental outcomes whilst minimising impacts on existing water users. The intention of these model runs was to allow assessment and consideration of *the scale* of the benefits and impacts that could be achieved under each of the three reference points. *By no means should they be considered to be final model runs for adoption and on-ground implementation*. Rather, they represent indicative changes which need further refining, including integrated modelling with the tributaries and improved modelling of potential changes associated with Snowy/Murray environmental flows.

Three proposed flow scenarios have been put together for each reference point, by combining a series of different 'option components' (or individual structural and operational changes, and changes to water sharing). The scenarios were developed by the MDBC, and were based on a set of ecological principles developed by the SRP (see Appendix 2).

4.2 Scenarios used for comparison purposes.

The following three scenarios; Natural, Current, and Reference are provided to allow the results of the proposed scenarios to be compared with these baseline model runs as appropriate. A fourth scenario, Actual, was also provided to assist with calibration of the MFAT.

Natural Scenario

Natural conditions are simulated by running the model with a scenario in which the dams, locks and weirs are 'removed' (capacities set to zero), there is no diversion of water, and tributary inflows are derived from 'natural conditions' model runs provided by the States.

Current Scenario

The Current scenario represents the conditions that existed in 2002 in terms of operating rules, procedures, level of development and management practices (ie. Current conditions, or now). This includes the environmental flow provisions agreed in recent years in the River Murray System and its tributaries, for example, the Barmah-Millewa allocation (rules agreed by Ministerial Council in March 2001).

Reference Scenario

This scenario is important, as it forms the starting point (or "line in the sand") from which water recovered for the environment is measured (also referred to as the benchmark). That is, water recovered under each of the reference points (350 GL, 750 GL and 1500 GL) is counted as the change from the Reference scenario in the long term average annual amount of water either:

- diverted directly from the River Murray; or
- flowing from a tributary into the River Murray.

The Reference scenario selected by MDBC officers represents the cap conditions, with diversions in NSW, Vic and SA at full Cap levels (note that SA currently diverts less than is allowed under the Cap). It should be noted that the operational details modelled in the Reference scenario were selected by the MDBC for assessment and discussion purposes ONLY and have not been formally endorsed by the Ministerial Council.

Actual

The Actual scenario is based on actual historical data, showing the transition from natural to current conditions. Data is provided from 1971 to 1999 for calibration purposes only.

4.3 Reference point scenarios

Three proposed scenarios for each of the three reference points have been prepared for the River Murray system by combining an increase in inflows from the tributaries with a series of 'option components' (or individual structural and operational changes, and changes to water sharing). In the absence of integrated modelling of the River Murray System with the major tributaries, it was assumed that cap reductions were implemented on the tributaries, to provide the increase in inflows from these systems.

The following scenario descriptions apply to the ecological assessments undertaken for the River Murray system, zones A to H.

Cap Scenarios

The Cap is reduced on the NSW Murray, NSW Lower Darling, Vic Murray and SA Murray by approximately 4%, 7% and 15% for the 350, 750 and 1500 GL/yr Cap scenarios respectively, thereby reducing diversions along the Murray. Allocations on the tributaries were also reduced by 5%, 10% and 20% respectively, resulting in increased inflows to the River Murray.

B-Scenarios

In each scenario, structural and operational changes have been made on the Murray to target various environmental assets, primarily the Mitta Mitta River, wetlands downstream of Hume, Barmah-Millewa Forest and the Murray Mouth. Progressively more changes can be made as more water is recovered, for example, the Chowilla floodplain is added to the list of assets targeted in the 750 and 1500 GL/yr options. Allocations on the tributaries were also reduced by 5%, 10% and 20% respectively, resulting in increased inflows to the River Murray.

Further, each of the B scenarios assume that the outcomes of the Snowy Water Inquiry are implemented, generating water use efficiency savings to create an entitlement for the Snowy

River of 212 GL/year and an entitlement for the Murray of 70 GL/year. Assumed savings for the Snowy from the Goulburn of 50 GL/year result in increased Goulburn tributary flows (over and above any Cap reduction).

C-Scenarios

In each scenario, structural and operational changes have been made on the Murray and Lower Darling to target various environmental assets, primarily the Mitta Mitta River, wetlands downstream of Hume, Barmah-Millewa Forest, the Lower Darling and Anabranch, and the Murray Mouth. Progressively more changes are made as more water is recovered, for example, the Chowilla floodplain is added to the list of assets targeted in the 750 and 1500 GL/yr options.

In the 1500 GL - C scenario Lake Menindee on the Lower Darling is decommissioned and its capacity set to 0 GL. This is an initial scoping exercise to assess the potential benefits that the more natural flow regime, reduced evaporation, and increased flow bypassing the Menindee Lakes system would provide to the Lakes themselves, the Lower Darling and Anabranch, and the Lower Murray.

Allocations on the tributaries were also reduced by 5%, 10% and 20% respectively, resulting in increased inflows to the River Murray. The C scenarios do NOT include the outcomes of the Snowy Water Inquiry.

4.4 Scenarios for the tributaries

The ecological assessment of Zone J (the Murrumbidgee River) was undertaken on the basis of a slightly different set of scenarios, to those used as input for the River Murray System Scenarios. The scenarios assessed were; modified Year 6 Water Sharing Plan conditions, and 10% and 20% reductions in diversions on the Murrumbidgee, for the 350, 750 and 1500 GL/yr reference points respectively.

Similarly, the ecological assessment of Zone I (the Goulburn) will also be undertaken on the basis of a different set of scenarios to those used as input for the River Murray System Scenarios. The scenarios to be assessed will stem from environmental flow recommendations for the Goulburn River, which have been developed by the Scientific Panel (outlined in Cottingham *et al* 2003).

4.5 Comparison of reference point scenarios with total Basin runoff

The average annual runoff within the Murray-Darling Basin has been estimated to be 24,300 GL/yr (Crabb 1997). Under Reference conditions (the 1993/94 Cap), some of this water (12,000 GL) was used for irrigation, while the remainder was either used by the riverine environment en route (7,400 GL, through evaporation, seepage, filling of wetlands etc), or flowed out to sea (4900 GL). The estimated proportions for each of the other flow scenarios are presented in Table 4.1

Table 4.1. Proportion of annual runoff being used for irrigation, by the environment and flowing out to sea (assuming no change in total runoff).

Scenario	Irrigation	Riverine environment	Flowing out to sea
Natural	0 GL (0%)	12,000 GL (49%)	12300 GL (51%)
Reference (1993/94 Cap)	12000 GL (49%)	7400 GL (30%)	4900 GL (20%)
350 GL/yr	11650 GL (48%)	7580 GL (31%)	5070 GL (21%)
750 GL/yr	11250 GL (46%)	7660 GL (32%)	5390 GL (22%)
1500 GL/yr	10500 GL (43%)	7800 GL (32%)	6000 GL (25%)

Note 1; The following figures for the 350, 750 and 1500 GL/yr reference points are based on the 'cap reduction' scenarios - there are small variations for each of the B and C scenarios

Note 2; For the purposes of this Table, the change in irrigation assumes that the change in inflows from the tributaries is equivalent to the change in diversions from those systems

This Table indicates that under current conditions the average annual flow over the barrages at the mouth of the river is 4900 GL/yr. This is 40% of the volume which flowed out to sea under natural conditions. This increases to;

- 5070 GL/yr or 41% for the 350 GL/yr option
- 5390 GL/yr or 44% for the 750 GL/yr option
- 6000 GL/yr or 49% for the 1500 GL/yr option.

The 350, 750 and 1500 GL/yr options represent 3%, 6.3% and 12.5% of the total quantity of water currently diverted for irrigation.

For each of the 350, 750 and 1500 GL/yr scenarios, the environmental allocation has been sourced from both the River Murray and also the main tributaries. So not all of the water is available at any one point along the river, and this is reflected in the MSM-Bigmod modelling. Also, as this water moves down the river, a portion is 'lost' to, or consumed by, the environment (for instance through inundation of wetlands, evaporation and seepage), and not all of it reaches the mouth of the river. MSM-Bigmod does account for these 'losses', and has been calibrated for a range of flows in every reach of the river, including for overbank flows. This is calibrated on the basis of past events. However, as the recorded flow data for larger events are likely to be less reliable, and there are less of them to calibrate against, the 'losses' in the model for the flood events are less accurate than for those instream. Further, the 'losses' that may occur as a result of a flood that has been 'created' by environmental water allocations, might be different to those from a natural event (for instance due to different antecedent conditions).

5. THE REGIONAL ASSESSMENT PROCESS

5.1 Introduction

Under the guidance of the SRP, 10 Regional Evaluation Groups (REGs) were formed to undertake local and regional scale ecological assessments of the three environmental flow reference points. Each REG consisted of 5-9 scientists with knowledge of the ecology or hydrology across their zone. The SRP provided the assessment framework (the MFAT) as well as advice and quality assurance for each of the assessments undertaken by the REGs.

The ten river zones assessed by the REGs were (Figure 5.1);

- Zone A: Dartmouth Dam to Hume Dam (Mitta Mitta River)
- Zone B: Hume Dam to Yarrawonga Weir
- Zone C: Yarrawonga Weir to the Wakool Junction
- Zone D: Wakool Junction to Lock 11 (Mildura)
- Zone E: Lock 11 (Mildura) to Lock 3 (Overland Corner)
- Zone F: Menindee Lakes, the Lower Darling River and Darling Anabranch
- Zone G: Lock 3 (Overland Corner) to Wellington
- Zone H: Lower Lakes, Murray Mouth and Coorong.

In addition, two major tributaries are also being considered as part of this process:

- REG I: Goulburn River; and
- REG J: Murrumbidgee River.

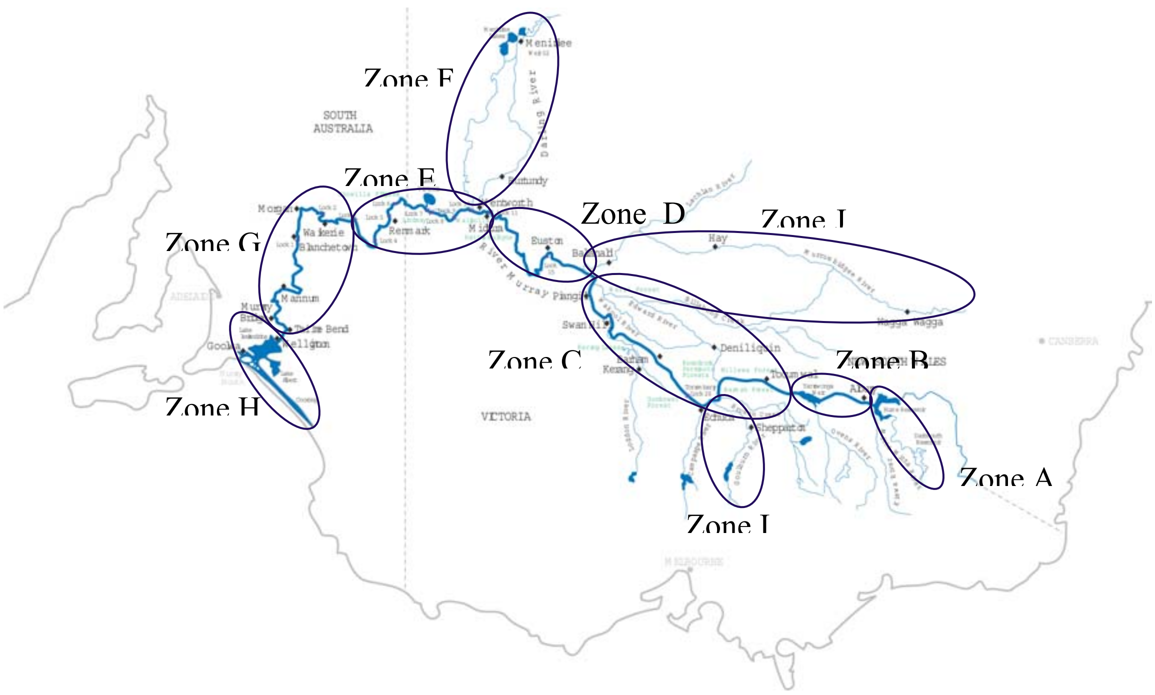

Figure 5.1. The ten zones along the River Murray System, being assessed using the MFAT as part of the Living Murray Initiative.

5.2 Choice of localities for assessment

The first task of each REG was to select a small set of key localities within their river zone for evaluation using the Murray Flow Assessment Tool (MFAT). The following guidelines were developed by the SRP to assist the REGs in the selection of these localities:

- It was recommended that a total of between 4 and 9 localities should be chosen. Choosing more localities would not necessarily improve the accuracy of the assessment, but would increase the task of data collection and assessment.
- The choice of localities would often be limited by the availability of data. Localities that have little and/or low quality data were discouraged as they would make the assessment more difficult and less reliable.
- A range of localities covering both floodplain and in-channel processes were to be selected. These localities should be representative of the diversity of in-channel and floodplain environments within that river zone.
- Key localities would be those which play an important ecological or hydrological role in the natural functioning of a major floodplain system on the River Murray.
- Other floodplain or in-channel localities were those which provide habitat for animals at a vulnerable stage in their life cycles, or provide a refuge during adverse conditions such as drought. For instance, a wetland or in-channel locality could be considered if it is an important source of food, spawning ground, nursery, or migration path for native fish stocks, particularly Murray Cod or threatened or endangered fish species.
- Alternatively, the floodplain or in-channel locality might support native plant or animal species or communities which are considered endangered or vulnerable at the national level.
- Key floodplain localities should include those specified by the Ministerial Council (see below), Ramsar sites and Ramsar nominated sites. The localities nominated by Ministerial Council were; Barmah-Millewa, Gunbower, Koondrook-Pericoota, Chowilla, the Murray Mouth, and the Coorong. Although not nominated by Ministerial Council, Hattah Lakes was also regarded as an important locality for assessment.
- Sites of ecological significance listed in the 'Directory of Important Wetlands in Australia' (Environment Australia. 2001), or identified in 'Significant Wetlands for waterbirds in the Murray-Darling Basin' (Kingsford *et al.* 1997), or nominated in previous expert panel reports (Thoms *et al*., 2000) were also to be considered.

When selecting localities, consideration must also be given to the MFAT ecological models that will be run at each site. The choice of models is partly determined by the type of locality (ie, the native fish and algal models are for in-channel localities, whereas the waterbird, floodplain vegetation, and wetland vegetation models are for localities across the floodplain). In addition, the plant or animal communities to be assessed within each model must also be selected. This will be determined by the communities currently living at this locality, but might also include any species or communities that might return after restoration. More specifically, in-channel localities for the assessment of Murray Cod were required, as this fish was nominated by Ministerial Council as an icon species. Recent public and scientific interest in the health of River Red Gums along the River Murray system resulted in this floodplain species also being given a high priority in the selection of localities.

A summary of the localities selected by each REG is presented in Appendix 4, and is also documented in the accompanying REG reports.

5.3 The REG assessment process

Once each REG had chosen a set of localities, the procedure for setting up the MFAT, running the software and then assessing the results, is summarised below.

a) Design a simple representation for each floodplain configuration. For each floodplain or wetland locality, a simple water balance model (or floodplain configuration) must be constructed using the MFAT floodplain hydrology model (see section 3.5). This model simulates the flood frequency, duration, inundated volume and area for each storage component within the configuration.

b) Calibration of floodplain configuration. Calibration is achieved by comparing model results for flood frequency, flood duration, inundated area and water depth, preferably with historical field data, or if this does not exist, with local knowledge. The natural, reference and actual scenarios are generally used for this calibration.

c) Setting up and calibrating the ecological models. At each locality, the ecological models must be set up using site specific information. This might include 'sub-indices' that require a single value (such as 'woody debris' in the fish model) or adjustment to preference curves. This required field data as well as knowledge of how ecological responses vary along the river. Where accurate field data is not available, expert scientific opinion might need to be applied. The scientific evidence (and level of confidence) justifying any changes to preference curves was loaded into the appropriate 'Evidence' fields. The ecological models also contain weightings for various indices, and these must be set by the REGs. In most instances, the SRP advised that a default weighting of 1 should be used, unless the REG could provide satisfactory evidence to the contrary. Any changes were justified in the appropriate 'Evidence' fields of MFAT. The one exception to this guidance was for the weighting between adult and recruitment habitat condition, where the SRP advised that recruitment should be given a higher weighting. Recruitment was considered to be the most critical process underpinning the sustainability of most taxon groups along the River Murray.

Once all data was loaded into the models, and site specific preference curves adjusted, the ecological models were tested, using the natural, reference and actual flow scenarios. The results for these scenarios were evaluated using any available data or expert scientific opinion. When calibration of each model was complete, the MFAT was run for all flow scenarios.

d) Assessing other issues, and constraints to recovery. There are a number of issues that the MFAT does not address and needed to be assessed manually by the REGs. These include issues such as salinity, water quality, the impact of exotic species, and grazing of floodplain or wetland vegetation. Some of these issues might constrain the ability of a system to respond to improved water management. A description of these constraints is included in each of the REG reports.

5.4 Assessment of proposed structural and operational improvements.

An assessment of the potential ecological benefits for a range of proposed structural and operational modifications, was also required. The MFAT can be used to model some (but not all) of these improvements by adjusting preference curves, 'sub-index values, and the floodplain configurations. This includes;

- Installation of regulators for controlling water flow into (and out of) wetlands
- Resnagging
- Improved fish passage
- Weir pool raising
- Thermal pollution mitigation

All structural and operational improvements were run together in a single model run for each flow scenario and the results for each river zone are reported in the accompanying REG reports. In this report, two case studies have been presented as examples; the installation of a regulator on a wetland in zone C, and thermal pollution mitigation in zone B.

5.5 Assessment of the Lower Lakes, Murray Mouth and Coorong

The MFAT was designed for application along freshwater river channels and the adjoining floodplain. It was not designed for the hydrological conditions experienced in estuarine lakes such as the Lower Lakes and Coorong which are located in zone H, adjacent to the Murray mouth. It also did not contain ecological models appropriate for the plant and animal communities that were present. Therefore a different assessment process was required. The team of scientists in REG H designed a similar assessment tool which used the same principle of evaluating a habitat condition index using a set of mathematical equations and indices. The relationship between these ecological indices and the hydrology was determined by using a set of preference curves similar to those used in the MFAT but customized for the estuarine plant and animal communities in this zone.

The Lower Lakes and Coorong region provided a number of challenges in the direct application of the MFAT because:

- The hydrology of these water bodies is dominated by water level influences that are not highly related to river flow;
- A daily hydrological time series for the Coorong is not available in the form required for application of the MFAT;
- The hydrology and ecological response of the region below the barrages are heavily influenced by tidal effects and these are not accommodated in the MFAT nor within the Murray Darling Basin Commissions hydrological models;
- The majority of ecological communities of particular interest in the Lower Lakes and Coorong region are specific to the region;
- The ecological needs and responses, and the way in which they need to be described, are quite different to communities found upstream of the region for which preference curves had already been developed;

A modified approach was therefore required for the Lower Lakes and Coorong Region from that which was applied upstream. Whilst the MFAT itself was not used, its inherent logic and methodology was used to provide a framework for the assessment.

The following key ecological communities and localities were selected to collectively describe the response of the system to past, present, and possible future flow scenarios.

Locality	Ecological model
Lower Lakes	
Narrung narrows	- Freshwater flood spawners
	- Wetland specialist fish
	- Emergent macrophytes
Tolderdol/Mosquito PT	- Lake edge aquatics
	- Behind lake edge aquatics
	- Samphire
Coolinderwerh Lagoon	- Behind lake edge waterbird habitat
	- Lake edge waterbird habitat
	- Melaleuca habitat
Coorong	
Coorong southern lagoon	- Ruppia habitat
Coorong northern lagoon	- Estuarine fish
Murray Mouth	- Mouth opening index (MOI)

The Mouth Opening Index (MOI) was used as an indicator for the Murray Mouth. The MOI is an MDBC indicator that describes the percentage of years with a risk of mouth closure.

5.6 Assessment of the tributaries; the Goulburn and Murrumbidgee Rivers

A significant portion of the water contributing to the three flow reference points originates from two of the main tributaries, the Murrumbidgee and Goulburn Rivers. It is therefore important to assess the benefits/impacts that might occur along these rivers, and so Murrumbidgee and Goulburn River REGs were set up to undertake this task.

The assessment of the Murrumbidgee River extended from downstream of Burrinjuck Dam to the confluence with the River Murray. This reach was subdivided into five distinctive sections based on geomorphic and hydrological characteristics. Localities were selected from four of these river sections. The majority of the localities were from the Lowbidgee and Riverine Plain Palaeo-floodplain as these areas have substantial floodplain and wetland development. Localities were selected if they were near to a river gauging site, typical of the wetlands in that zone, and if there were good hydrological data and ecological data available for that locality. The flow scenarios evaluated in the Murrumbidgee River, were approximately equivalent to those assessed in the River Murray (see section 4.4 for details).

These flow scenarios were derived using the IQQM river hydrology model, which was developed by the Dept. of Infrastructure, Natural Resources and Planning, for river management in NSW. The MFAT was used to generate waterbird, native fish, floodplain vegetation and wetland vegetation habitat condition indices.

At the time of the REG assessments along the Murray and Murrumbidgee Rivers, a separate expert panel assessment was being undertaken on the Goulburn River. Rather than disrupt the expert panel assessment, it was agreed to delay the REG assessment of the Goulburn River until expert panel had completed its task. The same team of scientists would then commence the REG assessment, thus allowing a direct comparison of the two methods. This meant that the REG assessment of the Goulburn River would be delayed by a few months.

5.7 SRP guidance and review of REG assessment process

During the regional assessment process, the SRP maintained close contact with each REG and provided guidance and advice when required. The SRP also reviewed the draft floodplain configurations and draft reports from each REG and recommended improvements or modifications. The SRP provided quality assurance as well as ensuring consistency in the assessment process across all REGs. The final REG reports were also reviewed and this resulted in some minor modifications, after consultation with the REG co-ordinators. All MFAT outputs in this Interim SRP Report are based on these checked and modified analyses. Outputs in the accompanying REG reports are as originally supplied to the SRP.

6. AGGREGATION TO WHOLE OF RIVER ASSESSMENT

6.1 Integrated assessment of each ecological model

A whole-of-river assessment was undertaken for native fish, waterbirds, floodplain vegetation and wetland vegetation (note - a system-wide algal bloom assessment was not considered to be appropriate since algal blooms only affect some sections of the river, and some REGs did not undertake this assessment for their zone). This included all of the zones along the main channel of the River Murray as well as the Lower Darling. It did not include the tributaries since the Goulburn River assessment is not yet completed and the Murrumbidgee assessment uses a slightly different set of flow scenarios, making integration more complex. The Lower Lakes/Coorong was not included since a different set of ecological models was used in this estuarine zone. Therefore, the results for the Murrumbidgee and Lower Lakes/Coorong are reported separately.

The combined habitat condition assessment for each zone reported by the SRP does not include outputs from the algal growth model. This was done for consistency purposes because not all river zones are under threat from toxic algal blooms, and consequently not all REGs assessed algal growth.

a) Whole-of-river native fish assessment

The native fish assessment undertaken for each zone was combined into a whole-of-river assessment by applying equal weightings to all zones. No zones received an increased weighting, since all zones were considered to (potentially) provide important habitat for one or more of the species being assessed. All preference curves and weightings applied by the REGs for each locality within a zone were retained (see appendix 4).

b) Whole-of-river waterbird assessment

Increased weightings were applied to zones containing the most important waterbird breeding and foraging sites along the Murray system. These were;

- Chowilla and the broader Riverland complex
- Barmah Millewa Forest
- Lowbidgee (reported separately)
- Gunbower Forest
- Hattah Lakes
- Coorong (reported separately)
- Lower lakes (reported separately)
- Menindee Lakes
- Anabranch Lakes

A summary table of the resulting weights is presented below.

Table 6.1. Weights for system-wide waterbird assessment

Zone	Zone weight	Waterbird complex
A	1	Lower Mitta
B	1	Quat Quatta St Leonards bend
C	3	Barmah-Millewa Gunbower
D	2	Hattah lakes
E	2	Lindsay island Merreti Clover Spectacle lakes
F	3	Northern anabranch lakes and channels Southern anabranch lakes Northern lower darling billabongs Unregulated Menindee lakes
G	2	Banrock complex Brenda Park complex

Note; Zones C and F are given a weighting of 3 because they contain more than one of the important bird sites.

All preference curves and weightings applied by the REGs for each locality within a zone were retained.

c) Whole-of-river floodplain vegetation assessment

Increased weightings were applied to zones which contained floodplain localities of high significance to the Murray system. These were;

- Lowbidgee (reported separately)
- Lindsay Wallpolla Island
- Gunbower Forest
- Koondrook Pericoota
- Hattah Lakes
- Chowilla (Werta Wert)
- Barmah Millewa Forest
- All of Zone B floodplain forests

A summary table of the resulting weights for each zone are presented below.

Table 6.2. Weights for system-wide floodplain vegetation assessment

Zone	Zone weight	Locality
A	1	Upper Mitta Lower Mitta
B	1	Quat Quatta floodplain Croppers floodplain
C	3	Barmah/Millewa Gunbower Koondrook/Pericoota
D	2	Hattah Belsar Island
E	2	Lindsay island Werta Wert (Chowilla) Merreti Spectacle Lakes Floodplain
F	1	Gluepot Popio halo Nearie halo floodplain Billabong halo nth floodplain Emu lake halo floodplain
G	1	Banrock Overland corner Nigra Brenda Park

Note; Zone C is given a weighting of 3 because it contains three of the most important floodplain vegetation sites.

All preference curves and weightings applied by the REGs for each locality within a zone were retained.

d) Whole-of-river wetland vegetation assessment

Increased weightings were applied to zones which contained wetland localities of high significance to the Murray system. These were;

- Lowbidgee (reported separately)
- Lindsay Wallpolla Island
- Gunbower Forest
- Koondrook Pericoota
- Hattah Lakes
- Chowilla floodplain
- Barmah Millewa Forest
- Werai Forest
- Zone B
- Menindee Lakes and Anabranch Lakes of the Lower Darling

A summary table of the resulting weights for each zone are presented below.

Table 6.3. Weights for system-wide wetland vegetation assessment

Zone	Zone weight	locality
A	1	Lower mitta
B	2	Quat Quatta Croppers lagoon
C	3	Barmah Werai Gunbower
D	2	Hattah Lakes Belsar island
E	2	Werta Wert (Chowilla)
F	2	Popio lake Nearie Lake Billabongs nth lower Emu Lake
G	1	Banrock lagoon Overland corner lagoon Nigra lagoon Schillers lagoon Brenda park lagoon

All preference curves and weightings applied by the REGs for each locality within a zone were retained.

6.2 Integrated assessment of icon species

a) Murray Cod

The localities and weightings to be used for Murray Cod are shown in the table below. Increased weightings were applied to those zones that were considered to provide the most important habitat for sustaining Murray Cod populations along the river.

b) River Red Gums

River Red Gums were not included by Ministerial Council as an icon species, but there has been increasing interest in this species, and therefore a separate assessment was undertaken. The localities and weightings to be used for River Red Gums (both woodland and forest plant groups) are shown in the table below. Increased weightings have been applied to those zones that contain the most significant Red Gum forests.

Table 6.4. Weights for system-wide Murray Cod assessment

Zone	Zone weight	Locality
A	0	Upper Mitta Lower Mitta
B	1	Richardsons bend Croppers lagoon
C	2	Yarrawonga to Tocumwal Edward River
D	2	Colignan R Wakool River
E	2	Lock 7 Mullaroo Ck
F	1	Darling anabranch weir 32 Northern lower darling - wycot
G	2	Maize island to overland corner Lock 1 to Nildottie river

Table 6.5. Weights for system-wide River Red Gum assessment.

Zone	Zone weight	Locality
A	1	Upper mitta Lower mitta
B	2	Quat Quatta floodplain Croppers floodplain
C	3	Barmah/Millewa Gunbower Koondrook/Pericoota
D	2	Hattah Belsar island
E	2	Lindsay island Merreti Spectacle Lakes Werta Wert
F	1	Billabong nth
G	1	Banrock Overland corner Brenda park

A zone weighting of 3 is used for zone C since it contains three of the most significant sites for red gums.

6.3 Adjustments by SRP to algal assessments

Four of the REGs (D, E, G and J) undertook an algal assessment within their zone. After reviewing each REGs input parameters and subsequent results, the SRP made some adjustments to ensure a more consistent approach across the whole river. The input parameters used by the SRP are presented below.

Modifications made to previous REG data or MFAT index scores:

	Seed pop.	Max. pop.	Growth rate	Decay rate	Wind speed*
Zone D	1	150,000	0.25	-0.80	x 3/4
Zone E	1	150,000	0.20	-0.80	x 2/3
Zone G	1	150,000	0.20	-0.80	x 2/3
Zone J	1	150,000	0.30	-0.80	x 2/3

* wind speeds reduced by this factor; wind speeds were too high, not allowing stratification. Weather Bureau data is for daytime (9am or 3pm) and would be reduced at night.

The index scores used (linking cell concentration to MFAT score) were altered to reflect exponential differences between levels, as shown below;

Level	Cells/mL	Index
None	0 - 200	0
Low	200 - 2000	-0.1
Moderate	2000 - 15000	-0.3
High	15000 - 10000	-1.0
Extreme	> 100000	-3.0

It should be noted that these adjustments mean that the indices presented in the SRP report for each zone are different to those reported by the REGs.

6.4 Statistics used for analysis of MFAT results

MFAT index scores are generated daily for 108 years of modelled flow data (1891-1999). Annual index scores are calculated from daily scores according to ecological rules relevant to each index component (represented as a preference curve). In the 'Explore' module of MFAT, 108 annual index scores are reported for each ecological model or sub-model (eg. Floodplain Vegetation or River Red Gum forests, etc.). The Explore module also provides several options of statistics for user analysis. These are:

- mean (average)
- median (50th percentile)
- minimum
- maximum
- S80 - difference between the 10th and 90th percentiles divided by the 50th
- coefficient of variation (CV), standard deviation divided by the mean.

In addition, it allows a 'Spells' analysis to be carried out. Australian rivers have highly variable flows, among the highest in the world. This 'event' nature of river flow – with droughts, floods and years in between - has a profound effect on river ecology (Young *et al.* 2001). Hence, hydrological and ecological analysis needs to consider an 'event-based' or 'spells' analysis to properly understand the relationship between a flow regime with high inter-annual variability and river health.

Ecologists may want to consider the types of spell – eg. whether wet or dry – their frequency, their duration, and the gap between them. Analyses are performed based on a user-specified threshold value, and a user-specified spell duration. The threshold value can be selected to examine specific hydrological events eg. the median (50th percentile) flow, or to examine differences between one flow option and another. Using these values the MFAT spells analysis calculates the following statistics:

- percent of years above the specified threshold value
- mean duration of spells above or below the specified threshold value
- total number of spells
- number of long (greater than specified threshold duration) spells above or below a specified threshold value

When examining raw hydrological data, all these options are useful. However, through individual preference curves, MFAT index scores already take into account many ‘event-based’ effects such as flood duration, flood magnitude, dry spell , etc. Consequently, the spells analysis routine is most useful for comparing MFAT index scores for one flow regime option with another. This is how it has been used by the SRP - in most cases to analyse the percentage of years better or worse than the ‘Reference’ scenario.

For the ecologically important reasons outlined above, the SRP has focused on the ‘events’ (spells) analysis to inform our assessments using the S/R statistic.

7. CRITIQUE OF THE MFAT IN THE CURRENT ASSESSMENT PROCESS

Environmental flow assessments can be undertaken at three levels of resolution (Fig. 1. Arthington *et al* 2003). The first involves hydrological or precautionary methods that have low scientific rigour and high risk of error. The second level of more sophisticated assessments includes holistic scientific panel methodologies that have moderate scientific rigour and a moderate risk of error. The most sophisticated techniques involve the use of hydrology-ecology response models and are scientifically more rigorous and provide a low risk of error. There are over 200 reported individual assessment methods reported in the literature (Tharme 2003).

The SRP evaluated five environmental flow assessment methods/tools all of which were either level 2 or intermediate between level 2 and level 3. The selected method was the EFDSS, developed by CSIRO Land & Water, the National Water Research Institute (NWRI) Canada, and the Murray Darling Basin Commission (MDBC).

The EFDSS has been revised for the Living Murray, Scientific Reference Panel assessments. It is known in its new form as the *Murray Flow Assessment Tool* (MFAT). Like EFDSS, the MFAT is a 'decision support system' designed to demonstrate the ecological benefits of increased environmental flows. It is underpinned by flow-ecology relationships, identified through scientific studies or expert opinion. In MFAT, scientific knowledge of flow-ecology relationships is captured in 'preference curves'. These provide a means of assessing improvements to river habitat condition for a range of biota and life history stages. Habitat is a major, but not the only, determinant of the population size and persistence of a species. For example, antecedent conditions may determine the capacity of some organisms to respond. In some areas there may be only a muted response to a single flow, because stocks are depleted by long periods without appropriate flows. As a consequence, the MFAT cannot predict the full implications of environmental flows in terms of the population dynamics and recruitment of aquatic and floodplain biota. To predict the outcomes of particular environmental flow allocations would require both detailed hydrology-ecology response models and information about the current ecological status of the species. Detailed hydrology-ecology models are not currently available for any Australian aquatic or riparian species, let alone a whole riverine biological community.

The MFAT is an improvement on the holistic expert panel approach because it provides transparent documentation of expert opinion. It can be used to provide advice on the most likely outcomes of different flow scenarios, and their relative ecological benefits (or impacts). It is best applied at a river zone (10's – 100's km's) or whole-of-river scale. It should not be expected to provide quantitative predictions about ecological responses at a specific site, but it can tell us that improvements in habitat condition are probable, given particular quantities of water in the river and its floodplains.

The Living Murray is attempting to improve the ecological condition of the entire River Murray. The MFAT is designed to provide advice on the likely outcomes of environmental flows for the whole river based on an aggregation of assessments at the river zone scale. While site assessments can be undertaken, these are subject to a number of limitations, partly because the MFAT is habitat based and does not include many of the factors that may affect change at a specific site. Sites are selected for inclusion in the MFAT to represent key ecological features of a river zone. Two alternate approaches are possible, first that water is allocated to improve the condition of specific sites or second that sites believed to be sensitive to the modelled flow scenarios could be included in the analysis. While both of these options could be undertaken, neither of them address the question of how the flow scenarios would affect overall river condition. As a consequence the effects of the flow scenarios were examined at a range of sites believed to represent the range of conditions along a river zone, and along the whole river. The approach does not assess flow responses to some floodplain areas replaced by agricultural areas or cut-off by levee banks.

MFAT receives river *hydrological* data derived from the MDBC MSM-Bigmod daily flow models (see section 4.1). From an ecological point of view, it would be better to have outputs of *hydraulic* data (water depth, water velocity, substrates) as this is what most organisms actually respond to. However, this was not possible to include hydraulic data in the time available for the current assessment process. An example of the limitations this imposes occurs in weir pools. The application of MFAT to weir pool habitats can be problematic because the relationship between hydrology and physical habitat within weir pools is altered. This has the potential to affect fish assessments, but is less likely to affect wetland and floodplain assessments as floodplain calibrations can be changed to reflect the altered conditions. Consequently, hydrological data currently enables a more holistic analysis of the likely outcomes of the proposed flow scenarios for the river zone and whole river, rather than exact site or species specific responses.

The MFAT has undergone significant development over the past 6 months, under a very tight timeline. The modifications were directed by advice from ecologists with knowledge of the River Murray environment. The current version of the MFAT represents a synthesis of the knowledge of REGs, the SRP and technical working groups convened to consider specific issues. In the post-interim report phase (after August 2003), the review and synthesis process can be taken further and additional expertise consulted. The current version of the MFAT represents the best outcome that could be achieved within the time frame of the project.

The application of the MFAT is based on the modelling of 5 biological indicator groups, namely native fish, waterbirds, wetland vegetation, floodplain vegetation and blue-green algae. They do not represent all plant and animal groups in the river ecosystem but are chosen because of the availability of supporting scientific knowledge which can support development and ‘population’ of the ecological models. Four of these groups were selected for inclusion in the original EFDSS because there was both sufficient data available to describe their flow-ecology relationship and because an assessment of these groups would provide a reasonable indication of overall river condition. In the MFAT an extra ecological model was added (wetland vegetation) and some additional species incorporated into the other four models to reflect our improved understanding of river ecology (since EFDSS was developed in the mid to late 1990’s). There is, however, scope for further additions in the post-interim phase, if we believe that extra models (or additional species within the existing models) would provide a better assessment, and if sufficient scientific data and knowledge is available. One possible candidate for inclusion in the native fish model would be alien (introduced) fish species.

There are costs of including more and more ecological groups, and greater and greater complexity does not necessarily provide a more accurate and precise assessment. Indeed, the opposite may in fact be true. Additional indicator groups and MFAT assessment models de-sensitises the MFAT to changes in available habitat for any one species within an assessment. Also, if additional models are based on less reliable data, there is the risk that the overall level of confidence in MFAT assessments could suffer. Increasing model complexity may also increase error propagation and uncertainty, and therefore does not necessarily result in an improved assessment tool. Hence, all additions to MFAT should be approached with a broad understanding of the possible positive and negative consequences, and the balance between them.

As stated earlier, the MFAT is a work in progress and all aspects of the model may be refined to enhance its performance or capture new knowledge or regional variation in the ecology of the species being assessed. This would be significantly enhanced by the development of more flexible and more realistic modelling of floodplain hydraulic processes. Useful scientific feedback has already been received on this matter, and will be passed on to the developers of the MFAT.

The analysis undertaken by the SRP, based on MFAT, was founded on hydrological data provided by the MDBC. The flow scenarios being assessed changed the existing River Murray operating rules to achieve a number of ecological principles provided by the SRP (see Appendix 2). As a consequence the precise delivery of water for the 350, 750 and 1500 GL/yr options has not been exactly determined or optimised. For instance, the flow scenarios developed for this assessment process do not yet include full modelling of the tributaries, the Goulburn and Murrumbidgee Rivers. Hence, the flow scenarios modelled for these options should be treated as indicative only. Further development of these operational scenarios may increase the benefits that can be achieved from any given environmental flow option.

In summary, MFAT is best considered as providing 'estimates of ecological potential for any flow management scenario'. It should be seen as a 'work in progress', being based on our current best knowledge of the system and of how to represent that knowledge in a decision support system. Its structure as a decision support system and the ecological knowledge embedded therein, is constantly under analysis and review by the scientists involved. Consequently, the ecological index scores provided by MFAT are the product of consensus, rather than unanimous scientific opinion.

8. RESULTS

In this chapter the following results are presented;

- A summary of MFAT index statistics for each zone. For this Interim Report, the results for each zone do not incorporate any of the proposed structural or operational improvements under the MDBC Implementation Program, and therefore only assesses expected benefits from changes to flow. (Potential non-flow improvements are dealt with qualitatively in a separate section.) More detailed results of zone assessments, such as statistics for particular localities, are contained in the accompanying REG reports.
- Summary statistics at the 'whole of river' scale for; habitat condition for native fish, waterbirds, floodplain vegetation, wetland vegetation, and for algal growth at the zone scale.
- Assessment of icon species at the whole of river scale, and icon sites.
- Summary of the potential benefits from structural and operational changes.
- Effects of flow scenarios on river salinity and probable ecological response.
- Key findings of the MFAT model sensitivity analysis (undertaken separately by Charles Sturt University on behalf of the SRP and MDBC).

Two statistics were selected to examine the improvements in annual MFAT indices for each test scenario relative to the reference scenario. These were 1) threshold analysis of the ratio of the test scenario to the reference scenario (S/R) for the 108 years of data, and 2) the arithmetic mean.

The first statistic used was a ratio of the test scenario (S) over the reference scenario (R). Thresholds for levels of improvement are defined in Table 8.1. The S/R threshold statistic uses upper and lower threshold limits to define the % of years occurring within specified 'bands' of improvement above the reference scenario. The categories used here are consistent with those used in the mean statistic, however the bands of improvement are not scaled relative to the difference between natural and reference as has been done for the mean statistic.

The mean annual MFAT (habitat condition) index (summarised over 108 years of flow data), was generated for each river zone, each ecological assessment module and also for each icon site and icon species. The Lower Lakes and the Coorong were not assessed using the MFAT, but results for both these icon site are also presented separately. The difference between the arithmetic means for the natural and reference scenarios were used to scale the level of improvement achieved for each test scenario (Table 8.2). The result for each test scenario was assigned a colour code to indicate this level of improvement.

Table 8.1. Threshold for categories for improvement relative to the reference scenario.

Key	Improvement relative to the reference scenario (S/R threshold analysis)
Worse	% of years each scenario is more than 10% below the reference scenario (% years S/R <0.90).
No Significant Change	% of years each scenario is within a band of 10% below to 10% above the reference scenario (% years S/R >0.90 but < 1.10).
Some Improvement	% of years each scenario is within a band of 10% to 50% above the reference scenario (% years S/R >1.10 but < 1.50).
Substantial Improvement	% of years each scenario is more than 50% above the reference scenario (% years S/R >1.50).

Table 8.2. Threshold for categories for improvement relative to the difference between the reference and natural scenario.

Key	Improvement relative to the reference scenario (arithmetic mean)
Worse	Scenario annual mean is more than 10% below the reference scenario mean, scaled relative to the difference between natural and reference
No Significant Change	Scenario annual mean is within a band of 10% below to 10% above the reference scenario mean, scaled relative to the difference between natural and reference
Some Improvement	Scenario annual mean is within a band of 10% to 50% above the reference scenario mean, scaled relative to the difference between natural and reference
Substantial Improvement	Scenario annual mean is more than 50% above the reference scenario mean, scaled relative to the difference between natural and reference

8.1 Combined habitat condition index for each zone

Figures 8.1-8.8 report MFAT combined (habitat condition) index scores for zones A to G along the River Murray and Lower Darling. In the majority of zones habitat condition improves with increasing allocation of water from 350 to 1500 GL/yr, and substantial improvement is only achieved by the 1500GL scenarios. The exception to this trend is in zone A, where improvement observed under the 750b and 1500b scenarios are similar. The number of years showing a substantial improvement over the reference condition is not uniform among regions with zone E having no years substantially better, zones A, C, D and G having substantial improvement in less than 5% of years and zones B and F showing 12% and 33% of years substantially improved respectively. The Cap, b and c scenarios also varied in their effect depending on which reach was being assessed. Zones in the upper Murray responded best to scenario b while zone E responded best to the Cap scenario. Zones F and G responded best to scenario c. The arithmetic mean statistics show similar trends (Table 8.3). This is broadly consistent with the operational rules of the ‘b’ and ‘c’ scenarios. The ‘b’ scenarios target environmental outcomes in; the upper Murray, wetlands downstream of Hume, Barmah-Millewa Forest, and the Murray Mouth. The ‘c’ scenarios additionally target environmental the Lower Darling (Zone F) and result in increased flows reaching the lower Darling and lower Murray zones (Zones F and G).

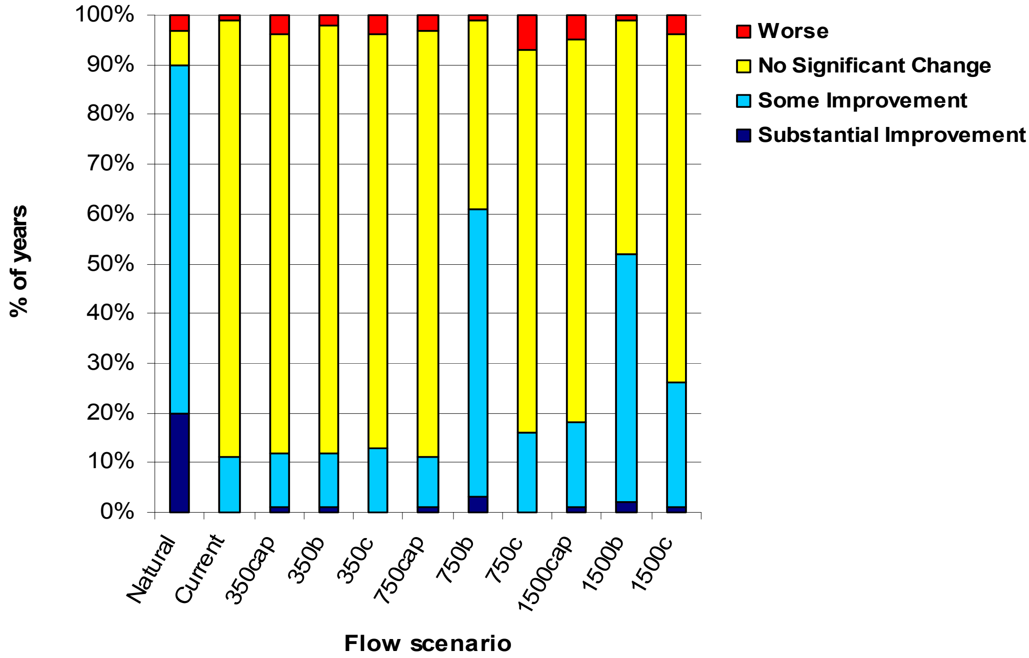

Figure 8.1. The improvement in combined habitat condition in zone A (Mitta Mitta River) relative to the reference scenario, defined as % of years (n=108) that the Scenario/Reference statistic falls into the improvement categories listed in table 8.1.

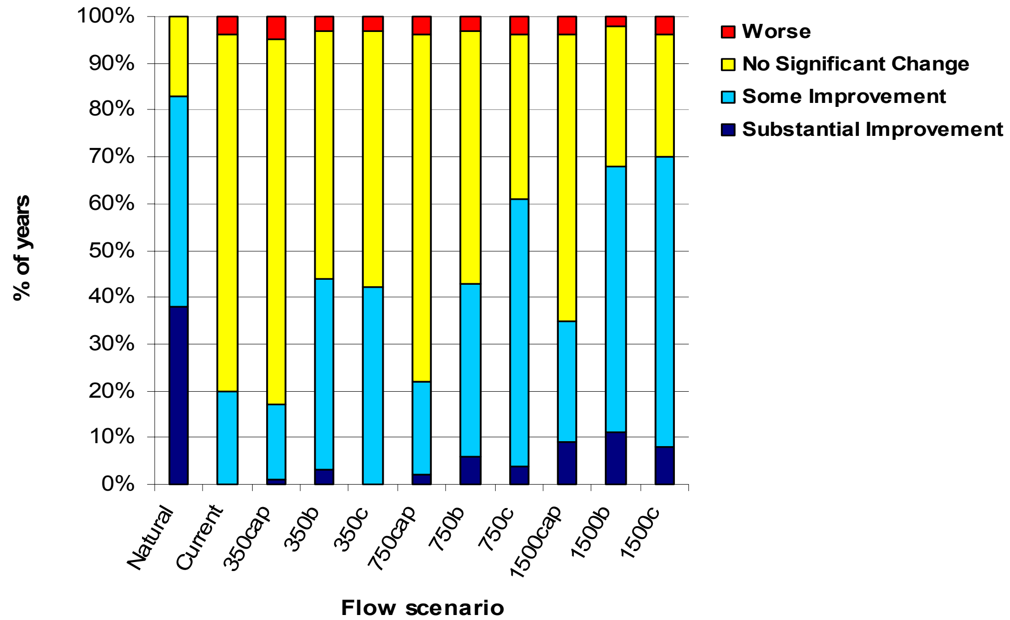

Figure 8.2. The improvement in combined habitat condition in zone B (Hume Dam to Yarrawonga Weir) relative to the reference scenario, defined as % of years (n=108) that the Scenario/Reference statistic falls into the improvement categories listed in table 8.1.

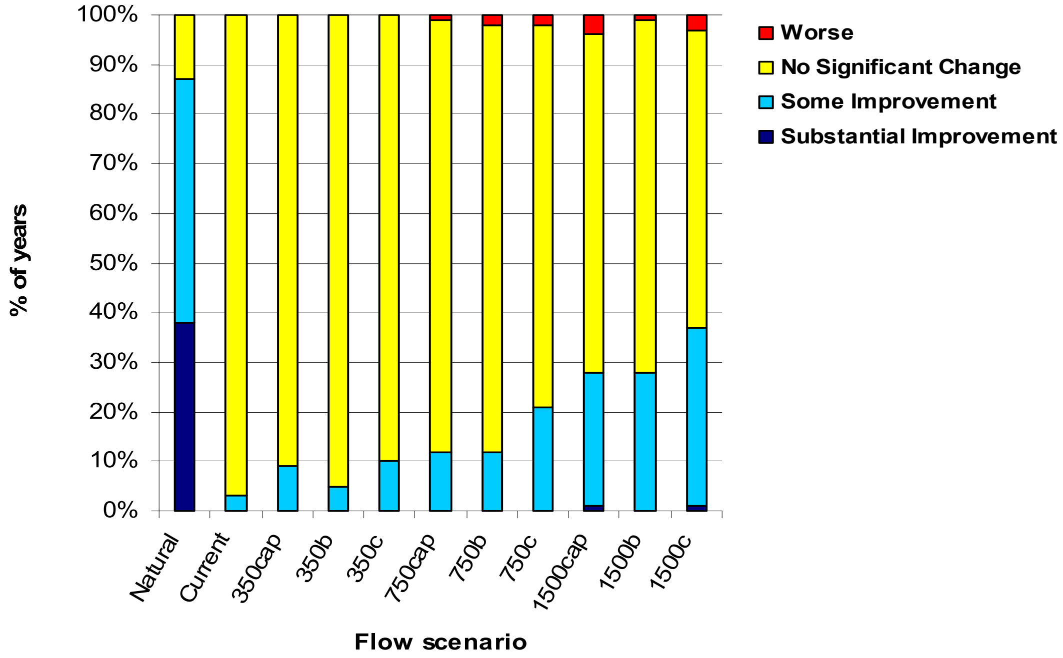

Figure 8.3. The improvement in combined habitat condition in zone C (Yarrawonga Weir to Wakool Jn.) relative to reference scenario, defined as % of years (n=108) that the Scenario/Reference statistic falls into the improvement categories listed in table 8.1.

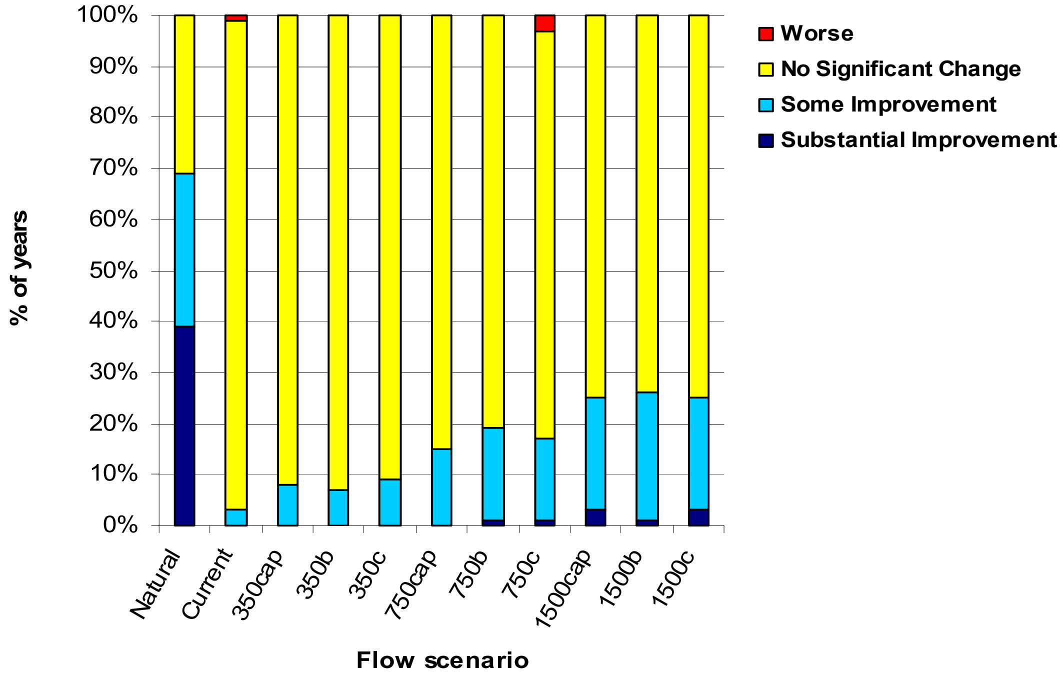

Figure 8.4. The improvement in combined habitat condition in zone D (Wakool Junction to Lock 11) relative to reference scenario, defined as % of years (n=108) that the Scenario/Reference statistic falls into the improvement categories listed in table 8.1.

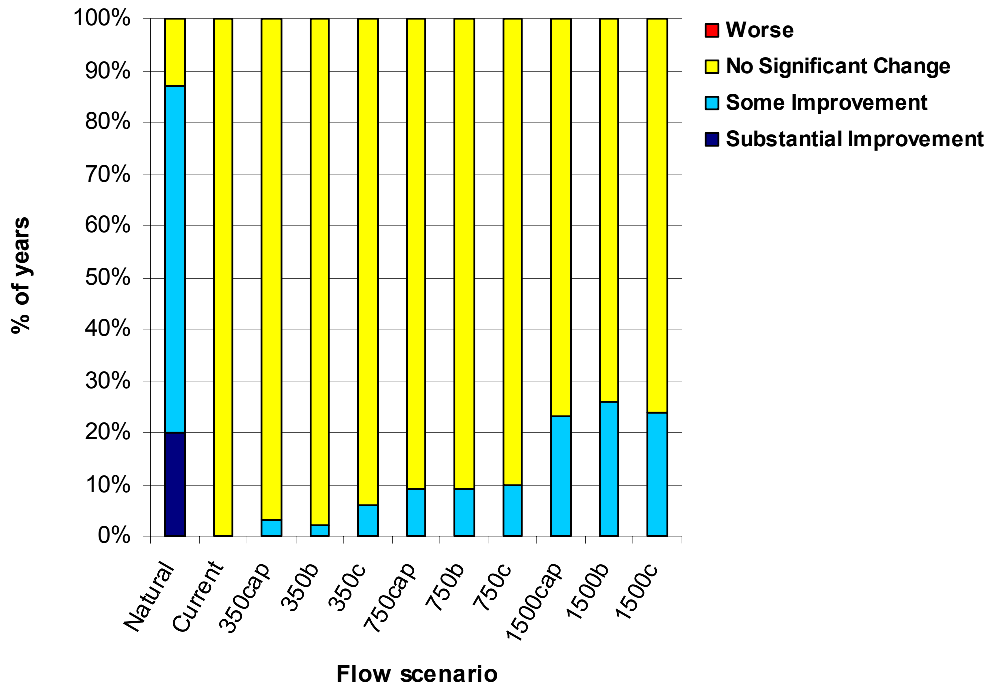

Figure 8.5. The improvement in combined habitat condition in zone E (Lock 11 to Overland Corner) relative to the reference scenario, defined as % of years (n=108) that the Scenario/Reference statistic falls into the improvement categories listed in table 8.1.

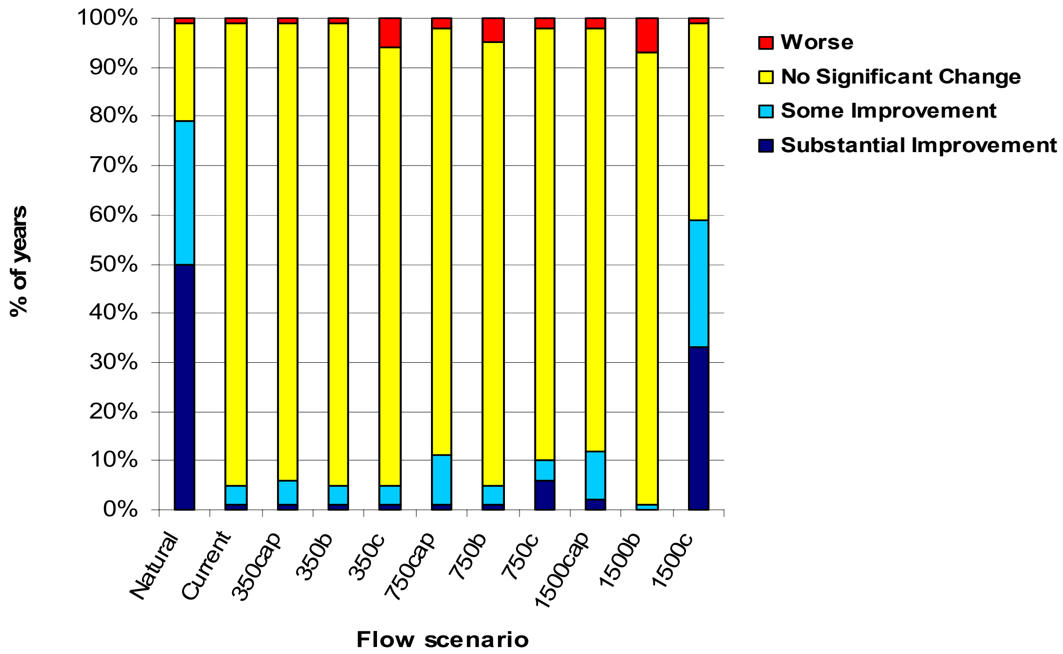

Figure 8.6. The improvement in combined habitat condition in F (Darling River and Anabranch) relative to the reference scenario, defined as % of years (n=108) that the Scenario/Reference statistic falls into the improvement categories listed in table 8.1.

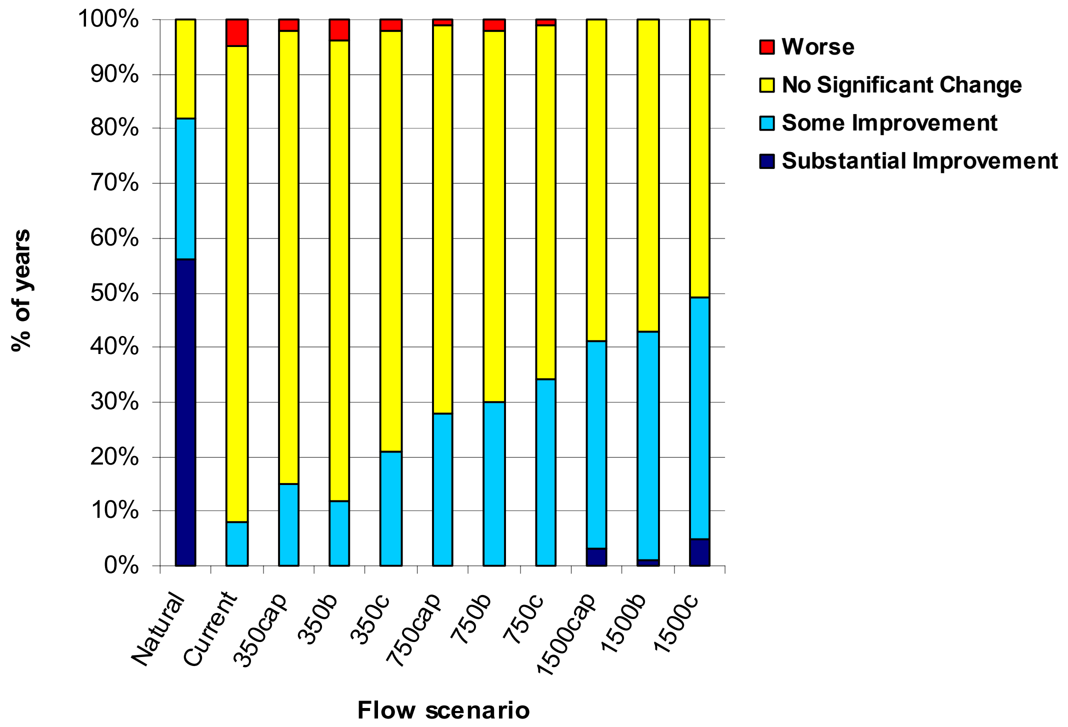

Figure 8.7. The improvement in combined habitat condition in zone G (Lock 3 to Wellington) relative to the reference scenario, defined as % of years (n=108) that the Scenario/Reference statistic falls into the improvement categories listed in table 8.1.

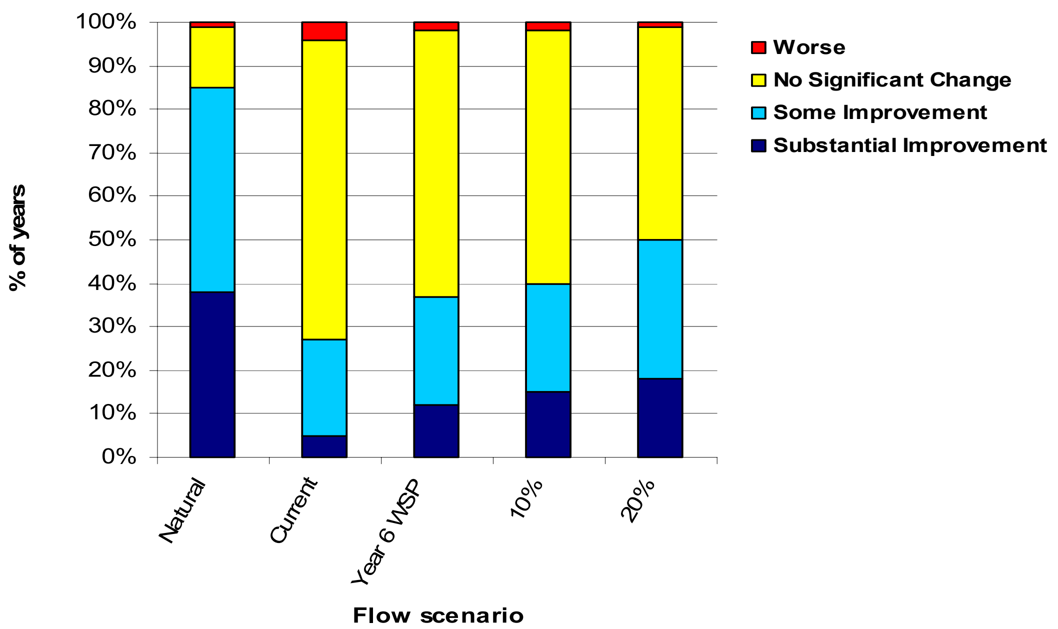

Figure 8.8. The improvement in combined habitat condition in zone J (Murrumbidgee River) relative to the reference scenario, defined as % of years (n=108) that the Scenario/Reference statistic falls into the improvement categories listed in table 8.1.

Table 8.3. The combined habitat condition in zones A-G in the form of arithmetic mean of annual indices (n=108). Thresholds are defined in table 8.2.

Zone	A	B	C	D	E	F	G
Natural	0.58	0.62	0.65	0.61	0.58	0.53	0.60
Reference	0.42	0.44	0.47	0.44	0.45	0.36	0.41
Current	0.43	0.46	0.47	0.45	0.45	0.37	0.42
350cap	0.44	0.46	0.48	0.45	0.46	0.37	0.43
350b	0.44	0.50	0.48	0.45	0.45	0.37	0.43
350c	0.43	0.49	0.48	0.45	0.46	0.36	0.43
750cap	0.43	0.47	0.48	0.46	0.46	0.37	0.44
750b	0.48	0.50	0.48	0.46	0.46	0.36	0.44
750c	0.44	0.52	0.49	0.46	0.46	0.37	0.44
1500cap	0.44	0.49	0.50	0.48	0.47	0.37	0.46
1500b	0.48	0.55	0.50	0.48	0.47	0.35	0.46
1500c	0.44	0.53	0.50	0.48	0.47	0.47	0.47

Table 8.4. The combined habitat condition in zone J in the form of arithmetic mean of annual indices (n=108). Thresholds are defined in table 8.2.

	Overall River Zone Health	Native Fish Habitat Condition	Waterbird Habitat Condition	Floodplain Vegetation Habitat Condition	Wetland Vegetation Habitat Condition
Natural	0.69	0.82	0.69	0.49	0.76
Reference	0.47	0.61	0.43	0.32	0.51
Current	0.50	0.63	0.50	0.31	0.57
Year 6 WSP	0.53	0.65	0.50	0.34	0.62
10%	0.53	0.64	0.53	0.32	0.62
20%	0.55	0.66	0.55	0.37	0.63

8.2 Native fish habitat assessment

Figure 8.9 presents the whole-of-river (zones A to G) assessment for native fish habitat condition. It shows the level of improvement of the MFAT index score for each scenario compared with the reference scenario (93/94 Cap) for the 108 years of flow data. It is evident that all scenarios provide very little, or no, improvement in index scores. Table 8.5 presents the arithmetic means for the annual indices, for zones A to G and also for the whole-of-river. These results show that the 1500 G/yr options provide some improvement, although many zones (B, C and D) still show no significant change. No scenarios show a 'substantial' improvement in any of the zones. Within the native fish assessment there was marked variation in the response of individual fish groups to the flow scenarios, with flow sensitive groups such as flood spawners showing a response whilst groups that are less sensitive such as Murray Cod showing very little response to the range of flows examined. Figure 8.9b shows the response of flood spawners at the system level. The lack of response by the fish groups that are less sensitive to flow dampened out the response to the scenarios for the aggregated, overall fish index.

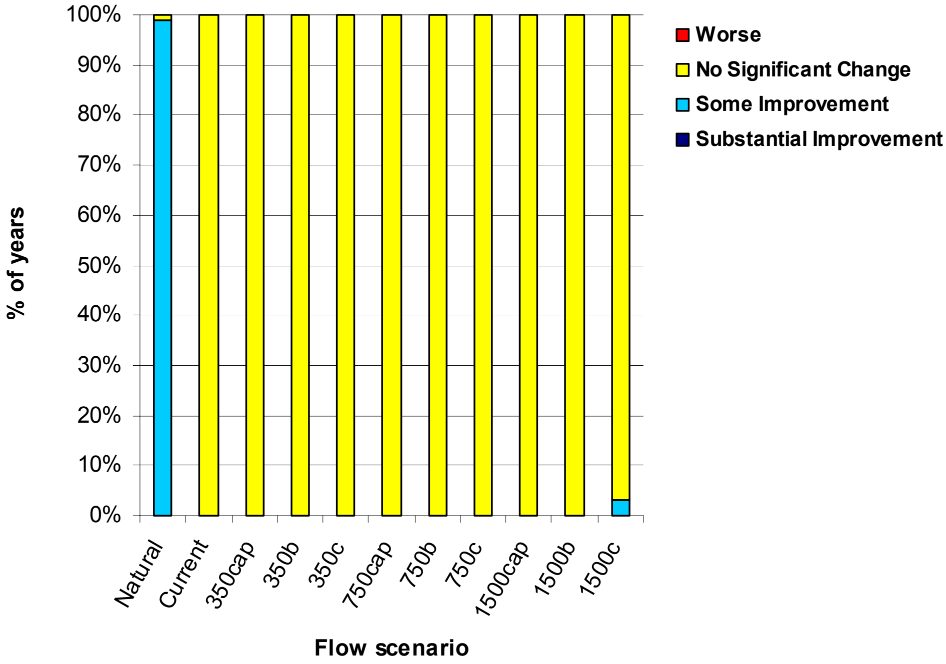

Figure 8.9a. The improvement in River Murray system native fish habitat condition, relative to the reference scenario, defined as the percentage of years (n=108) that the test scenario/reference scenario statistic for fish habitat condition (zones A-G combined) falls into each of the improvement categories listed in table 8.1.

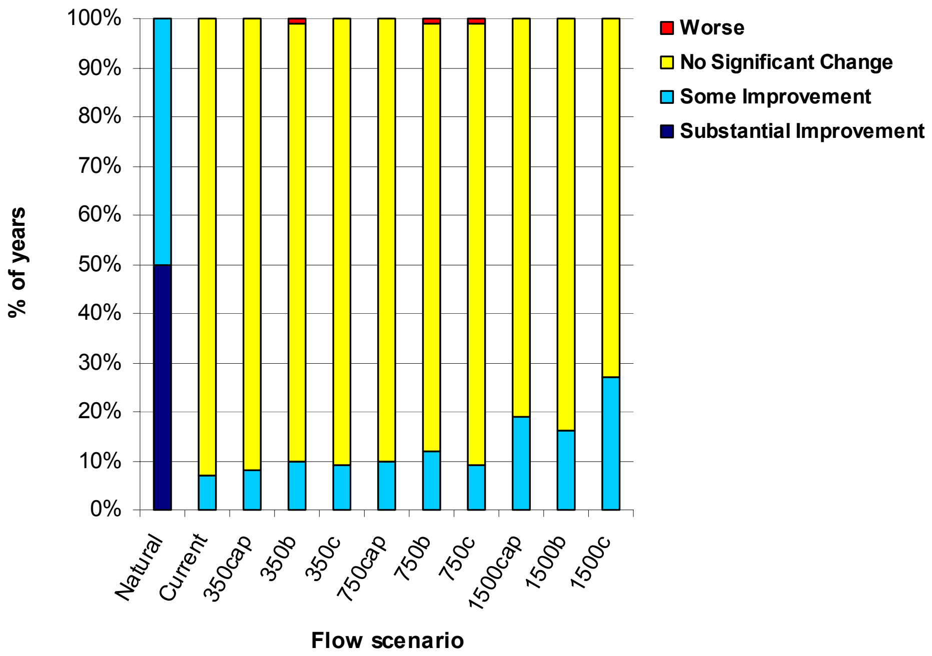

Figure 8.9b. The improvement in River Murray system for flood spawner fish habitat condition, relative to the reference scenario, defined as the percentage of years (n=108)

that the test scenario/reference scenario statistic for flood spawner habitat condition (zones A-G combined) falls into each of the improvement categories listed in table 8.1.

Table 8.5 The native fish habitat condition index for each river zone in the form of arithmetic mean of annual indices (n=108). Thresholds and improvement categories are defined in table 8.2.

Zone	A	B	C	D	E	F	G	SYSTEM
Natural	0.81	0.85	0.84	0.80	0.86	0.66	0.74	0.79
Reference	0.55	0.53	0.63	0.75	0.73	0.55	0.59	0.62
Current	0.56	0.52	0.63	0.75	0.73	0.55	0.60	0.62
350cap	0.56	0.53	0.63	0.75	0.74	0.55	0.61	0.62
350b	0.56	0.53	0.63	0.75	0.74	0.55	0.61	0.63
350c	0.56	0.53	0.63	0.75	0.74	0.55	0.61	0.62
750cap	0.56	0.52	0.63	0.75	0.74	0.55	0.61	0.62
750b	0.59	0.52	0.63	0.75	0.74	0.55	0.61	0.63
750c	0.56	0.53	0.63	0.75	0.74	0.55	0.60	0.62
1500cap	0.56	0.55	0.63	0.76	0.75	0.56	0.62	0.63
1500b	0.58	0.54	0.63	0.76	0.75	0.55	0.61	0.63
1500c	0.57	0.53	0.63	0.76	0.75	0.59	0.61	0.63

8.3 Waterbird habitat assessment

Figure 8.10 presents the whole-of-river (zones A to G) MFAT index scores for waterbird habitat condition. As with the results for the whole of river combined assessment, the greatest improvements are recorded by the 1500 GL options, and in particular the 1500c scenario, which shows ‘some improvement’ in up to 60% of years and ‘substantial improvement’ in over 10% of years. The 750 and 350 GL scenarios provide some improvement in 25-40% and 10-20% of years respectively but only 750 GL provides years with substantial improvement, although these are less than 5%. Table 8.6 presents the arithmetic means for the annual indices, for zones A to G and also for the whole-of-river. The 1500 GL options provide the best response, in particular the 1500c option. The 350 and 750 GL options show either ‘no’ or only a ‘minor’ improvement.

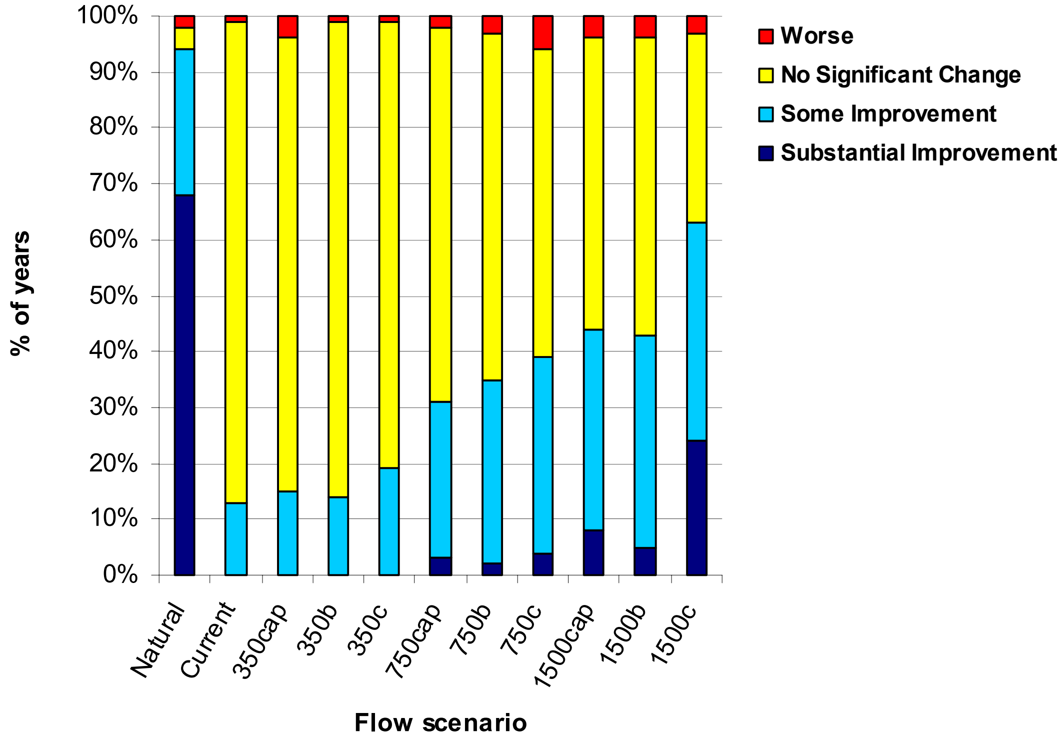

Figure 8.10. The improvement in River Murray system waterbird habitat condition, relative to the reference scenario, defined as the percentage of years (n=108) that the test scenario/reference scenario statistic for fish habitat condition (zones A-G combined) falls into each of the improvement categories listed in table 8.1.

Table 8.6 The waterbird habitat condition index for each river zone in the form of arithmetic mean of annual indices (n=108). Thresholds and improvement categories are defined in table 8.2.

Zone	A	B	C	D	E	F	G	SYSTEM
Natural	0.40	0.60	0.56	0.63	0.34	0.42	0.60	0.50
Reference	0.27	0.44	0.29	0.39	0.20	0.23	0.33	0.29
Current	0.27	0.46	0.30	0.39	0.20	0.24	0.33	0.30
350cap	0.27	0.47	0.31	0.39	0.20	0.24	0.34	0.30
350b	0.28	0.47	0.31	0.39	0.20	0.24	0.34	0.30
350c	0.28	0.45	0.31	0.39	0.21	0.23	0.34	0.30
750cap	0.27	0.47	0.32	0.41	0.21	0.24	0.36	0.31
750b	0.27	0.47	0.32	0.41	0.21	0.23	0.36	0.31
750c	0.28	0.46	0.32	0.40	0.21	0.25	0.36	0.32
1500cap	0.28	0.48	0.35	0.43	0.22	0.24	0.38	0.33
1500b	0.29	0.48	0.34	0.43	0.21	0.22	0.38	0.32
1500c	0.28	0.46	0.34	0.42	0.22	0.36	0.39	0.35

8.4 Floodplain vegetation habitat assessment

Figure 8.11 presents the whole-of-river (zones A to G) MFAT index scores for floodplain vegetation habitat condition. The floodplain vegetation indices show a greater response to the flow scenarios than for any of the other ecological models. The 350Cap and 750Cap scenarios provide the least benefit, with 'some improvement' in only 10-30% of years. The 1500b and 1500c scenarios provide the most benefits with 'some improvement' in over 70% of years and 'substantial improvement' in about 15% of years. Table 8.7 presents the arithmetic means for the annual indices, for zones A to G and also for the whole-of-river. These results show a marked difference in response between zones, with zone B showing by far the greatest improvement and zones D and E showing the least response. Within the 1500 GL volume, zones A and B showed a greater response to scenario a while zones F and G showed the greatest response to scenario c.

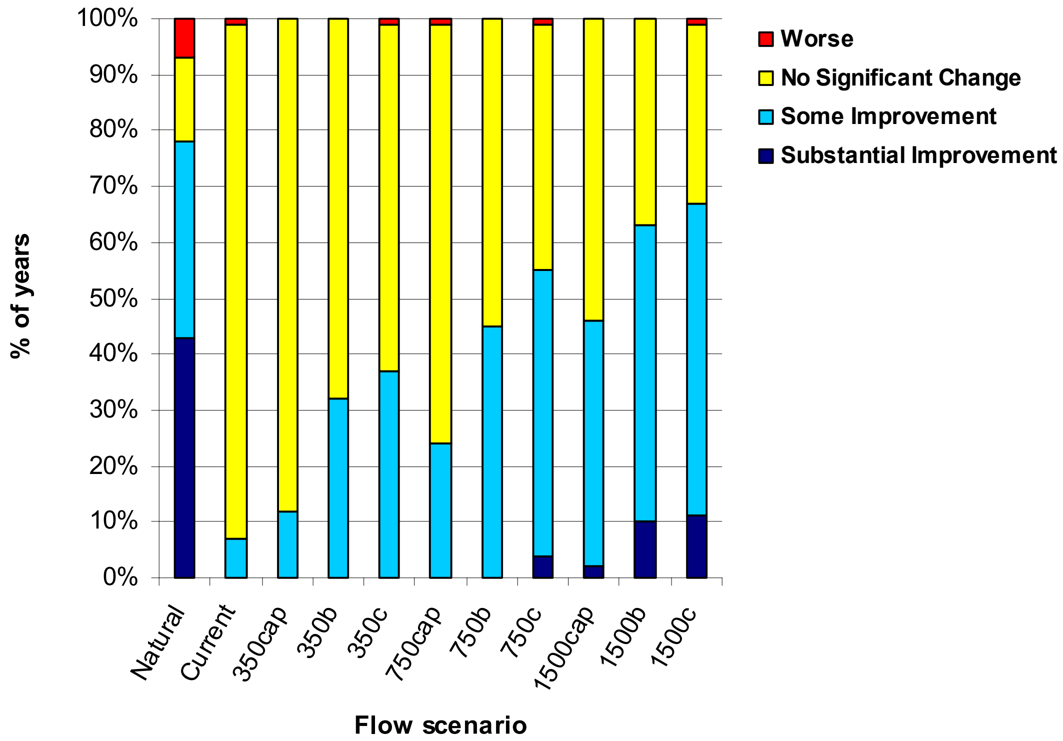

Figure 8.11. The improvement in River Murray system floodplain vegetation habitat condition, relative to the reference scenario, defined as the percentage of years (n=108) that the test scenario/reference scenario statistic for floodplain vegetation habitat condition (zones A-G combined) falls into each of the improvement categories listed in table 8.1.

Table 8.7 The floodplain vegetation habitat condition index for each river zone in the form of arithmetic mean of annual indices (n=108). Thresholds and improvement categories are defined in table 8.2.

Zone	A	B	C	D	E	F	G	SYSTEM
Natural	0.47	0.42	0.55	0.45	0.49	0.43	0.47	0.48
Reference	0.34	0.32	0.38	0.28	0.36	0.36	0.28	0.34
Current	0.35	0.35	0.39	0.28	0.36	0.38	0.29	0.35
350cap	0.35	0.34	0.40	0.28	0.37	0.38	0.29	0.35
350b	0.35	0.48	0.40	0.28	0.36	0.38	0.29	0.36
350c	0.34	0.48	0.41	0.28	0.37	0.37	0.30	0.37
750cap	0.35	0.37	0.40	0.29	0.37	0.38	0.30	0.36
750b	0.39	0.50	0.40	0.29	0.37	0.37	0.31	0.37
750c	0.35	0.56	0.42	0.29	0.38	0.38	0.31	0.38
1500cap	0.35	0.40	0.43	0.31	0.39	0.38	0.32	0.38
1500b	0.39	0.60	0.43	0.31	0.39	0.37	0.33	0.40
1500c	0.37	0.59	0.43	0.30	0.39	0.44	0.34	0.40

8.5 Wetland vegetation habitat assessment

Figure 8.12 presents the whole-of-river (zones A to G) MFAT index scores for wetland vegetation habitat condition. Again, the 350 GL/yr options show little or no benefit and the 1500 GL/yr options show the greatest benefit. The best scenario, the 1500c, shows 'some improvement' in 60% of years and 'substantial improvement' in over 10% of years. Table 8.8 presents the arithmetic means for the annual indices, for zones A to G and also for the whole-of-river. These results show a difference in response between zones, with the greatest benefits in the upstream zones and the least benefit in the Lower Darling zone. Like the combined habitat condition assessment, these figures also reveal that, in zone A, similar results are obtained under the 750 b and 1500 b scenarios.

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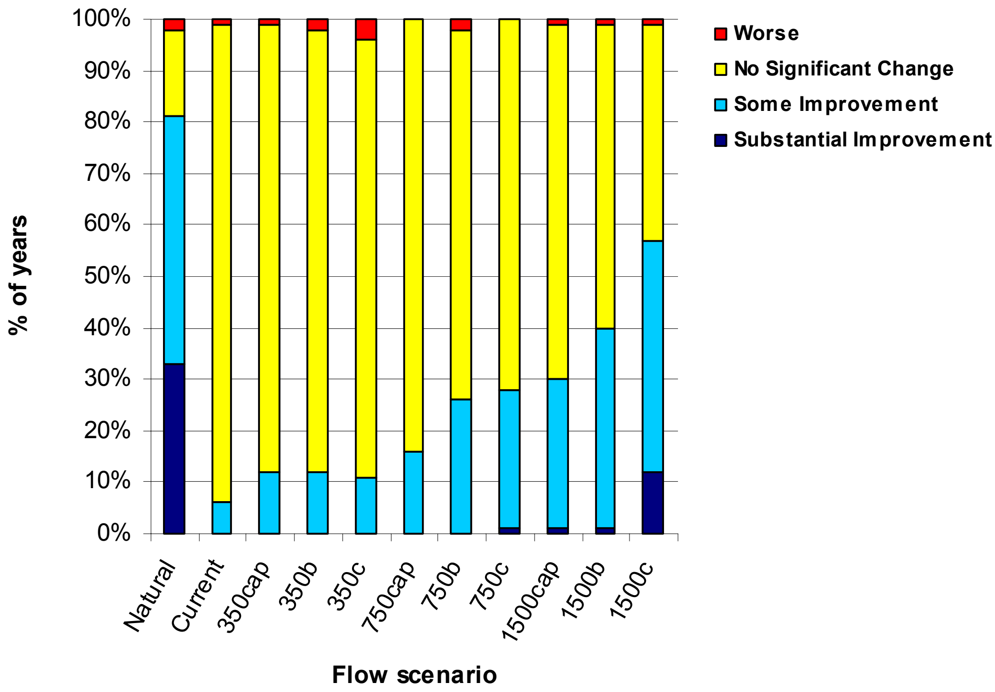

Figure 8.12. The improvement in River Murray system wetland vegetation habitat condition, relative to the reference scenario, defined as the percentage of years (n=108) that the test scenario/reference scenario statistic for wetland vegetation habitat condition (zones A-G combined) falls into each of the improvement categories listed in table 8.1.

Table 8.8. The wetland vegetation habitat condition index for each river zone in the form of arithmetic mean of annual indices (n=108). Thresholds and improvement categories are defined in table 8.2.

Zone	A	B	C	D	E	F	G	SYSTEM
Natural	0.55	0.63	0.64	0.57	0.63	0.60	0.59	0.61
Reference	0.46	0.48	0.56	0.37	0.50	0.29	0.46	0.45
Current	0.48	0.50	0.57	0.37	0.51	0.30	0.45	0.46
350cap	0.48	0.51	0.57	0.38	0.51	0.30	0.46	0.47
350b	0.47	0.52	0.57	0.38	0.51	0.30	0.46	0.47
350c	0.48	0.50	0.57	0.38	0.51	0.28	0.47	0.46
750cap	0.47	0.51	0.58	0.40	0.52	0.30	0.48	0.47
750b	0.56	0.53	0.57	0.40	0.52	0.28	0.48	0.48
750c	0.48	0.53	0.59	0.40	0.51	0.32	0.50	0.48
1500cap	0.48	0.52	0.58	0.42	0.53	0.30	0.50	0.48
1500b	0.55	0.56	0.60	0.41	0.53	0.27	0.50	0.49
1500c	0.48	0.56	0.60	0.42	0.53	0.50	0.52	0.53

8.6. Icon Species

8.6.1 Murray Cod Assessment

Figure 8.13 presents the Murray Cod (a sub-group of the MFAT native fish model) results for the whole-of-river (zones A to G) assessment. It is evident that all scenarios provide very little, or no, improvement in MFAT index scores (the reasons for the lack of response are discussed in section 9.3). This is not surprising as Murray Cod would not be expected to respond significantly to flows across the reference point range. Large overbank flows are believed to be a key driver of successful Murray Cod recruitment.

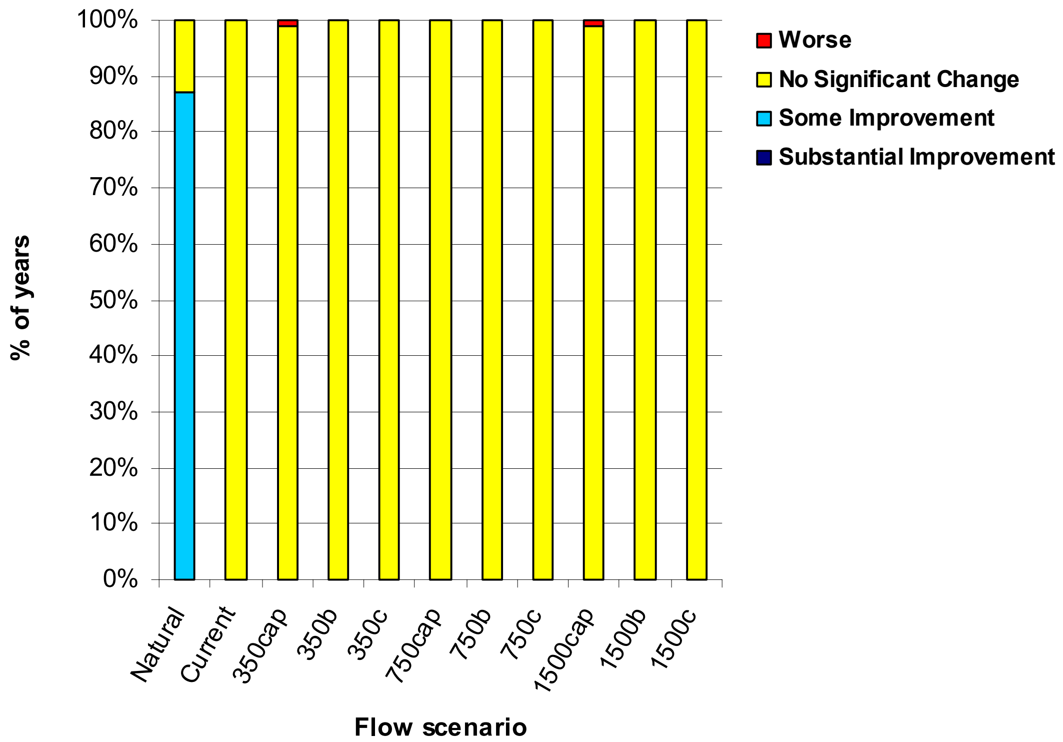

Figure 8.13. The improvement in River Murray system Murray Cod habitat condition, relative to the reference scenario, defined as the percentage of years (n=108) that the test scenario/reference scenario statistic for Murray Cod habitat condition (zones A-G combined) falls into each of the improvement categories listed in table 8.1.

8.6.2 River Red Gum Assessment

Figure 8.14 presents the results for River Red Gum forests and woodlands at the 'whole-of-river' scale. The 1500C scenario provides the greatest benefit with 35% of years showing a substantial improvement. Of the 750 GL options, the greatest benefit is derived from the 750c scenario which provides substantial improvement in 20% of years. The 350 GL options provide the least benefit, with the best scenario being 350c, which provided substantial improvement in only 12% of years.

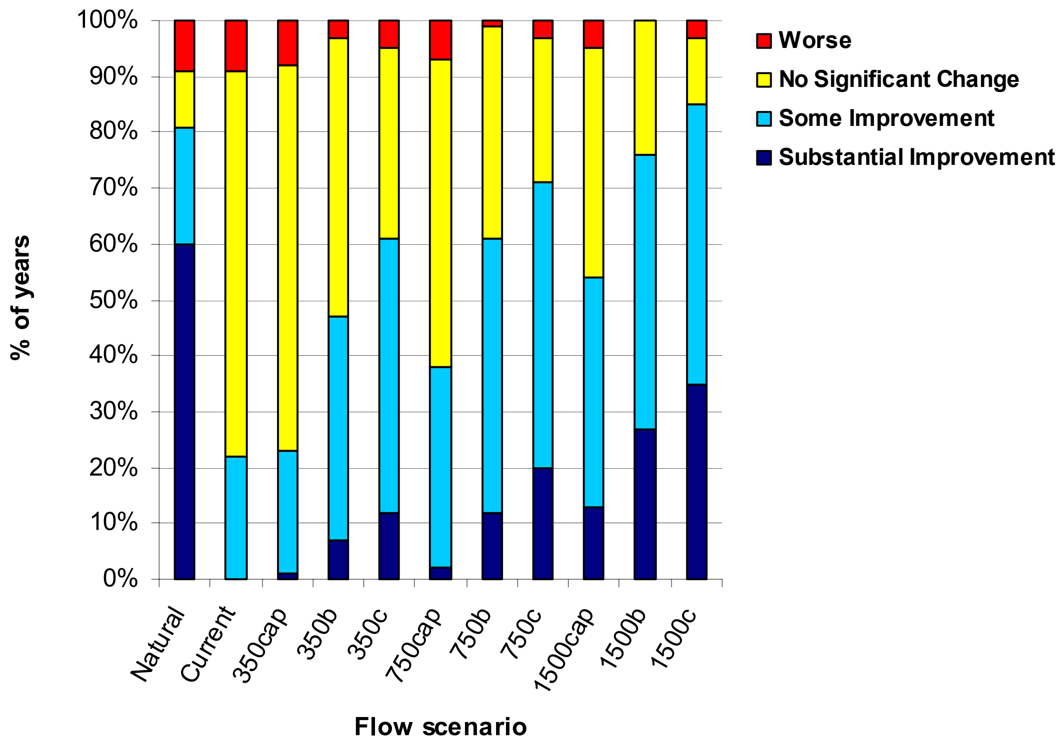

Figure 8.14. The improvement in River Murray system River Red Gum habitat condition, relative to the reference scenario, defined as the percentage of years (n=108) that the test scenario/reference scenario statistic for River Red Gum habitat condition (zones A-G combined) falls into each of the improvement categories listed in table 8.1

8.7 Assessment of Icon sites

In this section MFAT index scores for the following icon sites are reported; Barmah Millewa Forest, Gunbower Forest, Koondrook-Pericoota Forest, Hattah Lakes, Riverland (Chowilla), the Murray Mouth and the Coorong.

Broadly, 5 of the icon sites are floodplain wetland complexes of international significance, and these all showed similar responses to those recorded for the river as a whole. Under 1500 GL/yr scenarios, floodplain vegetation showed a substantial improvement in condition in 8% to 18% of years and waterbird habitat showed substantial improvement in around 20% of years. The results also varied in response to the particular scenario with best results at Barmah-Millewa under the 1500 c scenario and Gunbower, Riverland (Chowilla) and Hattah under the 1500 b scenario. The assessment of the Coorong and Murray Mouth indicate that the 1500b and 1500c scenarios provide the best improvement of environmental conditions in the Coorong and the extent to which the Murray Mouth remains open.

8.7.1 Barmah-Millewa Forest

Barmah-Millewa Forest is located between Echuca, Deniliquin and Tocumwal and covers an area of approximately 60,000 ha, forming the largest River Red Gum forest in the world. Barmah-Millewa is a wetland of international importance under the Ramsar Convention. The forest provides major breeding sites for waterbirds, provides habitat and food sources for native fish, has diverse plant associations and supports rare and threatened plant species.

For MFAT assessment, the waterbird model (Colonial nesting waterbirds), the floodplain vegetation model (River Red Gum forest and woodland, and Black Box) and the wetland vegetation model (Spiny mudgrass and Giant rush) were each run at this locality. A summary of the results are presented below and the full details are presented in the accompanying REG C report.

The results for the waterbird assessment (Figure 8.15) indicate that the 1500 GL/yr options provide the most benefit, and the 350 GL/yr options the least. The best scenario, 1500c, indicates 'substantial improvement' in habitat condition in just over 20% of years.

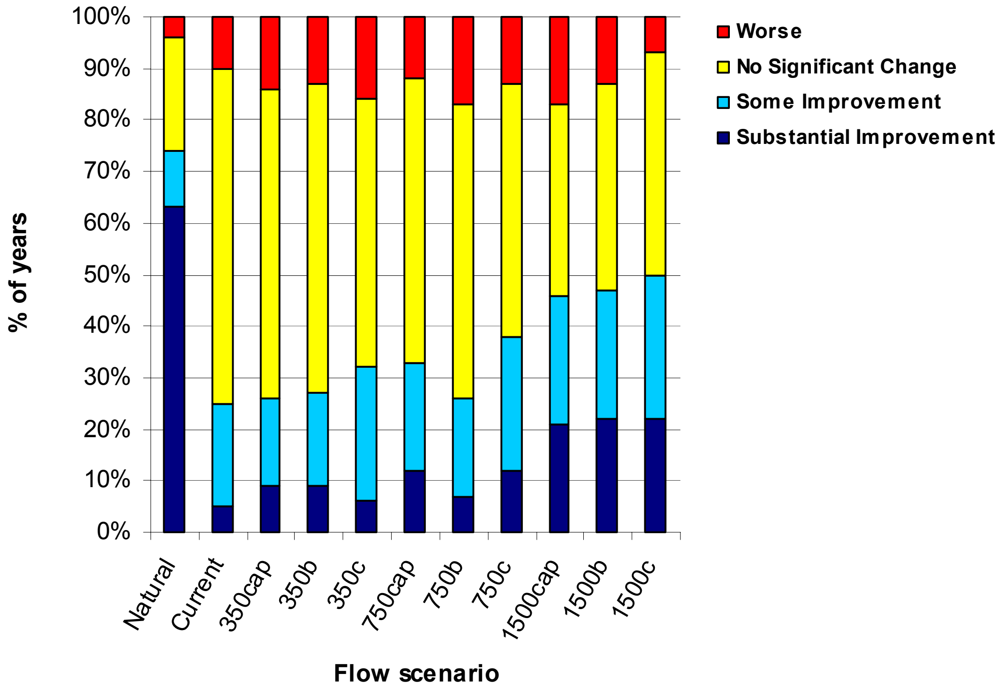

Figure 8.15. The improvement in waterbird habitat condition in the Barmah-Millewa Forest, relative to the reference scenario, defined as the percentage of years (n=108) that the test scenario/reference scenario statistic for River Red Gum habitat at this locality falls into each of the improvement categories listed in table 8.1

For the wetland vegetation index scores, there was a marked difference in response between species. The performance of Giant Rush was much better under the current scenario than natural. The spread of Giant Rush has been promoted by low, frequent minor summer flooding associated with the bank full operation of the River Murray upstream of the Barmah Choke. The model predicted that the habitat condition of Giant Rush would be reduced closer to the natural level under the 1,500 GL/yr options. The habitat condition for Spiny mudgrass (Moira grass) did not decline greatly from natural to current conditions, which corresponds with scientific belief. It is understood that Spiny mudgrass tolerates a greater range of water regimes than currently occur on the Spiny mudgrass plains. However to remain as the dominant species, it depends on water regimes that discourage the encroachment of Giant Rush and Red Gum from the wetter and drier extremes, respectively (pers. comm. Keith Ward, North East Catchment Management Authority 13 June 2003). It is necessary to reduce the growth of Giant Rush to restore the Spiny mudgrass plains.

Overall floodplain vegetation health benefited the most from the three 1500 GL/yr scenarios and the 750c scenario (Figure 8.16), with each of these producing a 'substantial improvement' in 15-20% of years. The Red gum forest and woodlands benefited more than the Black Box woodlands. This corresponds well to our understanding of the importance of medium level floods (greater than 40,000 ML/day) which have become much less frequent under current conditions (Bren 1988). There was little difference in the performance of Black Box between natural and current conditions. The frequency and duration of the large floods required to inundate these areas has not been greatly altered since the regulation of the river and a large difference was not expected.

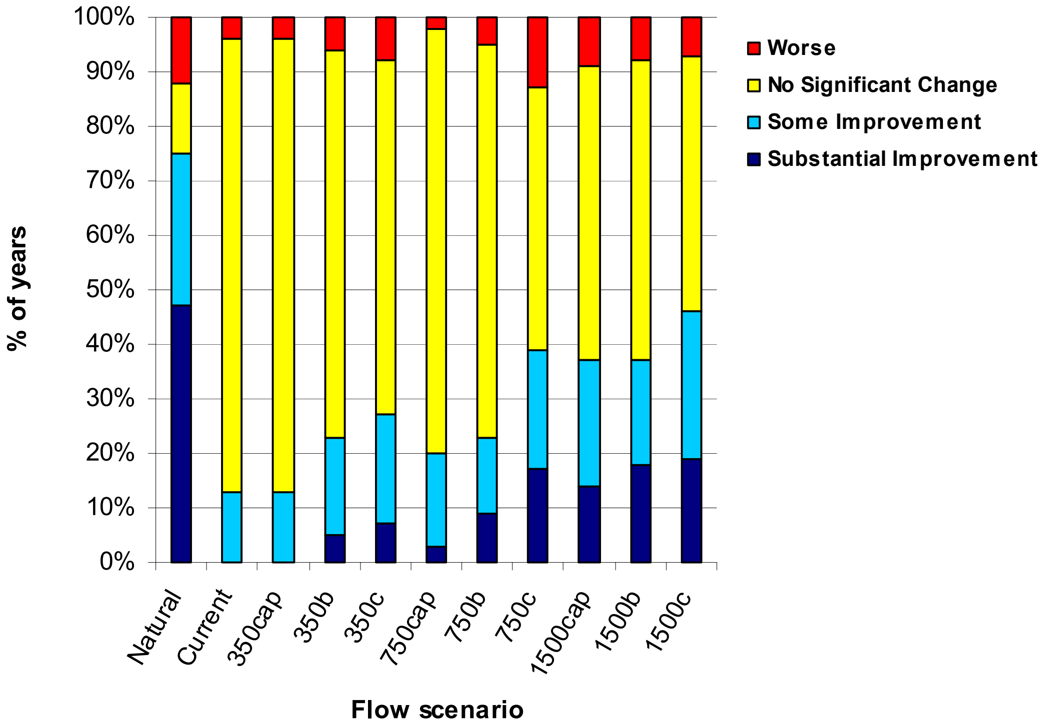

Figure 8.16. The improvement in floodplain vegetation habitat condition in the Barmah Millewa Forest, relative to the reference scenario, defined as the percentage of years (n=108) that the test scenario/reference scenario statistic for floodplain vegetation habitat condition at this locality falls into each of the improvement categories listed in table 8.1

8.7.2 Koondrook-Pericoota Forest

Koondrook-Pericoota is a Red Gum forest in New South Wales located between Moama and Barham and covers approximately 30,000 ha. Koondrook-Pericoota is nominated for listing as a wetland of international significance under the Ramsar convention. It provides habitat for wetland plants and animals when flooded and is an important waterbird breeding site. The forest is flooded principally by the Burrumburry-Barber Creek system which receives flow from the River Murray above Torrumbarry Weir via Swan Lake. The main hydrological impact on this forest has been the reduction in frequency and duration of floods between 30,000 to 40,000 ML/day.

For MFAT assessment, the floodplain vegetation model (River Red Gum forest) was run at this locality. A summary of the results are presented below and the full details are presented in the accompanying REG C report.

There was only a small level of benefit from any of the scenarios, as shown in Figure 8.17, with all of the 1500 GL/yr options performing the best with 'substantial improvement' in about 10% of years.

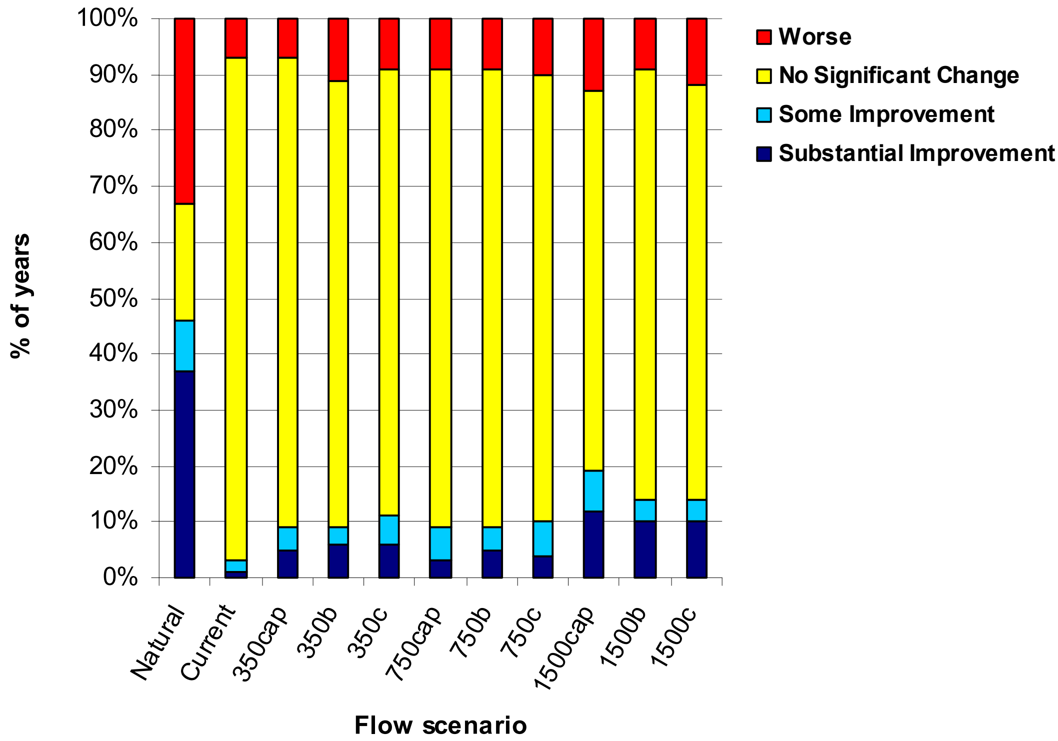

Figure 8.17. The improvement in River Red Gum vegetation habitat condition in the Koondrook-Perricoota Forest, relative to the reference scenario, defined as the percentage of years (n=108) that the test scenario/reference scenario statistic for River Red Gum vegetation habitat condition at this locality falls into each of the improvement categories listed in table 8.1

8.7.3 Gunbower Forest

Gunbower Forest covers most of Gunbower Island and is located between Torrumbarry and Koondrook and is a wetland of international significance under the Ramsar Convention. It provides breeding habitat for colonial nesting waterbirds as well as for rare or threatened species such as the Carpet Python and White-bellied Sea Eagle. As the second largest Red Gum forest in Victoria, it is an important floodplain ecosystem with ecological linkages to the River Murray and surrounding landscape.

For MFAT assessment, the waterbird model (Colonial nesting waterbirds), the floodplain vegetation model (River Red Gum forest and woodland, and Black Box) and the wetland vegetation model (*Phragmites* and Ribonweed) were each run at this locality. A summary of the results are presented below and the full details are presented in the accompanying REG C report.

The MFAT index scores for waterbirds at Gunbower were very similar to those at Barmah-Millewa, with most response noted for the 1500 GL/yr options where just under 20% of years experienced a substantial improvement. Similarly, the floodplain vegetation responded most to the 1500 GL/yr options, but only about 10% of years showed 'substantial improvement' (Figure 8.18).

It may be noted that for some assessments such as River red gums at Koondrook-Perricoota Forest (Figure 8.17) the natural scenario has a much greater portion of 'worse' years than the other scenarios. This may be attributed to the high variability of flows (wet and dry years) under the natural scenario compared with other scenarios. This results in high fluctuation of the MFAT index and is reflective of the natural boom-bust pattern of the Australian environment. As a result the index may fluctuate below the designated threshold for 'worse' in more years than other scenarios which have a much narrower index range.

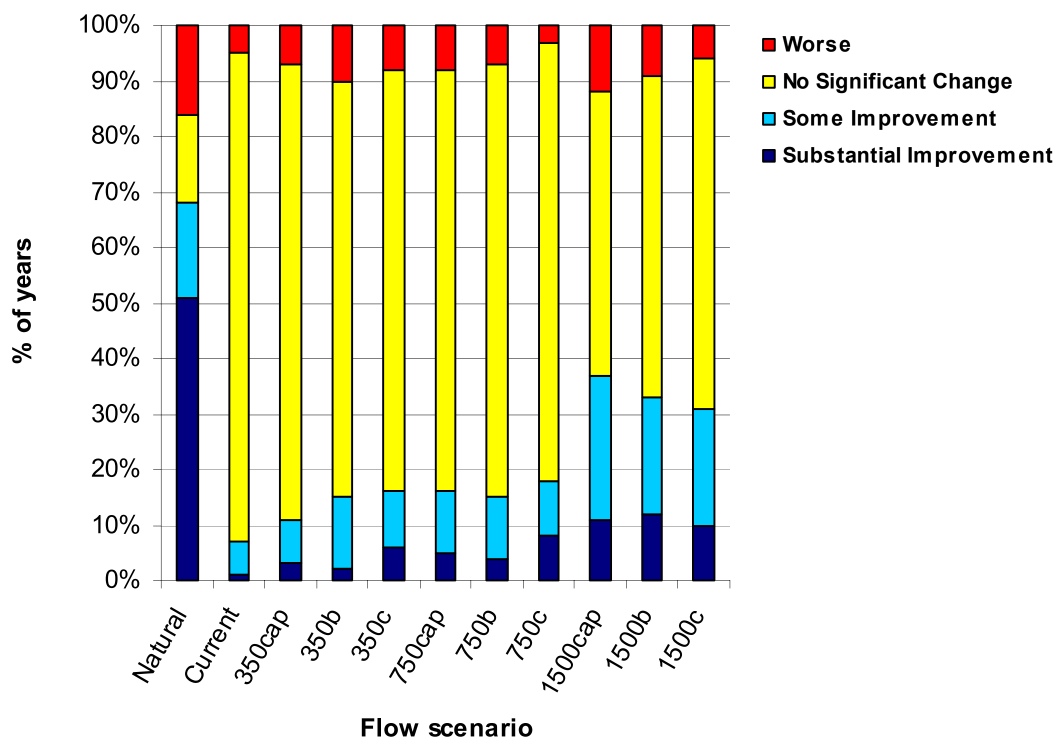

Figure 8.18. The improvement in floodplain vegetation habitat condition in Gunbower forest, relative to the reference scenario, defined as the percentage of years (n=108) that the test scenario/reference scenario statistic for floodplain vegetation habitat condition at this locality falls into each of the improvement categories listed in table 8.1

The red gum forests and woodlands, which are closer to the river and relatively low lying, responded more than the Black Box woodlands which are higher up the floodplain and only inundated during large floods. The frequency and duration of these events is not influenced by the scenarios being tested. Wetland vegetation showed a similar response to the floodplain vegetation, with the 1500 GL/yr options providing the most benefit, with a 'substantial improvement' being recorded for between 10 and 20% of years (Figure 8.19).

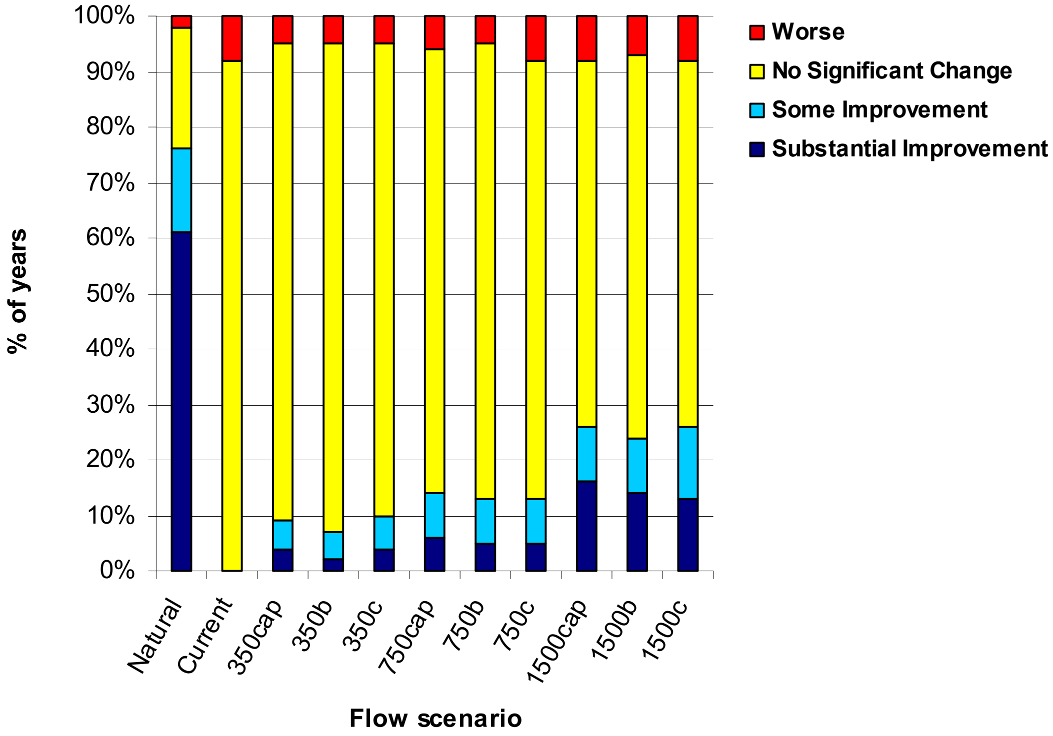

Figure 8.19. The improvement in wetland vegetation habitat condition in Gunbower forest, relative to the reference scenario, defined as the percentage of years (n=108) that the test scenario/reference scenario statistic for wetland vegetation habitat condition at this locality falls into each of the improvement categories listed in table 8.1

8.7.4 Hattah Lakes

The Hattah Lakes are a declared wetland of international significance under the Ramsar Convention and are contained within the Hattah-Kulkyne National Park, which is a designated Biosphere Reserve under the UNESCO 'Man and the Biosphere' program. They are located approximately 15 km from the River Murray and are fed via Chalka Creek. There are 17 lakes in the complex that are inundated at a range of river discharges from 36,700 ML/d to 152,000 ML/d. Hattah Lakes provide important breeding and foraging habitat for a range of water birds. Wetland vegetation is predominantly lake-bed herbs and sedges, including spiny mudgrass grassland, while the lakes are surrounded by River Red Gum and Black Box woodland and Lignum shrubland within a Mallee landscape.

Table 8.9 lists the MFAT assessment undertaken at Hattah Lakes. A summary of the results are presented below and the full details are presented in the accompanying REG D report.

Table 8.9. Assessments undertaken at Hattah Lakes by REG D

Ecological Assessment	Species group assessed
Waterbird Habitat Condition	-Colonial Nesting Waterbirds -Waterfowl and Grebes
Floodplain Vegetation Habitat Condition	River Red Gum woodland
	Black Box woodland
	Lignum shrubland
	Rats tail couch grassland
Wetland Vegetation Habitat Condition	Cumbungi rushland
	Phragmites australis
	Spiny mudgrass grassland
	Giant rush rushland
	Ribbon weed herbland

In general, there is a progressive improvement in waterbird habitat condition (Figure 8.20), wetland vegetation habitat condition (Figure 8.21) and floodplain vegetation habitat condition (Figure 8.22) with increasing flow volumes. However, like most other sites along the Murray, particularly those at a distance from the main channel, there still remains a large difference between natural and the 1500 GL scenarios. This is not unexpected given that a return of 1500 GL to the riverine environment represents only 12.5% of the water currently being diverted.

8.7.5 Riverland wetland complex (including Chowilla)

The Chowilla floodplain is a part of the Riverland wetland complex in South Australia, near the Victorian border. Riverland is listed as a wetland of international significance under the Ramsar Convention, and contains a large variety of habitats including significant areas of River Red Gum, Black Box and Lignum woodlands. It is also an important area for waterbird breeding and foraging.

Table 8.10 lists the MFAT models considered in the River lands complex. A summary of the results are presented below and the full details are presented in the accompanying REG C report.

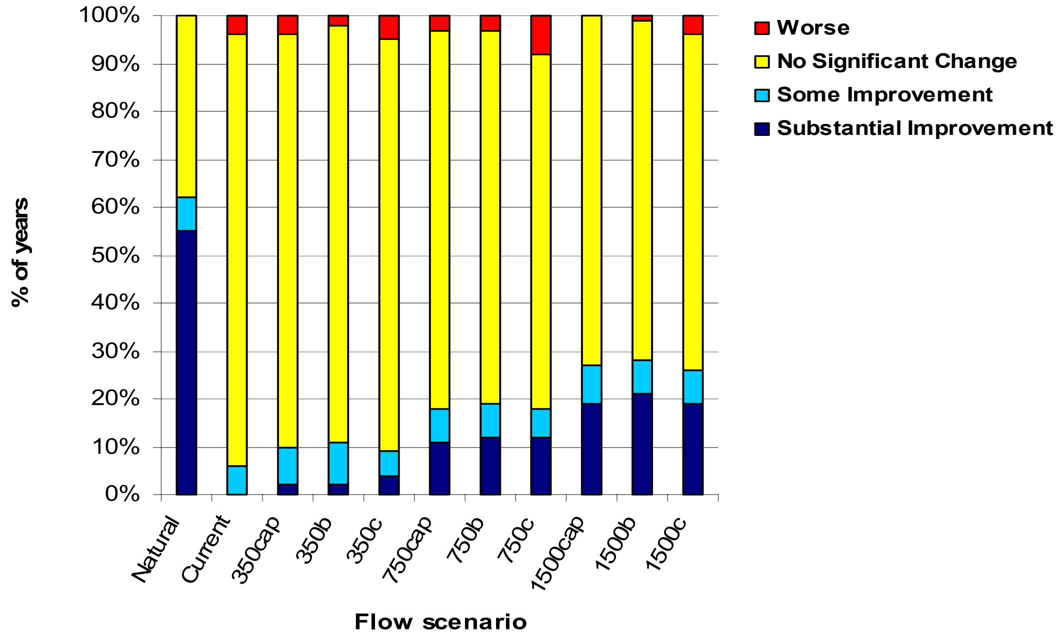

Figure 8.20. The improvement in waterbird habitat condition at Hattah Lakes, relative to the reference scenario, defined as the percentage of years (n=108) that the test scenario/reference scenario statistic for waterbird habitat condition at this locality falls into each of the improvement categories listed in table 8.1

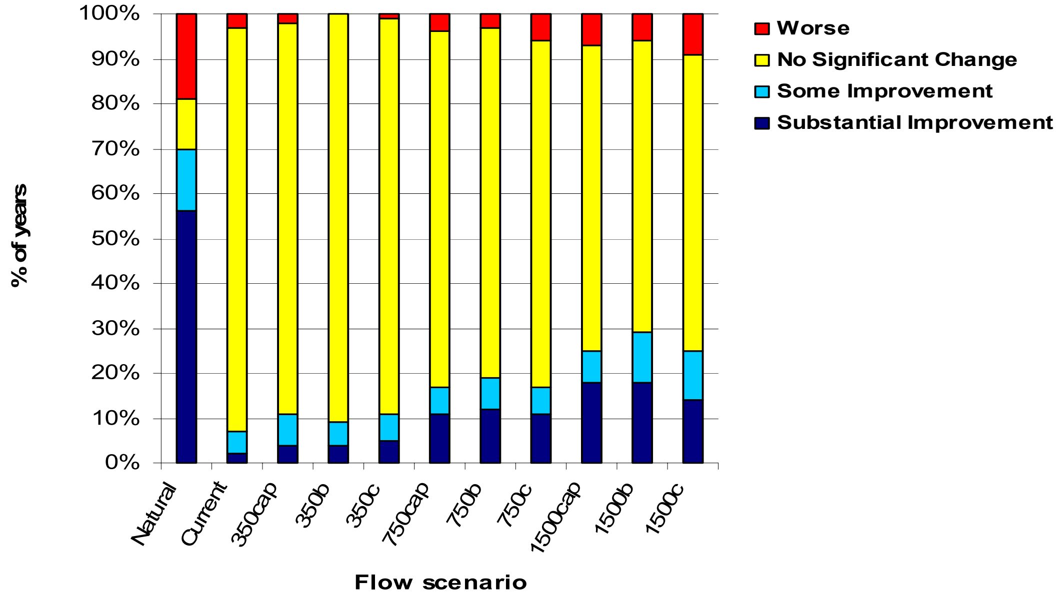

Figure 8.21. The improvement in floodplain vegetation habitat condition at Hattah Lakes, relative to the reference scenario, defined as the percentage of years (n=108) that the test scenario/reference scenario statistic for floodplain vegetation habitat condition at this locality falls into each of the improvement categories listed in table 8.1

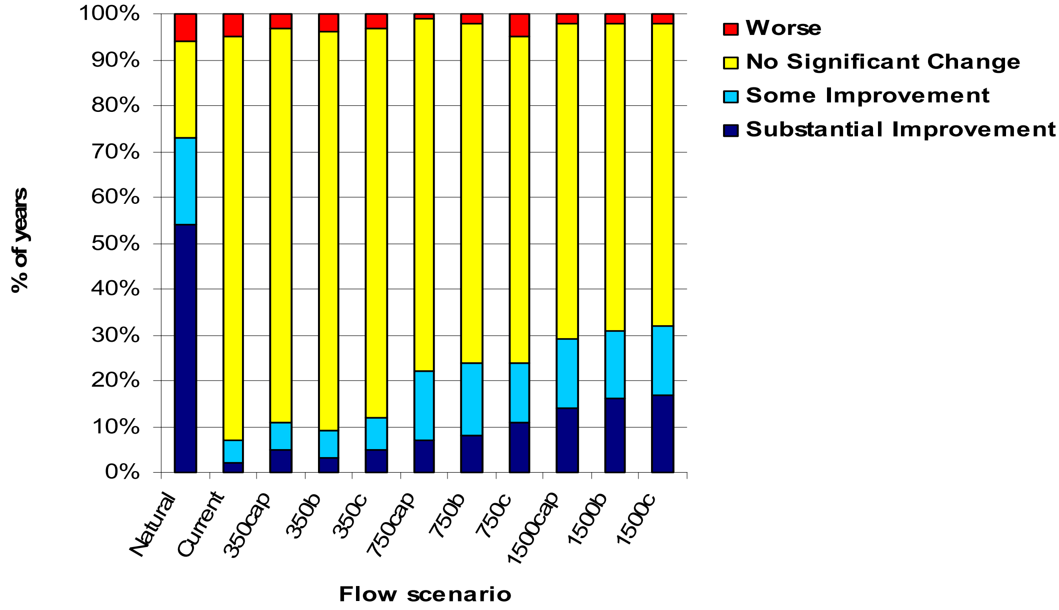

Figure 8.22. The improvement in wetland vegetation habitat condition at Hattah Lakes, relative to the reference scenario, defined as the percentage of years (n=108) that the test scenario/reference scenario statistic for wetland vegetation habitat condition at this locality falls into each of the improvement categories listed in table 8.1

Table 8.10 MFAT Assessments undertaken at Riverland (incl. Chowilla) by REG E

Ecological Assessment	**Species group assessed**	**Localities**
Waterbird Habitat Condition	-Colonial Nesting Waterbirds -Waterfowl & Grebes	-Merreti-Clover
Floodplain Vegetation Habitat Condition	River Red Gum woodland	-Merreti-Clover -Werta Wert
	Lignum shrubland	-Merreti-Clover -Werta Wert
	Rats tail couch grassland	-Merreti-Clover -Werta Wert
	Black Box woodland	-Werta Wert
Wetland Vegetation Habitat Condition	Ribbon weed herbland	-Merreti-Clover -Werta Wert

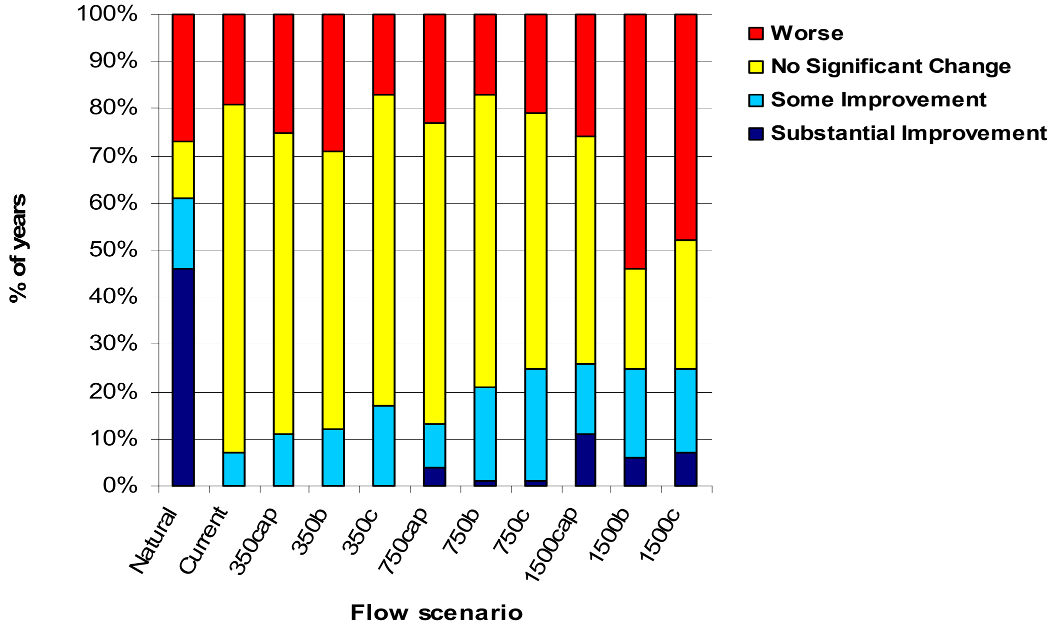

Figure 8.23. The improvement in waterbird habitat condition at Riverland (incl. Chowilla), relative to the reference scenario, defined as the percentage of years (n=108) that the test scenario/reference scenario statistic for waterbird habitat condition at this locality falls into each of the improvement categories listed in table 8.1

The waterbird assessment (Figure 8.23) indicated that the 1500Cap scenario provided the greatest benefit, with just over 10% of years showing 'substantial improvement'. The 350 and 750 GL/yr scenarios showed 'substantial improvement' in less than 5% of years.

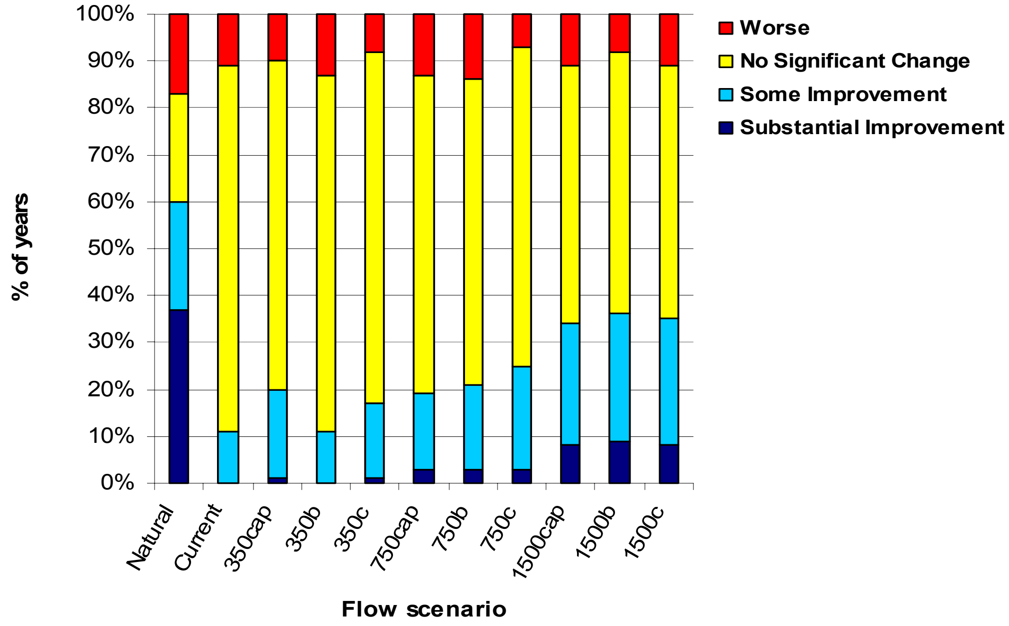

Figure 8.24. The improvement in floodplain vegetation habitat condition at Riverland (incl. Chowilla), relative to the reference scenario, defined as the percentage of years (n=108) that the test scenario/reference scenario statistic for floodplain vegetation habitat condition at this locality falls into each of the improvement categories listed in table 8.1

The results for floodplain vegetation at Riverland (Figure 8.24) show a substantial improvement for less than 10% of years under the 1500 GL/yr options. The 350 and 750 GL/yr options indicate 'substantial improvement' in less than 5% of years. The wetland vegetation assessment (Figure 8.25) showed very little response from any of the scenarios.

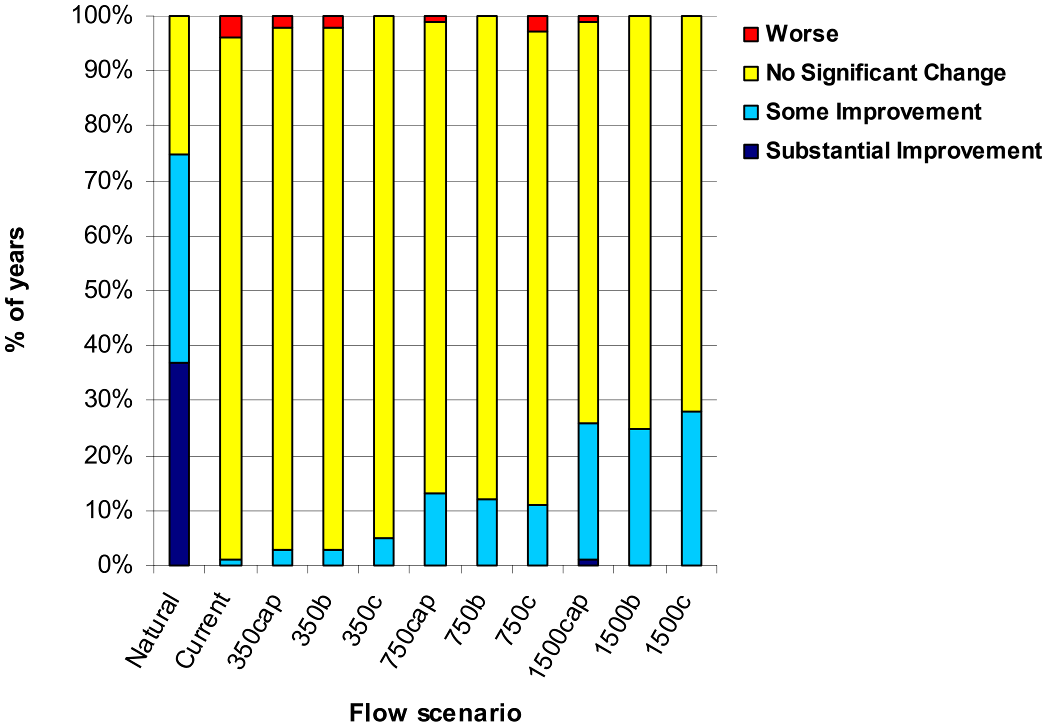

Figure 8.25. The improvement in wetland vegetation habitat condition at Riverland (incl. Chowilla), relative to the reference scenario, defined as the percentage of years (n=108) that the test scenario/reference scenario statistic for wetland vegetation habitat condition at this locality falls into each of the improvement categories listed in table 8.1

8.7.6. Murray Mouth and Coorong.

Three indicators were used to assist in selecting a preferred flow scenario for the Coorong and Murray Mouth. These were; *Ruppia tuberosa* (a key component of the food chain for waterbirds in the Coorong), estuarine fish and the MOI. The most relevant results for these are summarised below in Table 8.11 along with what have been assessed as being critical thresholds for each.

Based on the model results, the probability of a year of poor performance for *Ruppia* under natural conditions was less than 1%. Under reference conditions poor years would occur about 1 in 6 years (17%), consistent with observed declines in the extent of *Ruppia* in the southern Coorong. The 350GL and 750GL scenarios still leave an unacceptably high risk (5-14%) of *Ruppia tuberosa* failing to set propagules for the next year.

However the 1500GL b and 1500 GL c scenarios reduce this risk to around 1%. These two scenarios also provide the best outcome as far as securing an open Murray Mouth and are substantially better than all of the other options (Table 8.11). Whilst the 1500 GL b and c scenarios achieve significant improvements, the Murray Mouth is still five time more likely to close then under natural conditions. The 1500 GL b and c scenarios also provide conditions suitable for spawning for estuarine fish more frequently than the other options.

Based on the preference curves, the modelling predicts that conditions that favour the hypermarine and estuarine habitats of the Coorong and the extent to which the Murray Mouth remains open, increase with more water. The level of increase, however, is small for the lower volumes of water (350 GL, 750 GL) compared with 1500 GL (Table 8.11).

8.8 Algal growth assessment

The algal model was run at zone D (Mildura Weir), zone E (lock 5), zone G (Lock 1-2) and zone J (Maude Weir). The percentage of years under each scenario that are at 'some algal risk' and 'high algal risk' are plotted for each zone in figures 8.26-8.29. The MFAT index for some risk is < -0.1, the high risk threshold is < -0.3. The trend in algal risk for the scenarios is that 1500c, 1500b and 750c provide the best conditions for limiting algal growth. The other scenarios provide little or no improvement over reference conditions.

Zone D (Mildura)

For Mildura weir, the Current scenario is similar to the Reference scenario, with potential algal problems in about 1 in every 3 years (long term average). No significant reductions in algal risk occur for any of the 350 GL options. Minor reductions are achieved with 750cap and 750b options, and slightly better reductions with the 750c option (high risk in 21% of years).   The 1500cap option provides a similar reduction to the 750 options (high risk in 20% of years). The best outcome is achieved with the 1500b and 1500c options, which provide moderate improvement (high risk in only 15%-18% of years). The 1500b option reduces the 'high risk' category by over one-half compared with reference conditions.

Zone E (Lock 5)

For lock 5, the current scenario is similar to the reference scenario, with potential algal problems about 1 in every 3 years (long term average). No significant reductions in algal risk occur for any of the 350 GL options and minor reductions are achieved with the 750Cap and 750b options. The best options for this zone are 750c, 1500b and 1500c, which reduce the risk of algal problems by about one-third compared with reference.

Table 8.11. The Coorong and Murray Mouth - High stress years as survival indicators

Indicator	Reference	Natural	350GL Cap	350GL b	350GL c	750GL Cap	750GL b	750GL c	1500GL Cap	1500GL b	1500GL c
Frequency that *Ruppia tuberosa* annual index is less than 0.2	17%	<1%	14%	9%	8%	13%	8%	5%	8%	1%	1%
Change in frequency that *Ruppia tuberosa* annual index is less than 0.2 with respect to the current scenario[1]	0%	-17%	-3%	-8	-9%	-4%	-9%	-12%	-9%	-17%	-16%
Frequency that estuarine fish spawning failure in consecutive years.[2]	10%	1%	13%	2%	3%	9%	2%	2%	7%	1%	1%
Change in frequency that estuarine fish spawning failure in consecutive years.	0%	-9%	0%	-8%	-7%	-1%	-8%	-8%	-3%	-9%	-9%
MOI annual index less than 0.05 (Oct to Sep water year)	36%	<1%	32%	26%	27%	30%	25%	22%	23%	9%	8%

Notes

1: Calculated as the difference in frequency (expressed as a percentile) between the test and current scenarios. A negative figure indicates an improvement in predicted condition.

2: Spawning failure as a result of flow regime only - other factors not specifically water flow also influence spawning and may also cause failures which have not been considered

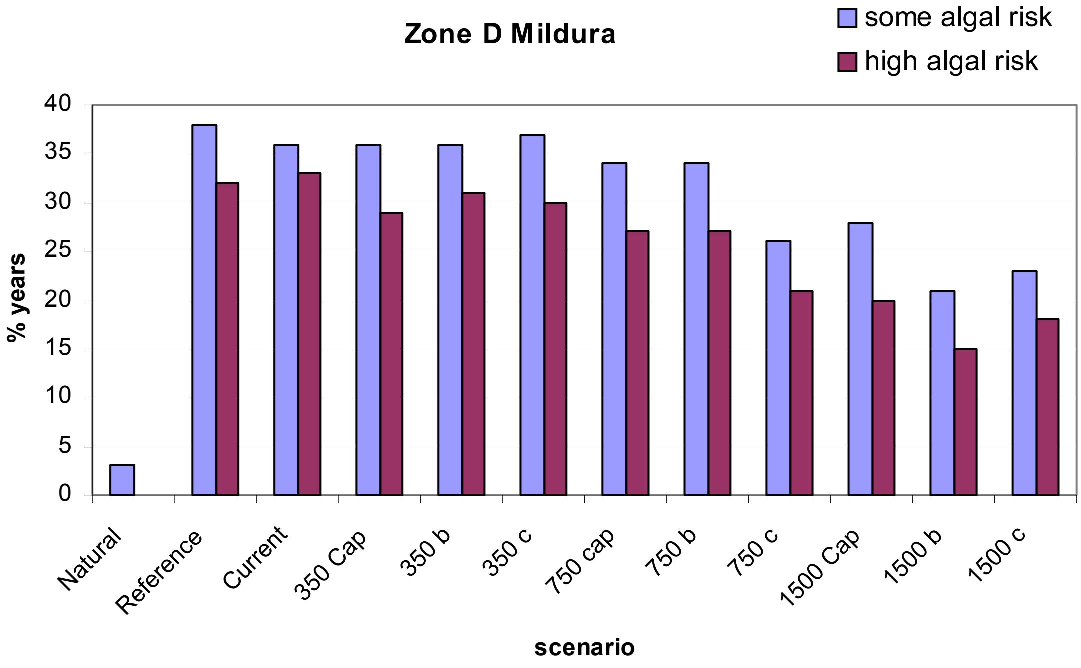

Figure 8.26. The percentage of years that Mildura Weir (zone D) experiences 'some' or 'high' algal toxin risk under each scenario ('some' and 'high' algal risk thresholds are < -0.1 and < - 0.3 respectively).

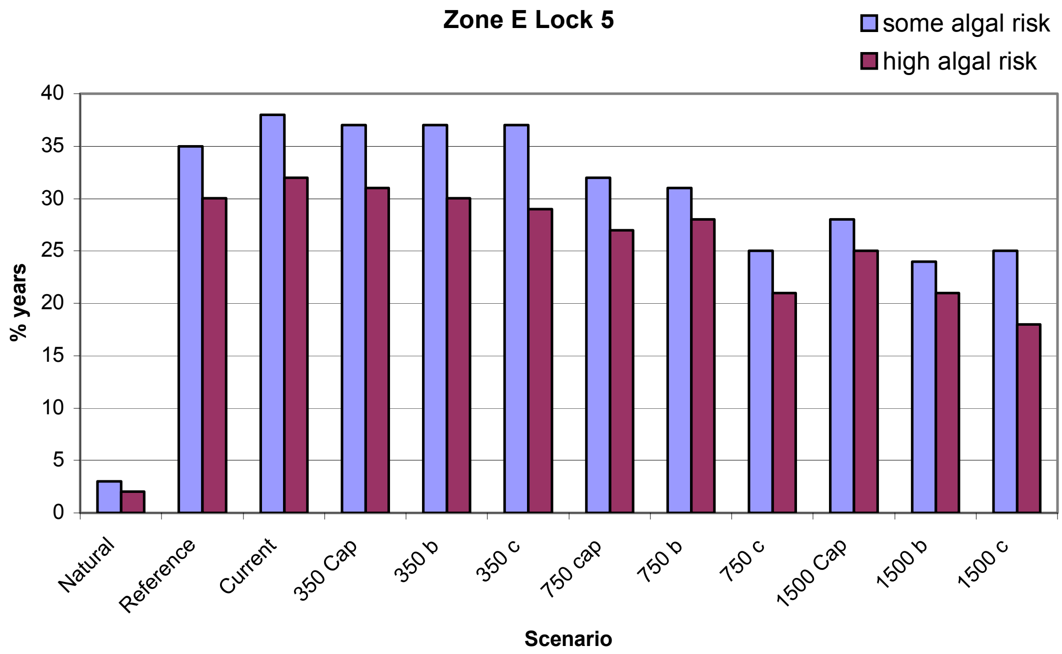

Figure 8.27. The percentage of years that Lock 5 (zone E) experiences 'some' or 'high' algal toxin risk under each scenario ('some' and 'high' algal risk thresholds are < -0.1 and < - 0.3 respectively).

Zone G (Lock 1-2)

For Lock 1-2 in Zone G, the current scenario is similar to the reference scenario, with potential algal problems in about 1 in every 8 years. The 350GL options, and the 750cap and 750b scenarios only offer a slight reduction in algal toxin risk. Better reduction is provided by the 1500b and 1500c scenarios (high risk in 3-4% of years) and the best reduction is from the 750c scenario (high risk in only 2% of years).

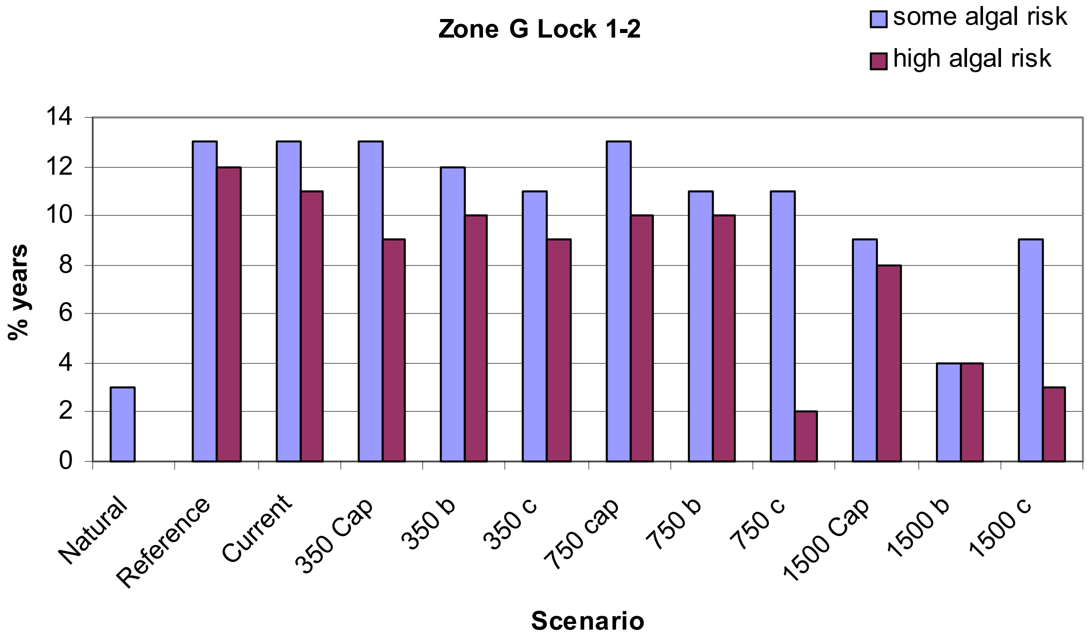

Figure 8.28. The percentage of years that Lock 1-2 (zone G) experiences 'some' or 'high' algal toxin risk under each scenario ('some' and 'high' algal risk thresholds are < -0.1 and < - 0.3 respectively).

Zone J (Maude)

The current scenario for Maude weir (Zone J) is improved relative to reference, with potential algal problems about 1 in every 4 years (long term average) compared with 1 in every 2-3 years under reference scenario. The Year 6 WSP is similar to Current scenario. The 10% cap reduction offers slight improvement compared with current scenario, though probably not significant. The 20% cap reduction offers significant improvement compared with current, with algal problems in 13-24% of years. The 40% cap reduction offers major reduction in algal risk, with problems in 9-16% of years. The current scenario for this zone is already significantly improved relative to the reference scenario. To obtain significant further improvements, a diversion reduction of 20-40% would be required.

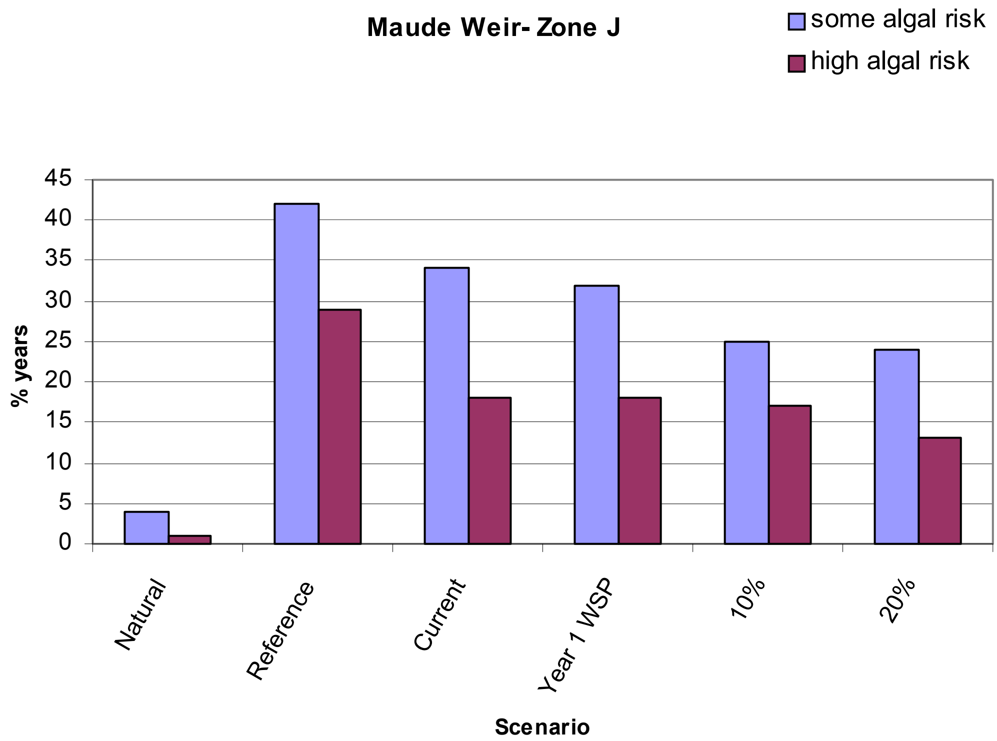

Figure 8.29. The percentage of years that Maude Weir (zone J) experiences 'some' or 'high' algal toxin risk under each scenario ('some' and 'high' algal risk thresholds are < -0.1 and < - 0.3 respectively).

8.9 Salinity results

Figure 8.30 shows the mean salinity at Morgan for each scenario. The trend is that the 350GL and 750GL show a minor improvement of around 20-40EC compared to reference, whilst the 1500GL scenarios substantially reduce EC, by up to 90EC relative to the reference scenario of 594 EC.

8.10 Structural and operational improvements

The selected structural and operational improvements being assessed were run together in a single model run for each flow scenario and the results for each river zone are reported in the accompanying REG reports. In this report, two case studies have been presented as examples; the improved operation of a regulator on a wetland in zone C, and thermal pollution reduction in zone B.

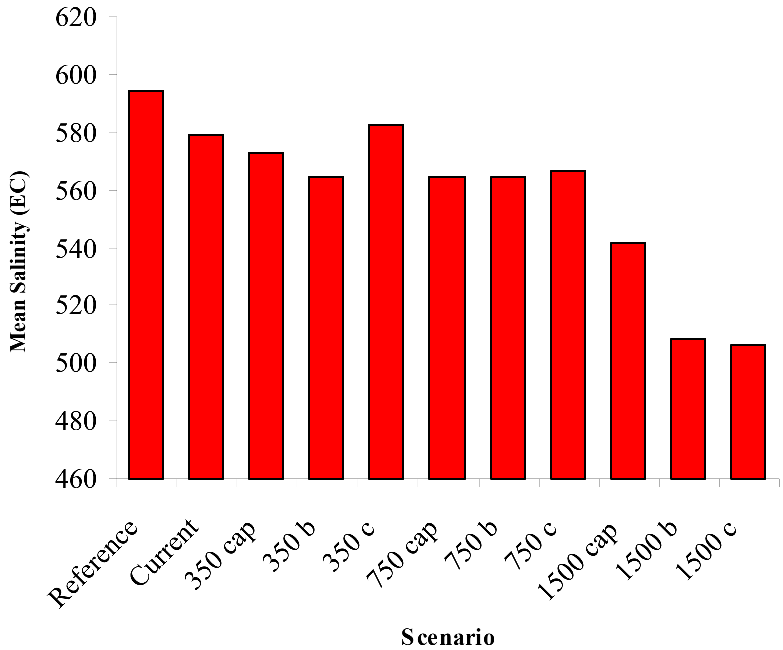

Figure 8.30. The mean (n=109) salinity (EC) for each scenario at Morgan (South Australia).

8.10.1 Addition and improved operation of a regulator - Gunbower Forest

The MFAT was used to assess proposed structural and operational improvements to water management in Gunbower Forest. This involved modelling a new regulator to allow the release of additional flows from Gunbower Creek to wetlands in the forest. The annual operation of the regulators (particular months open or closed) on wetland inlets and outlets was set up according to local requirements for flood timing and duration. These changes were expected to provide benefits to both waterbird and wetland vegetation habitat condition in the lower-lying permanent and semi-permanent wetlands of the forest.

Both the waterbird and wetland vegetation habitat condition indices indicated that the benefits obtained under the 750GL scenarios WITH the additional structural and operational improvements in place produced an equivalent benefit to the 1500GL scenarios WITHOUT these structural and operational improvements in place (Tables 8.12 and 8.13). The wetlands at which these responses were measured are, however, relatively low-lying areas of the forest that commence to flow at river discharges of around 15,000ML/day. Vegetation communities at higher floodplain elevations would not be expected to respond to the same degree as these lower-lying wetland areas, particularly under the lesser flow volume scenarios.

The S/R threshold analysis, shows the percentage of years that were improved relative to the reference scenario, and illustrates the trend of increasing benefit with increasing flow volume (Figures 8.31 and 8.32).

The ecological benefits obtained from the addition and/or improved operation of existing regulators are **localised** in effect and would not be expected to provide system-wide improvements. Similarly, the operation of regulators must be tailored to suit local environmental water requirements. The Gunbower Forest example highlights one such localised benefit that can be obtained from targeted use of water entering the forest, assisted by structural and operational improvements to enhance the benefit obtained from any given volume of water.

Presently the MFAT cannot model event based regulator operation, rather it models a given set of operating conditions annually, over the entire modelled sequence. An improved ability to model varied regulator operation from year to year would likely result in even greater predicted improvements than were illustrated by this preliminary analysis.

Table 8.12. Improvement in mean Waterbird Habitat Condition with additional structural and operational improvements

Structural/ Operational Improvements	WITHOUT	WITH	% increase
Natural	0.46		
Reference	0.20		
Current	0.20	0.22	2
350cap	0.22	0.23	1
350b	0.22	0.23	1
350c	0.22	0.24	2
750cap	0.23	0.25	2
750b	0.23	0.25	2
750c	0.23	0.25	2
1500cap	0.25	0.28	3
1500b	0.25	0.28	3
1500c	0.25	0.27	2

Table 8.13. Improvement in mean Wetland Vegetation Habitat Condition with additional structural and operational improvements

	Phragmites australis		Ribbon weed herbland		Overall Wetland Vegetation		% increase Overall
Structural/ Operational Improvements	WITH OUT	WITH	WITH OUT	WITH	WITH OUT	WITH	
Natural	0.74		0.64		0.69		
Reference	0.29		0.51		0.40		
Current	0.28	0.37	0.51	0.54	0.39	0.45	6
350cap	0.30	0.40	0.52	0.55	0.41	0.48	7
350b	0.30	0.40	0.52	0.55	0.41	0.48	7
350c	0.31	0.41	0.53	0.55	0.42	0.48	6
750cap	0.32	0.41	0.51	0.54	0.42	0.48	6
750b	0.32	0.41	0.51	0.55	0.42	0.48	6
750c	0.31	0.40	0.52	0.55	0.42	0.48	6
1500cap	0.37	0.47	0.55	0.56	0.46	0.51	5
1500b	0.35	0.46	0.55	0.58	0.45	0.52	7
1500c	0.36	0.45	0.54	0.57	0.45	0.51	6

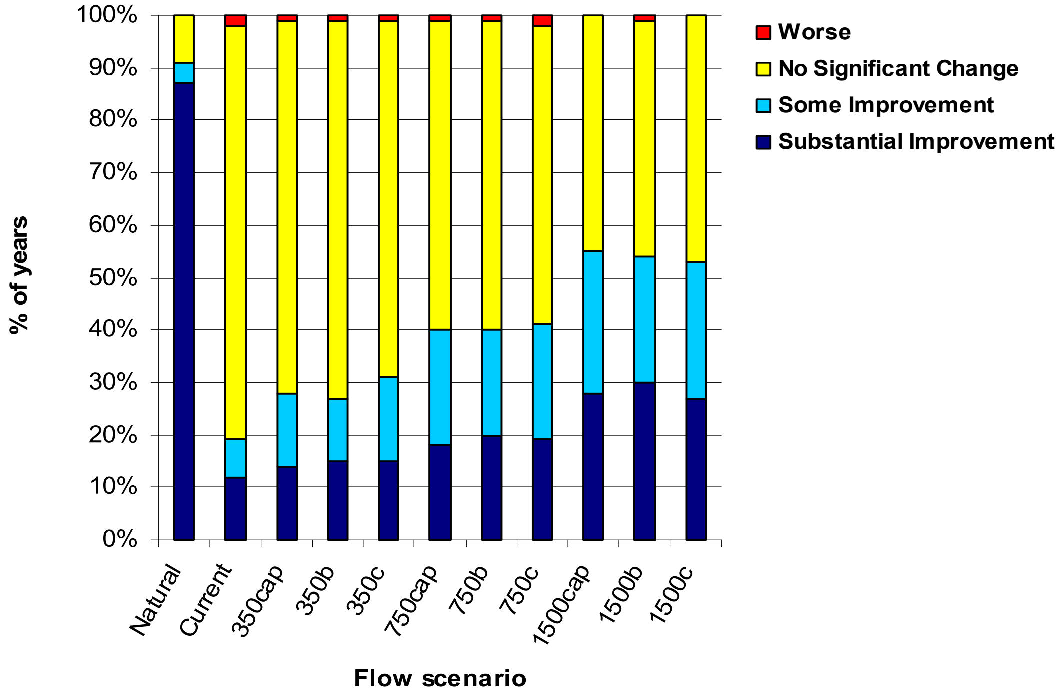

Figure 8.31. The improvement in waterbird habitat condition in Gunbower forest with structural and operational changes, relative to the reference scenario, defined as the percentage of years (n=108) that the test scenario/reference scenario statistic for waterbird habitat condition at this locality falls into each of the improvement categories listed in table 8.1

8.10.2 Reduction in thermal pollution - Hume Dam to Yarrawonga Weir

Thermal pollution (cold water release below dams) is a potential limiting factor to the health &/or recovery of many native fish. The MFAT was used to model the effect of a reduction in thermal pollution on native fish habitat condition in zone B (below Hume Dam to Yarrawonga Weir).

The 'water temperature' sub-index in the MFAT Native Fish model was improved by one 'category', and the spawning timing preference curves for each fish group were adjusted to reflect an increase in the calendar months in which spawning could occur.

The mean native fish habitat condition index results indicate that thermal pollution has an overriding influence on native fish habitat condition in this river zone, such that without any thermal pollution mitigation there is *no significant change* in the native fish habitat condition index for any flow scenario (Table 8.14). The addition of thermal pollution mitigation improves the native fish habitat condition index by 6-8%.

The S/R threshold analysis, shows that native fish habitat condition improved across all scenarios relative to the reference scenario, but particularly so in the 1500GL scenario (Figure 8.33). Thermal pollution mitigation increases the percentage of years in the 'some improvement' category. The degree of improvement is, however, similar across all flow

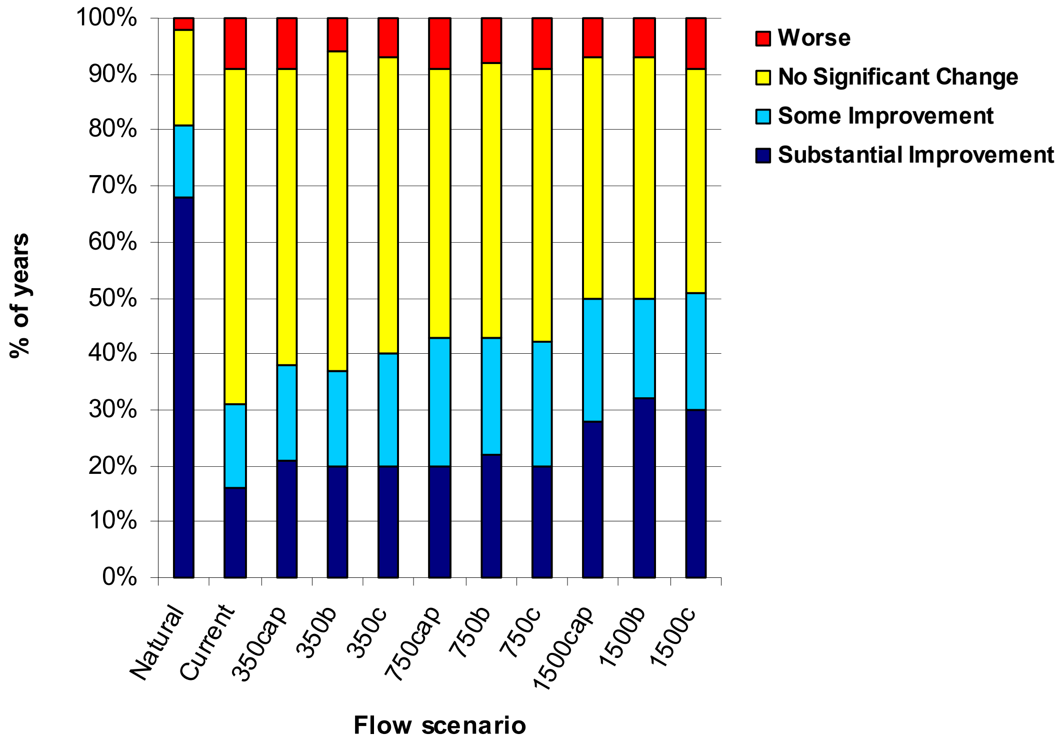

Figure 8.32. The improvement in wetland vegetation habitat condition in Gunbower forest with structural and operational changes, relative to the reference scenario, defined as the percentage of years (n=108) that the test scenario/reference scenario statistic for wetland vegetation habitat condition at this locality falls into each of the improvement categories listed in table 8.1

scenarios, again indicating that thermal pollution has a very strong influence over the native fish habitat condition and will have an important influence on the recovery of native fish.

Table 8.14. Improvement in mean Native Fish Habitat Condition with additional structural and operational improvements

Scenario	WITHOUT	WITH	% increase
Natural	0.85		
Reference	0.53		
Current	0.52	0.60	8
350cap	0.53	0.60	7
350b	0.53	0.61	8
350c	0.53	0.60	7
750cap	0.52	0.60	8
750b	0.52	0.60	8
750c	0.53	0.61	8
1500cap	0.55	0.61	6
1500b	0.54	0.62	8
1500c	0.53	0.60	7

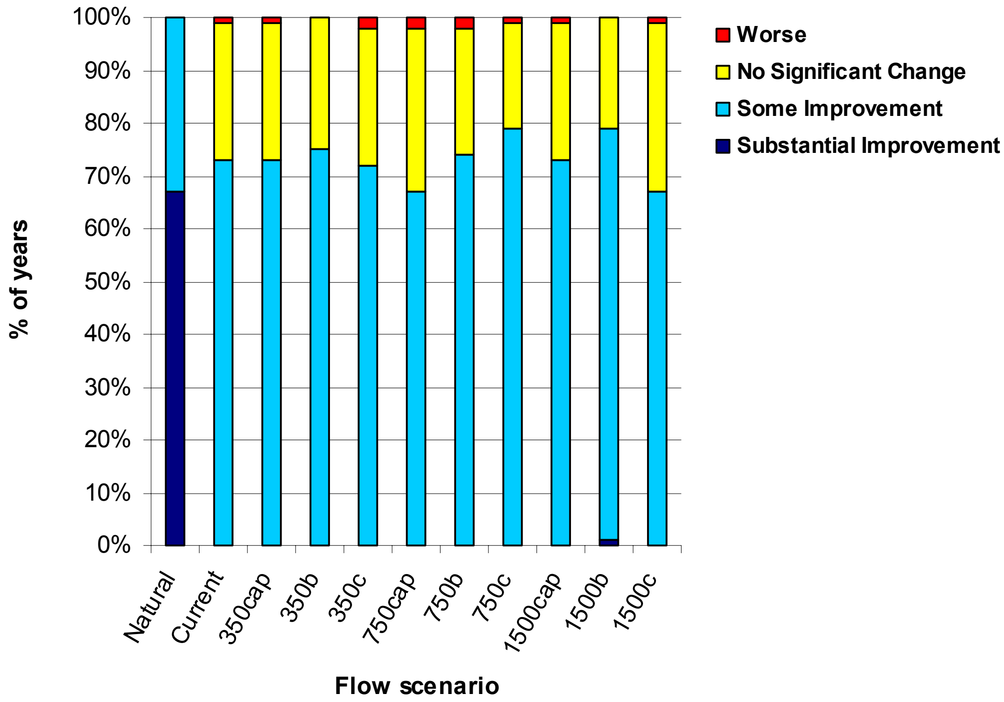

Figure 8.33. The improvement in native fish habitat condition in zone B with structural and operational changes, relative to the reference scenario, defined as the percentage of years (n=108) that the test scenario/reference scenario statistic for fish habitat condition in this zone falls into each of the improvement categories listed in table 8.1

8.10 Sensitivity analysis

In August 2003, the MDBC commissioned a preliminary assessment of the sensitivity of the MFAT results to variations in the adjustable model parameters. This provides a broad indication of the key areas of sensitivity in the MFAT models to changes in input parameters. A more comprehensive sensitivity analysis may be subsequently required to further investigate particular aspects of the model sensitivity. A summary of key results is provided below, and further details can be obtained from appendix 5 or from the MDBC website (www.thelivingmurray.mdbc.gov.au).

The sensitivity analysis was carried out on two levels. Firstly, a *standard assessment* was undertaken to investigate the overall changes in the model results between (i) the *SRP default* parameter settings, and (ii) the parameter settings adjusted by each REG (**if** adjusted from SRP default settings). This assessment was carried out for every zone and every ecological model. Secondly, a number of *additional assessments* were undertaken to investigate the sensitivity of the MFAT to changes in parameter settings in the floodplain hydrology model, and specific changes to ecological model preference curves and weightings.

Key findings of the initial sensitivity analysis are that:

- For the *standard assessment*, the different MFAT ecological models varied in their sensitivity to the adjustments made to parameters settings by the REGs from the SRP default settings. For example, the **Floodplain Vegetation** model assessments under

REG adjusted parameter settings varied widely from those calculated under SRP default settings, with the absolute differences in index score ranging from 0.05 to 0.34. The **Wetland Vegetation** model and **Waterbird model** were less sensitive to these adjustments and showed only small differences (absolute difference <0.05) in results between SRP default and REG adjusted parameter settings. Most **Native Fish** assessments showed small or moderate differences in results between SRP default and REG adjusted parameter settings (absolute difference <0.08), with the exception of REG C which showed a >0.19 difference.

- *Locality* specific assessments tended to be more sensitive to changes in parameter settings compared to *river zone* assessments which aggregate assessments from several localities within a river zone. This could be due to the effects of aggregation 'diluting' or 'dampening' the influence of individual localities in a zone level assessment.

- In most assessments the MFAT models responded with a similar level of sensitivity (magnitude of change) to both flow scenarios tested ('Current" and "1500c").

- The native fish index scores are strongly dependent on the fish species selected for testing.

9. DISCUSSION

9.1 Preamble

In reaching the Interim Assessments provided in this chapter, the SRP have drawn significantly, though not exclusively, on the MFAT outputs reported in Chapter 8. MFAT is a decision support system (not a predictive model) and thus is not a decision making tool on its own.

MFAT ecological model outputs are best suited for comparing the ecological benefits (or disbenefits) of a flow management scenario relative to a benchmark flow regime. For the purposes of the SRP report and the Living Murray process more broadly, that benchmark is the 1993/93 Cap condition (so called 'reference' condition).

In addition to providing assessments of relative ecological benefits, the MDBC has asked the SRP to provide a summary statement of absolute ecological condition under each flow reference point. In other words, whether any of the flow reference points, combined with planned structural and operational improvements, can provide a 'healthy working' River Murray system. To do this, the SRP must compare the various flow reference points with the modelled natural flow regime. Our knowledge of riverine ecological structure and functional processes is simply not detailed enough to 'build' a desired or target condition from the 'ground up' so to speak. In the absence of such knowledge, and supporting predictive models, deviation from modelled natural is the best yardstick available for assessing likelihood of absolute ecological condition.

This does not mean that 'modelled natural' is the target condition. It clearly is not for a working river like the Murray. It is simply a benchmark against which ecologists can make assessments of potential or actual ecological condition.

The Discussion thus contains both types of assessment:

1. Ecological benefits relative to reference condition. This analysis is based on the MFAT model index scores. Consequently, the SRP relative assessments are transparent and easily interrogated (by reference to the populated MFAT models for each zone).

2. Brief assessments drawing upon personal expert knowledge and experience, as well as MFAT outputs. Consequently, such assessments are less transparent and less easily interrogated.

9.2 Assessment relative to target condition – a healthy working River Murray system

Based on a combination of MFAT analyses and personal knowledge and experience, it is the considered opinion of the SRP that at the whole of river scale, the 1500 GL options alone (ie without structural, operational and water quality improvements) will deliver at best, a moderate improvement for the plant and animal communities assessed.

However, combined with improved structural, operational and water quality management – including all options currently being assessed by the MDBC, there is a possibility that a further 1500 GL of environmental flow allocation, could deliver a healthy working River Murray system. Whether or not this proves ultimately to be sustainable would depend on the setting of realistic ecological condition targets and objectives, plus a commitment to on-going and well funded river operations and monitoring in an active environmental management context.

This assessment is not surprising. The 350GL option represents a return of only 3% of flow to the environment relative to total annual discharge - 1500 GL about 12.5 %.

Although having used a different assessment method, the present SRP interim assessments are consistent with previous advice from the former Expert Reference Panel. The ERP report (Jones *et al* 2002) stated that a further 1630 GL had only a moderate probability of achieving a healthy river and that up to 4000 GL would be required to have a high probability of achieving a healthy working river. The present interim results also reinforce the ERP's assessment that allocations of 900 GL and 350 GL have a low probability of achieving a healthy working river, although significant local or regional outcomes may be possible.

9.3 Comments on the native fish habitat assessment

The response of habitat condition index scores indicates that the 1500 GL/yr scenarios provide greatest improvement for native fish habitat along the river. However, even the 1500 GL/yr scenarios provide only a very small improvement in the index scores, with the mean index score increasing by 15% and 36% in zone E and F respectively. The native fish model shows less response than any of the other ecological models. According to the draft Native Fish Strategy for the Murray-Darling Basin 2002-2012 (MDBC, 2002), improved flow management alone could account for only 25% of the rehabilitation of native fish populations. This is in agreement with the very low response from the MFAT fish model to the small changes in flow being assessed here (note that the 1500 GL/yr option is equivalent to only 12.5% of total water diversions).

Three additional factors should be considered when interpreting the fish habitat results. First, seven different groups of fish are represented in the fish model, and each of these groups responds differently to changes in the hydrology, and in particular over-bank flows. Some groups, such as the 'flood spawners', showed a greater response since they rely on connection with the floodplain for spawning, while other groups such as the 'low flow specialists' or 'in-channel generalists' have far less dependency on floods for breeding or adult survival. Nevertheless large over-bank floods may lead to very successful recruitment through indirect beneficial effects on river productivity (rather than through direct habitat effects as considered in MFAT). Further improvements in operational rules may allow more overbank flows and hence a stronger fish response. The overall index for native fish combines the individual results for each fish group and so the higher response of groups such as the flood spawners is 'diluted' by the low response of other groups, as already discussed in section 9.8.

Second, the effects of flow on fish may be indirect, through the influence of flow on water quality. For example, flows may affect salinity which may affect recruitment. Flows may also affect turbidity, which may affect predator-prey interactions and thus affect fish populations. There is no water quality component in the present MFAT and no linkages between components that would allow inclusion of these types of flow mediated interactions.

Third, while our knowledge of fish ecology has improved over the last decade there are still knowledge gaps that may limit our ability to assess the impact of flow modification on fish habitat. These gaps include the role of floods in fish ecology which is still being widely debated. Recent research on the Lake Eyre Basin is showing considerable response by native fish species to inundation of floodplains (Puckridge *et al* 2000). Also, we still have little information about the ecology of juvenile fish and the factors that influence their survival. It is possible that these knowledge gaps reduce the response of fish habitat to the flow scenarios.

These caveats suggest that the fish assessment has been conservative in its estimates of the impact of flow modifications. The results do, however, broadly agree with the Native Fish Strategy which stated that 25% fish recovery could be achieved through restoration of flows. The analysis undertaken here has indicated that less than 25% will be achieved with only partial restoration of flows. The challenge will be to allocate flows that do not jeopardise the coexistence of members of the native fish community or enhance alien fish species. The response of habitat condition index scores indicate that the 1500 GL/yr scenarios provide the greatest improvement for native fish along the river. However, even the 1500 GL/yr scenarios provide only a very small improvement in the habitat condition index scores. The native fish model shows less response than any of the other ecological models, and this will be the subject of further analyses in the post-interim analysis phase.

9.4 Murray Mouth and Coorong

The Coorong is used by large numbers of migratory and endemic waders and a wide variety of water birds during summer and autumn, and is particularly important as a drought refuge. An open Mouth is critical to maintaining this system along with the maintenance of appropriate water levels during spring and into summer.

The 1500GL b and 1500 GL c scenarios provide the best outcome as far as securing an open Murray Mouth and improving conditions for estuarine fish and also for the growth of *Ruppia tuberosa* in the Coorong. These two scenarios are substantially better than all of the 350GL and 750GL scenarios assessed. Whilst the 1500 GL b and c scenarios achieve significant improvements, the Murray Mouth is still five time more likely to close then under natural conditions.

The extent to which environmental flows can provide respite for the Coorong and Murray Mouth is also dependent on the pattern of release of water over the barrages. For instance, benefits can potentially double under scenario b or scenario c compared to the Cap reduction for a particular volume of water. Thus irrespective of the volume of water, changes to barrage operation can maximize the potential environmental benefits for that particular volume water.

9.5 Structural and operational improvements

The MFAT was primarily designed to assess the relative benefits of different flow regimes. It does include a number of non-flow related parameters, that can be used to assess some of the proposed structural changes. There are two major types of structural changes within the MFAT. One relates to the fish assessment and includes woody debris, water temperature, channel condition and fish passage. These parameters can be further divided into those requiring local works that would have broad scale impacts (fish passage and thermal pollution) and those requiring broad scale intervention to have reach scale impacts (woody debris and channel condition). These parameters have been modelled with a fairly simple scale of index scores that enable gross changes in these parameters to be modelled. Within the fish assessment these structural changes may produce some improvement in most zones – and very significant improvements in some zones. This is in broad agreement with the assessment of the MDBC Native Fish Strategy.

The second type of structural change modelled within MFAT are those that alter flooding regimes. These include altering weir pool operations and the installation of regulators. Change in the operation of a weir pool has the potential to affect a section of river while the installation of regulators generally only has the capacity to affect specific sites. This component of the model has been used to make a first assessment of the potential benefits of installing a regulator in Gunbower Forest. The resultant waterbird and wetland vegetation habitat condition indices indicated that the benefits obtained under the 750GL scenarios WITH the additional structural and operational improvements produced a benefit equivalent to the 1500GL scenarios WITHOUT these structural and operational improvements. The wetlands at which these responses were measured are, however, relatively low-lying areas and vegetation communities at higher floodplain elevations would not be expected to respond to the same degree.

In summary, improvements to ecological outcomes can be obtained through smarter use of the water that is available. This will require changes to weir structure, and the installation and *on-going management* of floodplain regulators. This MFAT-based assessment should only be considered as the first stage of a more detailed process that includes more complex modelling and design and operational optimisation, as well as detailed on-site surveys.

9.6 Algal risk

Blue-green algal blooms may have a major impact on local and regional communities. The MFAT analysis suggests that the current risks of algal problems in mid and lower Murray remain unchanged compared with reference condition. However, the current scenario is significantly improved over reference for Lower Murrumbidgee (Maude). For the Murray, significant improvements in risk reduction are likely only with options 750 'c', 1500 'b' and 1500 'c', with 1500 'c' appearing to offer the greatest reduction overall (across zones D, E and G). These trends are similar to those recorded for other indicators in which substantial improvement is only observed under the higher flow reference points.

9.7 Index scores for natural versus reference scenarios

Index scores represent the arithmetic mean of annual habitat condition for the 108 year flow record. The index scores under the Natural scenario, for the four ecological models, vary from 0.86 to 0.34. These values are within the range expected in an Australian river with its highly variable and unpredictable flow regimes. They reflect the 'boom and bust' nature of the environment. Birds provide a good example of the variation captured in these index scores. Under natural conditions colonial nesting birds would not breed every year. Black Box woodlands may be flooded sufficiently to stimulate recruitment once in only every 10 years or less often (Young *et al*, 2001). These fluctuations in conditions would have the effect of reducing the mean of 108 annual index scores to significantly less than 1.0

Also, the mean annual index scores for each ecological model are an aggregation of sub-indices representing various groups of species (eg. up to 7 fish groups contribute to the native fish index). No one year would be perfect for all groups either in nature or in the model as each group has different and sometimes partially conflicting environmental requirements. This inherent inter-annual variability helps support the diversity of the system and also ensures that no one component of the river ecosystem will be highly favoured all the time.

A comparison of index scores for natural versus reference (1993/943 Cap) scenarios (see table 8.3) appears to indicate that there has been less degradation of the river than would be predicted by some ecologists. The results are, however, consistent with the results of the Land and Water Resources Audit and the Snapshot of the Murray-Darling Basin which reported moderate to substantial modification of the fauna and water quality. There are, however, a number of reasons that the index scores may underestimate the degree of decline in the current river condition.

The first reason is that, as noted earlier, the MFAT is an assessment of the effects of flow on habitat availability and many other factors are not considered. The floodplain, wetland and bird assessments do not consider land management, levees, drainage, feral animals, salinity or other non-flow factors that may affect habitat availability. These factors have almost certainly had additional detrimental impacts on habitat availability. It is also highly likely that these other degrading influences interact with flow modification in a synergistic manner so that the overall degradation of the ecosystem is probably greater than the sum of the components. As a consequence the fact that the assessment indicates that habitat has been degraded by 18-52% by flow alone suggests that flow is a major factor in determining habitat availability, and thence the condition of the river.

The second explanation for the apparent discrepancy is that, as discussed in section 7, the MFAT has been run using hydrological data. The relationship between hydrological data and the hydraulic environment that organisms respond to is complicated and therefore changes in hydraulics are not adequately captured in an analysis of daily flows.

The third reason is that the MFAT is only an assessment of habitat availability and, as discussed in section 7, other factors associated with flow modification are probably also having a detrimental impact on current ecological condition. The Murray Expert Panel (Thoms *et al*, 2000) identified three ecosystem attributes that should be considered, namely habitat, connectivity and metabolic function. All three attributes have been affected by flow and the effects probably interact.

9.8 System-wide versus local benefits - how to distribute the water

As discussed earlier, the analysis was undertaken to determine system wide benefits from the allocation of 350, 750 and 1500 GL. The results indicate that under some scenarios, system wide benefits may not be significant. If the first step-decision is to allocate volumes of water that will not have system wide effects, the community may wish to consider the relative merits of allocating water to achieve specific local or regional outcomes. Consideration of this type of scenario should also consider the possibility of developing a year to year roster for the allocation of water to particular locations along the Murray to achieve specific environmental outcomes. A similar process to the one described in this report could be undertaken to guide these decisions, but this task is outside the existing brief.

For this to occur the community will need to refine Basin-wide targets for a healthy working river to produce quite specific targets that will enable prioritisation of sites and environmental values. Specific targets will provide a framework against which a range of potential flow and management scenarios can be assessed.

9.9 Addressing constraints to recovery

The health of the River Murray system has been impacted by many factors other than changed flow regime. These include; water quality problems (such as salinity, thermal pollution and turbidity), dryland salinity across the floodplain, construction of barriers across the river channel, snag removal, bank erosion, over-grazing of the floodplain and wetland vegetation, logging of forests, construction of levees, the spread of exotic species, and fishing. The full benefits that can potentially be derived from a recovery of water for the environment cannot be realised unless these other impacts are also addressed.

The decline in health of the riverine ecosystems along the River Murray has occurred gradually over more than 100 years. With any hydrological change there will be a lag time before the ecological response can be detected, and the extent of this lag time will depend on the component in question. For many of the more familiar organisms (large fish, riparian trees) there would be considerable lag time, with recent hydrological development taking decades to be transferred into detectable environmental impact. For example, Thoms and Walker (1993) have demonstrated that the physical responses of the lower River Murray to weir construction are still incomplete after more than 70 years. Likewise, any recovery in health will also occur over many decades, and might not be noticeable for many years after any allocation of extra water for the environment has been introduced.

9.10 Assumptions and limitations of the assessment process

The *Murray Flow Assessment Tool* (MFAT) is a 'decision support system' designed to demonstrate the potential benefits of increased environmental flows. It refers to habitat condition, and not to population dynamics or recruitment. It is developmental, and outputs should be represented as indicative rather than prescriptive. Judgments made using the MFAT are a synthesis of opinion, in that the performance of the model is weighed against expert opinion (the process is circular in that regard). It is in the nature of science that there are points of doubt or contention, and that element of uncertainty is not suppressed in this report. Further details about the assessment process and the MFAT are provided in section 7 of this report.

10. FUTURE MODEL DEVELOPMENTS

As discussed in Section 2.11 the MFAT is a work in progress and so there are a number of areas in which the MFAT could be improved. One area is the uneven development of the components. This has arisen partly because our knowledge of different indicator groups is at different stages of maturity, but it is also due to the way the MFAT has evolved. An example of the disparity in knowledge can be found within the fish module where there is good information about Golden Perch, but very little data on catfish. An example of the uneven development can be seen by comparing the fish component with the floodplain component. The fish component includes consideration of a range of non-flow parameters that may affect fish recovery where the floodplain, wetland and bird components do not include these considerations, despite the fact that we know that there are many issues apart from flow that affect these communities. Examples include grazing, salinity, groundwater and feral animals.

At present each component of the MFAT is arithmetically combined to produce an index score, meaning that each component is relatively independent of the other components. This is obviously a simplification of the natural world. Birds and fish are dependent on vegetation condition while birds and fish interact in a variety of ways depending on the species involved. The inclusion of some of the known interdependencies should be investigated in an attempt to improve the accuracy of future assessments.

10.1 Floodplain component

The floodplain is a very complex habitat which is one of the reasons that it is able to support high biodiversity. The floodplain and wetland modelling within the MFAT requires that this complex habitat be configured as comparatively simple series of mathematical buckets and pipes. This form of modelling was favoured during development of the EFDSS because the data requirements matched that available. The MDBC has invested in collecting ‘commence-to-fill’ data for most of the wetlands along the River Murray and accurate elevation data. This data, combined with the use of river water levels (rather than flow volumes), will enable more sophisticated floodplain modelling that may allow greater realism to be incorporated into the floodplain assessment. The feasibility of incorporating this type of floodplain modelling into future assessments should be investigated.

The development of more sophisticated floodplain modelling may overcome some of the problems encountered in floodplain modelling including accurately describing the rates of rise and fall, spatial patterns of inundation over time, and the relationship between wetlands and their riparian vegetation.

10.2 Native fish habitat condition model

As noted above the fish model evaluates the response to flow of a number of guilds for which our knowledge ranges from reasonable to scant. There is also considerable disparity in our knowledge of the ecology of the different life stages of these native species. While we have data on adult habitat requirements for many species and spawning habitat requirements for some species, we have very little information on larval and juvenile habitat requirements. A better understanding of these requirements is essential if we are to ensure successful recruitment of fish species. In the long term this knowledge gap highlights the need to collect basic information about the ecology of all life stages. A further limitation of the fish model is that introduced pest fish species are not currently included. The risk of not including introduced species is that particular environmental flows may favour introduced fish which may reduce or negate the positive effects for native species.

Despite the fact that the fish component is one of the best developed models in the MFAT, there is still the potential for further improvement. There has been some discussion of the need to incorporate a water quality parameter into the fish model as water quality, particularly salinity, is a major determinant of habitat suitability for certain species. The impact of the inclusion of a water quality parameter or modification of some of the other parameters on the outcomes of the assessments should be investigated. This does not detract from the ability of MFAT to describe *potential* outcomes for flow scenarios.

10.3 Waterbird habitat condition model

The waterbird component was affected by the floodplain modelling because waterbirds move among floodplain habitats to breed and forage. Refinement of the floodplain modelling may allow more realistic modelling of habitat use by birds. An example is the use of wetland riparian vegetation for breeding which is currently difficult to model, but which may be easier in a more sophisticated floodplain model.

There was considerable discussion about the choice of waterbird groups and their associated habitat preference curves. Due to time constraints, the SRP provided an initial set of preference curves which were reviewed by a panel of ornithologists from the REGs. This approach could be reviewed in the future as better data are acquired, and once a fuller scientific consultation has been undertaken.

10.4 Floodplain and wetland vegetation habitat condition models

As mentioned previously, there is no explicit spatial representation in the MFAT floodplain hydrology model, and therefore it is not possible to track the inundated water depth for any <u>specific</u> part of a floodplain or wetland over time. The incorporation of information from a Geographic Information System (GIS) or a Digital Elevation Model (DEM) would allow the spatial distribution of inundation depths and hence provide a better assessment of habitat condition for different plant species distributed across the floodplain.

The floodplain vegetation and wetland vegetation models were originally developed to represent reproduction from germinating seed. However, some floodplain and wetland species (Lignum and Ribbon weed for instance) reproduce vegetatively. There has been debate between scientists about whether the MFAT preference curves can be adapted to also represent vegetative reproduction. Investigation of the effects of including a vegetative reproduction parameter in the floodplain vegetation and wetland vegetation models could be undertaken as the MFAT is modified.

There was some discussion about the habitat preference curves within the floodplain vegetation and wetland vegetation models. Due to time constraints, the SRP provided an initial set of preference curves which were reviewed by a panel of botanists from the REGs. There is not yet consensus on the exact structure of the vegetation preference curves, and further review should be undertaken.

The concept of ‘flood memory’ is used in the floodplain vegetation model to consider the importance to adult habitat condition of the inter-annual sequence of flood years and non-flood years. This allows simulation of a long term decline in habitat condition in response to overall flood frequency. FM values are determined by a preference curve in terms of the value of a “memory counter”. The memory counter is a running total of ‘good’ and ‘bad’ years for adult habitat condition. Although this is an important ecological concept, the correct calibration of the preference curve by REGs has been difficult. This needs to be reviewed and further development or refinement of its use considered.

CONCLUDING REMARKS

This report and the results and assessments are 'interim'. They should be seen as providing initial guidance on the potential ecological benefits that may be provided by improved flow and non-flow management of the River Murray system. It provides estimates of 'ecological potential' for the options under consideration. The SRP believes that this report will provide a solid foundation for discussion and review amongst scientists, government officials and the broad community, which is its intended purpose. It is not the definitive or final statement of the SRP on ecological benefits potentially arising from the flow volume reference points. The final report is due for submission to MDBC in mid-2004 and there is much work, discussion and review that must occur before that time. The SRP and Cooperative Research Centre for Freshwater Ecology remains committed to providing the best advice to support the on-going Living Murray process.

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12. APPENDICES

Appendix 1. Selection of a Murray Flow Assessment Tool

Summary

The Scientific Reference Panel required a 'Murray Flow Assessment Tool' (MFAT) to assist with the assessment of the 3 environmental flow reference points for the River Murray system. Five environmental flow assessment methods/tools were assessed, and the EFDSS, developed by CSIRO Land & Water and the National Water Research Institute (NWRI) Canada and the Murray Darling Basin Commission (MDBC), was the only method to satisfy all selection criteria, and could be modified to produce a Murray Flow Assessment Tool within the limited time available.

Selecting a basis for the MFAT

The primary role of the MFAT is to provide a structured knowledge based assessment tool to enable scientifically sound judgments about the environmental benefits of the three reference points. It was required for use in late January 2003. This allowed 2-3 months of development time. The development of a new tool would take 1-2 years. It was therefore necessary to use an existing tool, with modifications if necessary.

The following essential criteria define an appropriate MFAT. It should be:

- Structured as a Decision Support System that estimates ecological responses to specified flow regimes for riverine environments at a range of spatial scales. A DSS would ensure that the assessments by each REG would be consistent, repeatable and using the same set of ecological knowledge. (A 'decision support system' is software that integrates models, databases or other decision aids, and packages them in a way that decision makers can readily use).

- Directly applicable to the River Murray system, or adaptable within 2-3 months. It should include ready-to-use tools that model the key elements of the channel and adjacent floodplain, as well as any major wetland complexes connected to the river.

- Effective using existing, available data or make best use of structured expert opinion, since there would be very little time for the collection of extra field data in this phase of the Living Murray Project.

- Applicable to local, regional and system-wide assessments.

There were a number of existing tools or frameworks available for environmental flow assessments (Arthington 1998, Arthington and Zalucki 1998, Tharme 2002) and several of these were considered by the SRP. These included:

- The Flow Events Method (FEM)
- FLOWS
- Downstream Response to Imposed Flow Transformations (DRIFT)
- Instream Flow Incremental Method (IFIM)

- Environmental Flows Decision Support System (EFDSS).

In the following section, each of these methods was evaluated against the 4 criteria listed above.

The Flow Events Method

The Flow Events Method (FEM) was developed by Dr Mike Stewardson and the Cooperative Research Centre for Catchment Hydrology (CRCCH) (Stewardson and Cottingham 2002). This method uses hydraulic parameters to compare different flow scenarios. Graphical outputs allow comparison between the recurrence interval of flow events for a reference flow regime against a set of modified flow regimes.

FEM does not meet criterion 1, since it relies upon an expert reference panel, rather than a DSS, to make judgements about the ecological and geomorphic responses of the system to each of the modified flow regimes. This does not ensure a repeatable prediction of ecological outcomes by different groups, which is considered essential for this project.

It has been used successfully throughout Victoria, including lowland rivers. However, it is designed for the assessment of the riverine channel and adjacent floodplain, not the associated wetland systems, and therefore only partially satisfies criterion 2.

FEM relies on hydraulic modelling of the river channel and this requires detailed hydraulic data for each river reach that is assessed. This data must be collected by field measurements over multiple cross sections within each reach. Enough cross sections must be measured to provide a representative sample of all types of sections within the reach. It is the opinion of the SRP that despite the considerable promise of the method, the time available to the REGs would not allow for this intensive data collection. Thus FEM does not meet criterion 3 as it has data requirements that cannot be met within the limited time available.

FEM can be easily expanded from the assessment of one location, to the assessment of multiple locations along a reach, or to a whole-of-river assessment, and hence meets criterion 4.

In conclusion, FEM has been successfully applied to a number of rivers throughout Victoria, including lowland rivers, but would not be suitable as the MFAT since it is not a structured, knowledge based DSS but instead relies upon an expert panel. It also requires the collection of a large amount of field data before the method can be applied.

FLOWS

FLOWS is an overarching framework being used successfully in Victoria to guide scientific reference panels when undertaking environmental flow assessments (SKM et al. 2002). The method considers environmental assets and their value, the threats posed by activities and processes such as flow regulation and the diversion of water for consumptive purposes, and then determines the key flow components that need to be restored to meet environmental or ecological objectives. FLOWS has been tested on three lowland rivers in Victoria, the Avoca, Wimmera and Glenelg Rivers, and is currently being applied to the Goulburn River.

The FLOWS method is used to develop recommendations for environmental water requirements that will satisfy a set of agreed environmental objectives, but can also be used for the assessment of environmental water provisions, such as the three reference points specified by the MDBMC (350, 750 and 1500 GL/yr).

The FLOWS method is usually applied by a scientific panel, which uses available hydrological, geomorphic and ecological data to describe relationships between the aquatic ecology and riverine hydrology. These ecological relationships are not provided in the form of a structured DSS, and hence the FLOWS method does not meet criterion 1.

FLOWS is a flexible and transparent framework that includes the use of tools such as hydraulic models to assess how changes to components of the flow regime affect the availability of physical features that serve as in-channel and floodplain habitat. The scientific panel also has the flexibility to adopt what it considers is the best available approach to developing environmental flow recommendations. For example, the Flow Events Method is being used in the current Goulburn River study to determine the frequency and timing of flow components that should be restored. The scientific panel also has access to a high resolution DEM to assess the water regime of the floodplain–wetland complex of the lower reaches. These tools are not normally available and have to be developed before the FLOWS method can be applied, and hence it only partially meets criterion 2.

The hydraulic modelling recommended by the FLOWS method requires a minimum of 3 cross sections to be established and measured at each site. On a whole-of-river basis, this would involve a large number of field surveys along the River Murray system, and hence criterion 3 is not satisfied.

The FLOWS method can be easily expanded from the assessment of one location, to the assessment of multiple locations along a reach, or to a whole-of-river assessment, and hence meets criterion 4.

In conclusion, FLOWS is a transparent framework which guides the assessment of environmental flows by a scientific panel. It is not a structured, knowledge based DSS, which is one of the key requirements of the MFAT. It has been successfully tested on lowland rivers in Victoria and would be equally applicable to the assessment of the River Murray system if suitable tools were readily available for the hydrologic and hydraulic assessment of the channel and floodplain wetlands.

IFIM (Instream Flow Incremental Method)

IFIM is a structured methodology that is used to predict the physical habitat condition for nominated target species. It has been applied to rivers in a number of countries. It is supported by an integrated habitat simulation and analysis system (PHABSIM - Physical Habitat Simulation System), which was developed under the leadership of the U.S Fish and Wildlife Service (Bovee 1982, Bovee *et al,* 1998).

IFIM provides quantitative predictions of changes in physical habitat as discharge is altered, and relates these changes to the implications for fish (and occasionally macroinvertebrates) with various habitat preferences. It does not aim to predict the population response of specific fish or other biota, only the change in habitat availability for each species.

IFIM is not a structured Decision Support System and therefore does not meet criterion 1.

In its current form, IFIM concentrates on the habitat requirements of fish and does not assess floodplains and their associated communities, and hence would need significant modifications. This would be likely to take more than 2 months and thus IFIM does not meet criterion 2.

IFIM requires intensive field data collection of measurements such as pH, dissolved oxygen, water depth, velocity, channel depth and cover along transects at multiple sites within each reach (Stalnaker *et al* 1995). Not all this data is readily available for the Murray system, and hence a major data collection exercise would need to be undertaken. Hence, IFIM does not meet criterion 3.

IFIM provides a structured, transparent and repeatable method for assessment at a local scale, but has not been applied on a system-wide scale such as the entire River Murray system. It therefore only meets part of criterion 4.

In conclusion IFIM has been fully tested internationally to assess the habitat requirements of fish, but would need significant modification to provide assessment of large-scale floodplain ecosystems. It is also not suitable for use as the MFAT due to the large amount of time that would be required for data collection.

DRIFT

DRIFT (Downstream Response to Imposed Flow Transformations) was developed by Professor Jackie King and others (King *et al,* in press; Brown and King, 2000) to assess environmental flows for rivers in South Africa. It is essentially a carefully designed set of data management tools linking changes in flow regime with geomorphological and ecological responses. It relies on the use of expert advice (including information from the published literature) from a multidisciplinary team in a workshop environment.

DRIFT consists of 4 modules. 1) Biophysical, 2) Socio-economic, 3) Scenarios for future flows, 4) Economic. For each potential future e-flow regime, DRIFT predicts;

- Biophysical consequences - condition of river ecosystem
- Socio-economic consequences for subsistence users of the river
- Yield changes of the scheme in terms of economics.

DRIFT supports a decision process and uses a custom built database to provide quantitative predictions of ecological response to specified flow regimes. These predictions are provided in the form of proportional changes for a broad range of geomorphological and ecological components at both local and system-wide scales. The database is populated during a specialist workshop, with the predicted consequences for the river of a range of possible changes to the flow regime. Although DRIFT is not strictly a DSS as the knowledge base is constructed from expert knowledge derived from a workshop, it does provide a structured, transparent and repeatable method of assessment, and hence partially meets criterion 1.

DRIFT was developed in upland rivers of South Africa but has also been applied to the Breede Basin (also in South Africa), which traverses both upland and lowland regions. Therefore DRIFT does meet criterion 2.

The main disadvantage of Drift is that it would require a vast amount of data collection. It is the opinion of the SRP that the data requirements of DRIFT may take up to one year, which exceeds the time available for the project. DRIFT thus does not meet criterion 3.

DRIFT can be used for the assessment of one location, a river reach, or the entire river, and hence meets criterion 4.

Although DRIFT does not meet all of the essential criteria, the SRP considers that DRIFT may be a suitable tool for use in future assessment of the environmental flow requirements in the Murray, when more time is available to make the required modifications and collect the necessary data.

The EFDSS

The EFDSS (Environmental Flows Decision Support System) was developed by CSIRO Land & Water and Environment Canada, with funding from the MDBC, LWRRDC and Environment Australia (Young *et al.*, 1999a,b).

It is a software package designed to assist communities and government agencies jointly explore the ecological outcomes associated with various flow regimes in regulated rivers. It provides a structured, transparent and repeatable method for assessment. Incorporated into the ecological models is expert knowledge on the relationship between aspects of riverine ecology and river flow. It integrates models of river hydrology, floodplain inundation, river geomorphology, weir pool stratification, and in-stream habitat in a single modelling system that provides predictions on the habitat condition for fish, waterbirds, algae and floodplain vegetation under different flow scenarios. The EFDSS thus meets criterion 1.

This tool was developed specifically for the Border Rivers in the north of the Murray-Darling Basin. It therefore includes the main river channel and associated floodplain, anabranches, billabongs and wetland complexes. The EFDSS thus meets criterion 2.

A large amount of scientific knowledge on lowland river ecology (specific to the Murray-Darling Basin) has already been incorporated into the ecological models of the EFDSS, and the data input required to run the models is therefore relatively low. The SRP estimates that data entry could be completed within 6 weeks and thus the EFDSS meets criterion 3.

The EFDSS contains methods for integrating results from different localities along the river to provide assessments at local, regional or system wide scales, and hence meets criterion 4.

The EFDSS was designed for use by catchment management groups and state or federal agencies, and has been designed with a 'user friendly' interface which allows relatively easy and rapid assessment of different flow scenarios. The EFDSS also contains a number of tools which assist with the analysis, interpretation and presentation of results.

In conclusion, the EFDSS meets all 4 essential criteria.

Final choice of assessment tool

The EFDSS is the only option that meets all selection criteria (see Table 1). It is a decision support system that provides quantitative predictions of ecological response to specified flow regimes in the form of indices, for a broad range ecological components, at both local and system-wide scales. It is applicable to a lowland river floodplain system, such as the Murray. The basic data input requirements are relatively low and can be met within 6 weeks. It provides a structured, transparent and repeatable method for assessment for each river zone by the Regional Evaluation Groups and also for a system-wide level of analysis. Finally, it has the future potential for use in adaptive management by the MDBC as new flow scenarios can easily be assessed and the models can be modified as new knowledge comes to hand. It was therefore the opinion of the SRP that under the limited time available, the EFDSS would be the most appropriate basis from which to develop the MFAT.

Table 1. Assessment of the 4 environmental flow assessment tools/frameworks

Criteria	1	2	3	4
Flow events Method	No	Yes/No	No	Yes
FLOWS	No	Yes/No	No	Yes
IFIM	No	No	No	Yes/No
DRIFT	Yes/No	Yes	No	Yes
EFDSS	Yes	Yes	Yes	Yes

Appendix 2. Developing flow scenarios for the three reference points

Background

MDBC has sought guidance from SRP on how to develop a set of flow scenarios for each of the three reference points.

The MDBC daily flow model, MSM-Bigmod, is designed to simulate different releases of water from dams and weirs for both irrigation and environmental purposes in the Murray. It incorporates operational rules describing physical constraints in the system and the need to deliver irrigation water at certain times of the year. MSM-Bigmod does not model flows in the two main tributaries, the Goulburn River and Murrumbidgee River, and the flow data for these rivers must come as end of system flows predicted by models that are run by Victoria and NSW respectively. This places a further restriction on the development of flow scenarios.

Despite these restrictions, for each reference point (350GL. 750 GL and 1500GL) the MDBC still has considerable flexibility to develop flow scenarios that apply the extra water to different parts of the river or floodplain at varying times of the season, or at different parts of the hydrograph. Information is still required about:

Timing

Possibilities such as

- Increase the height or duration of minor-moderate floods to allow greater flooding of a specified wetland
- Supply extra water during a dry spell to flush the channel or keep the mouth open

Location

Deployment of additional flows could be

- Send the water to the mouth
- Supplied to Barmah/Millewa forest or Chowilla floodplain
- Used as an in-channel fresh to assist with water quality and for instream fauna (fish).

Proposed rules for flow scenario optimisation

A set of priorities for optimising the flow scenarios for ecological benefit was proposed by the SRP. The priorites listed in no particular areelisted below;

- Restore/Improve water regime to the icon sites and species specified by Ministerial Council
- Restore/Improve water regime to Ramsar wetland sites
- Apply the Ministerial Council Objectives for Environmental Flows. These are; 1) Reinstate ecologically significant elements of the natural flow regime, 2) Keep the

Murray Mouth open to maintain navigation and fish passage and to enhance estuarine conditions in the Coorong, 3) Significantly improve connectivity between and within riverine, wetland, floodplain and estuarine environments.

The ERP had already developed 12 environmental flow requirements (EFRs) which satisfy the priorities and objectives outlined above. The ERP also developed 16 hydrological indicators that were associated with the EFRs. These have already been incorporated into the MSM-Bigmod model, and can be used to determine the effectiveness of each flow scenario in reference to these EFRs. A large set of indicators developed by other groups (MDBC, Sustainable Rivers Audit and Jurisdictional Reference Panel) has also been incorporated into MSM-Bigmod and can also be used (for instance the SRA hydrology indices for each river zone).

As a starting point, and to ensure a level of ecological equity between zones, it was proposed to use a subset of the EFRs and associated hydrological indicators developed by the ERP in each of the zones. The subset of EFRs and Hydrological Indicators that were selected are those that represent the key issues and priority sites, as determined by the SRP, along each river zone. These indicators should also respond to changes in flow regime that are expected from the 350, 750 and 1500 GL/yr reference points. In some instances, a few additional hydrological indicators developed by the SRA, MDBC or JRP were also included.

To ensure that the Icon sites specified by The Ministerial Council are given due attention, an increased weighting has been applied to the relevant hydrological indicators.

Table 1a. Proposed hydrological indicators for the flow scenario optimisation

River zone	Environmental flow requirement	ERP Hydrological Indicator	weighting
Zone 1 (Mitta Mitta R.)	Minimise high summer flows	I1. Median summer Tallandoon Flow Nov-Mar in GL/yr	Low
	Avoid unnaturally prolonged periods of constant river height	I2. Constant level: 75^{th}% of daily change in level, Nov-Feb, Tallandoon (cm)	Low
Zone 2 (Hume-Yarrawonga)	Minimise high summer flows	I3. Median summer Doctors Pt flow, Nov-Mar in GL/yr	Low
	Avoid unnaturally prolonged periods of constant river height	I4. Constant level: 75^{th}% of daily change in level, Nov-Feb, Tallandoon (cm)	Low

Zone 3 (Yarrawonga to d/s Wakool Junction)	Minimise high summer flows	I5. Median summer Yarrawonga flow, Nov-Mar in GL/yr	High
	Interval between floods approaches natural condition	I6. Flood flow sequence at Torrumbarry – median interval between Significant Flood Inundation (SFI) events (>40,000 ML/day for 14 days)	High
	Avoid unnaturally prolonged periods of constant river height	I7. Constant level: 75^{th}% of daily change in level, Nov-Feb, Tocumwal (cm)	High
Zone 4 (Wakool Junction to U/s Darling Junction)	Interval between floods approaches natural condition (CTF events)	I8. Flood flow sequence at Euston – median interval between Commence to Flow (CTF) events (>36,700 ML/day for 14 days)	High
	Interval between floods approaches natural condition (SFI events)	I9. Flood flow sequence at Euston – median interval between Significant Flood inundation (SFI) events (>48,900 ML/day for 14 days)	Low
Zone 5 (Darling Junction to Lock 3)	Flow related Water quality; Managing turbidity in South Australia	I10. Mean % Darling Water of total Wentworth Flow, Nov-Feb.	High
	Interval between floods approaches natural condition for SA wetlands	I11. Flood flow sequence to SA – median interval between SFI events	High
Zone 6 (Lock 3 to Wellington)	Total volume of flow greater than channel capacity – amount of water available to wetlands	I12. Average annual Lock 3 downstream flow > channel capacity (63,000 ML/day) (GL/yr)	Low
	Increase range of flows on seasonal basis	I13. Flow range: Seasonal amplitude index – zone 6	Low
Zone 7 (Lower Lakes, Coorong, Mouth)	Reduce risk of the Murray Mouth closing	I14. % years with mouth opening index < 0.05 (which indicates high risk of mouth closing)	High
Zone 8 (Lower Darling and Anabranch)	Continuity of fish passage	Fish passage; % yrs weir 32 drowned , Aug-Nov (>7,000 ML/day for 1 month)	Low

Table 1b. Additional Indicator to be assessed separately for all runs

Zone 7	Maximise river flows for salt dilution purposes, within the natural range	Salinity – Mean EC at Morgan	

Notes for Table 1, Currently there are no indicators being used for the Goulburn or Murrumbidgee Rivers because MSM-Bigmod does not model these tributaries. There might be a need for a manual assessment of ecological benefits/impacts associated with scenarios for these rivers.

Proposed set of model runs for the optimisation process

The MDBC will use the MSM-Bigmod model to test a range of different operating rules along the River Murray, for each of the three reference points. For each simulation, the proposed hydrological indicators (given in column 3 of Table 1) will be combined with their weighting (column 4 of Table 1) to provide the 'system level benefit index' along the river, which might be used to compare the benefits of each model run, and considered alongside estimates of the social and economic impacts to assess flow scenarios for each reference point (350, 750 and 1500 GL/yr).

Appendix 3. Summary of Hydrological Modelling of Scenarios for the Three Reference Points for the River Murray System

Introduction

This paper focuses on the modelling that has been undertaken using the hydrological model, MSM-Bigmod, for the three reference points.

MSM-Bigmod simulates the operation of the River Murray System under any given set of conditions, through the historic sequence of climate for which information is available (109 years, from 1891 – 2000The model includes an estimate of losses as the flows move down the river (both in-channel and overbank) and has been calibrated over the period 1973 to 1996, with special attention paid to water levels in the floods of 1981, 1992, 1993 and 1996 - four floods of similar magnitude. Further details regarding the hydrological model are provided in the MDBC report "*Setting up of MSM-Bigmod modelling Suite for the River Murray System*" (MDBC Technical Report No 2002/5, November 2002).

For *The Living Murray* Initiative, hydrological modelling has been undertaken around the three reference points nominated by the Ministerial Council in April 2002 – these involve the recovery of 350 GL, 750 GL and 1500 GL of water for the environment.

In line with Council's direction, the overall aim of the modelling is to develop scenarios around the three reference points that optimise environmental outcomes whilst minimising impacts on existing water users. The intention of these model runs is to allow assessment and consideration of the scale of benefits and impacts that could be achieved under each of the three reference points. By no means should they be considered to be definitive model runs for adoption and on-ground implementation. On the contrary, they represent coarse changes that need further refining, including integrated modelling with the tributaries and improved modelling of potential changes associated with Snowy/Murray environmental flows.

Up to three proposed scenarios have been put together for each reference point, by combining a series of different 'option components' (or individual structural and operational changes, and changes to water sharing).

Model runs for comparison purposes

The following four model runs; Natural, Current, Reference and Actual, are provided to allow the results of the proposed scenarios and option components (described in Sections 4 and 5) to be compared with these baseline model runs as appropriate. Such a comparison can be used to illustrate the costs and benefits associated with making the proposed changes.

Natural Conditions

Natural conditions are simulated by running the model with a scenario in which the dams, locks and weirs are 'removed' (capacities set to zero), there is no consumption of water, and tributary inflows are derived from 'natural conditions' model runs provided by the States. This model run is number 5327000.

Current Run

The Current run represents the conditions that existed in 2002 in terms of operating rules, procedures, level of development and management practices (ie. Current conditions, or now). This includes the environmental flow provisions agreed in recent years in the River Murray System and its tributaries, for example, the Barmah-Millewa allocation (rules agreed by Ministerial Council in March 2001). This model run is number 5348000.

The modelling of proposed scenarios that are designed to test changed operating or water sharing practices (as described in Sections 4 and 5) are compared to the conditions in the Current run as base conditions.

Reference Run

This model run forms the starting point (or "line in the sand") from which water recovered for the environment is measured (also referred to as the benchmark). That is, water recovered under each of the reference points (350 GL, 750 GL and 1500 GL) is counted as the change from the Reference run in the long term average annual amount of water either: 1) diverted directly from the River Murray; or 2) flowing from a tributary into the River Murray.

A model run has been selected by the MDBC office as the "Reference run" for assessment and discussion purposes ONLY. This run has not yet been signed off by the jurisdictions, and will be resolved by the jurisdictions and endorsed by Commission and Council in the near future.

The Reference run selected by the MDBC office represents the cap conditions, with diversions in NSW, Vic and SA at full Cap levels (note that SA currently diverts less than it is allowed to under the Cap). It also includes the operational rules that were in place in 1993/94 for NSW and Victoria, as that was the year upon which the Cap on diversions was based when it was established in 1995. This model run is number 5347000.

Actual

The Actual scenario is based on actual historical data, showing the transition from natural to current conditions. Data are provided from 1971 to 1999 for calibration of predicted values only. This model run is number 5495000.

Proposed flow scenarios for the three reference points

Three proposed scenarios for each of the three reference points have been prepared by combining an increase in inflows from the tributaries with a series of 'option components' (or individual structural and operational changes, and changes to water sharing). The 'option components', along with providing environmental benefits, result in reduced reliability of the River Murray water supply and a consequent reduction in average River Murray diversions.

In the absence of integrated modelling of the River Murray System with the major tributaries, it was assumed that cap reductions were implemented on the tributaries, providing the increase in inflows from these systems.

The scenarios were designed to illustrate some of the trade-offs that need to be made between the different parts of the environment along the River Murray eg Murray vs Darling and Murray main stem vs Murray Mouth.

Cap-Scenarios

350 GL – Cap

The Cap is reduced on the NSW Murray, NSW Lower Darling, Vic Murray and SA Murray by approximately 4%, thereby reducing diversions. Inflows from the tributaries (Murrumbidgee, Billabong Creek, Goulburn, Broken, Campaspe and Loddon) were changed by adjusting outflows by 5% of the difference between the outflows in the reference and natural conditions.

750 GL – Cap

The Cap is reduced on the NSW Murray, NSW Lower Darling, Vic Murray and SA Murray by approximately 7%, thereby reducing diversions. Allocations on the tributaries were reduced until the long-term average diversion reached 10% below Cap, resulting in increased inflows to the River Murray.

1500 GL – Cap

The Cap reduced on the NSW Murray, NSW Lower Darling, Vic Murray and SA Murray by approximately 17%, thereby reducing diversions. Allocations on the tributaries were reduced until the long-term average diversion reached 20% below Cap, resulting in increased inflows to the River Murray.

B-Scenarios

In each scenario, a number of structural and operational changes have been made on the Murray to target various environmental assets, primarily the Mitta Mitta River, wetlands downstream of Hume, Barmah-Millewa Forest and the Murray Mouth. Progressively more changes can be made as more water is recovered, for example, the Chowilla floodplain is added to the list of assets targeted.

Further, each of the B scenarios assume that the outcomes of the Snowy Water Inquiry are implemented, generating water use efficiency savings to create an entitlement for the Snowy River of 212 GL/year and an entitlement for the Murray of 70 GL/year. Assumed savings for the Snowy from the Goulburn of 50 GL/year result in increased Goulburn tributary flows (over and above any cap reduction).

Details on each scenario are provided below.

350 GL – B

A number of structural and operational changes have been made on the Murray which target the base list of environmental assets, as follows:

When planning releases from Dartmouth to Hume for the rest of the season, the maximum target for transfers between December and March is reduced from 10,000 ML/d to 5,000 ML/d, to reduce the impact of erosion on the Mitta Mitta River;

The maximum regulated release downstream of Hume Dam is increased from 25,000 ML/d to 42,000 ML/d for the purposes of environmental releases and flood pre-releases, to allow wetting of wetlands from Hume Dam to the Barmah choke;

The volume down to which the Barmah-Millewa Forest allocation in Hume can spill is increased from 200 GL to 300 GL. Further, the Barmah-Millewa medium-size flood target is increased from 21,000 ML/day for a month every three years to 35,000 ML/d every five years to achieve larger floods in the forest on a regular (although less frequent) basis; and

The Lower Lakes are operated between 0.6m AHD and 0.9m AHD to supply 2,000 ML/d over the barrages whenever possible, to keep the Murray Mouth open.

When combined with a 5% Cap reduction (or equivalent measures) on the tributaries, the overall long-term average impact on diversions and increase in tributary flows from these rules is equivalent to 370 GL/year from Cap conditions. This includes an extra 235 GL/year from tributaries, 70 GL/year less from the Snowy and 206 GL/year from reduced diversions on the Murray (including 90 GL/year of reductions associated with savings for the Snowy Scheme).

750 GL – B

A number of structural and operational changes have been made on the Murray which target the base list of environmental assets, plus the Chowilla floodplain, as follows:

When planning releases from Dartmouth to Hume for the rest of the season, any water (less 750 GL) that is scheduled to be released before February is brought forward to release in September-November in the form of a spring pulse, at rates up to 15,000 ML/day. This aimed at wetting the Mitta Mitta floodplain in spring, as well as reducing erosion by reducing the amount of time that transfers need to be made at channel capacity;

The maximum regulated release downstream of Hume Dam is increased from 25,000 ML/d to 42,000 ML/d for the purposes of environmental releases and flood pre-releases, to allow wetting of wetlands from Hume dam to the Barmah choke. In addition, irrigation releases downstream of Hume are reduced to 20,000 ML/day to go some way towards reducing the unseasonality of flows in this part of the river;

The Barmah-Millewa Forest environmental flow allocation (from Hume Dam) is manipulated so that it cannot spill (ie none of the e-flow allocation is wasted or lost). This enhances the effectiveness of releases from the e-flow account in achieving the pre-designed floods in Barmah Millewa.

Whenever the flow at Euston is greater than 50,000 ML/day, releases are made from Lake Victoria and Menindee Lakes at maximum rates, to increase the peak flow of these flood events, and increase the extent of flooding of the Chowilla floodplain; and

The Lower Lakes are operated between 0.6m AHD and 0.9m AHD to supply 2,000 ML/d over the barrages whenever possible, to keep the Murray Mouth open.

When combined with a 10% Cap reduction (or equivalent measures) on the tributaries, the overall long-term average impact on diversions and increase in tributary flows from these rules is equivalent to 751 GL/year from Cap conditions. This includes an extra 474 GL/year from tributaries, 70 GL/year less from the Snowy and 347 GL/year from reduced diversions on the Murray (including 90 GL/year of reductions associated with savings for the Snowy Scheme).

1500 GL – B

A number of structural and operational changes have been made on the Murray which allow further improvements to the base list of environmental assets, plus the Chowilla floodplain, as follows:

Releases from Dartmouth to Hume are adjusted to include the rules described for both the 350GL-B scenario and the 750GL-B scenario, and therefore aim to allow wetting of the Mitta Mitta floodplain in spring, as well as reducing erosion;

Releases downstream of Hume are adjusted as per the 750GL-B scenario, and aim to allow wetting of wetlands from Hume dam to the Barmah choke and go some way towards reducing the unseasonality of flows in this part of the river;

Contributions to the Barmah-Millewa Forest allocation by NSW and Victoria are increased from up to 75 GL/year each, to up to 150 GL/year each. The account is allowed to accumulate to 900 GL in size and cannot spill. Further, the Barmah-Millewa medium-size flood target is increased from 21,000 ML/day to 31,000 ML/day for a month every three years to achieve larger floods in the forest on a regular basis;

Replace additional dilution flow of 3,000 ML/d when Menindee Lakes storage is above 1,300 GL, with a release of 35,000 ML/d in September and October but only if no similar flood was received in the previous year, to increase the frequency of small flood events at the Chowilla floodplain;

Whenever the flow at Euston is greater than 50,000 ML/day, releases are made from Lake Victoria and Menindee Lakes at maximum rates, to increase the peak flow of these flood events, and increase the extent of flooding of the Chowilla floodplain;

South Australia's entitlement flow is increased by 2,000 ML/d every month, and the Lower Lakes are operated between 0.6m AHD and 0.9m AHD, to supply 2,000 ML/d over the barrages whenever possible to keep the Murray Mouth open.

When combined with a 20% Cap reduction (or equivalent measures) on the tributaries, the overall long-term average impact on diversions and increase in tributary flows from these rules is equivalent to 1518 GL/year from Cap conditions. This includes an extra 811 GL/year from tributaries, 70 GL/year less from the Snowy and 778 GL/year from reduced diversions on the Murray (including 90 GL/year of reductions associated with savings for the Snowy Scheme).

C-Scenarios

In each scenario, a number of structural and operational changes have been made on the Murray and Lower Darling to target various environmental assets, primarily the Mitta Mitta River, wetlands downstream of Hume, Barmah-Millewa Forest, the Lower Darling and Anabranch and the Murray Mouth. Progressively more changes can be made as more water is recovered, for example, the Chowilla floodplain is added to the list of assets targeted.

Further, the C scenarios do NOT include the outcomes of the Snowy Water Inquiry. Details on each scenario are provided below.

350 GL – C

A number of structural and operational changes have been made on the Murray which allow further improvements to the base list of environmental assets, plus the Chowilla floodplain and the Darling Anabranch, as follows:

When planning releases from Dartmouth to Hume for the rest of the season, the maximum target for transfers between December and March is reduced from 10,000 ML/d to 5,000 ML/d, to reduce the impact of erosion on the Mitta Mitta River. In addition, 30 % of the natural inflows to Dartmouth Dam *between June and September* are released from the Dam, to try and restore some of the natural flow variability to the river;

The maximum regulated release downstream of Hume Dam is increased from 25,000 ML/day to 42,000 ML/day for the purposes of environmental releases and flood pre-releases. In addition, releases from Hume Dam are boosted by 10,000 ML/day for a month when the modelled natural flow would have exceeded 32,000 ML/day (if a similar flood did not occur in the previous year). These changes aim to improve wetting of wetlands from Hume dam to the Barmah choke;

The volume down to which the Barmah-Millewa Forest allocation in Hume can spill is increased from 200 GL to 500 GL. Further, the Barmah-Millewa medium-size flood target is increased from 21,000 ML/day to 35,000 ML/day for a month every three years to achieve larger floods in the forest on a regular basis.

Whenever the flow at Euston is greater than 50,000 ML/day, releases are made from Lake Victoria and Menindee Lakes at maximum rates, to increase the peak flow of these flood events, and increase the extent of flooding of the Chowilla floodplain;

The replenishment releases to Great Darling Anabranch are replaced with piped supply, saving 35 GL/yr and allowing a more natural flow regime to be reinstated; and

The Lower Lakes are operated between 0.6m AHD and 0.9m AHD to supply 2,000 ML/d over the barrages whenever possible, to keep the Murray Mouth open.

When combined with a 5% Cap rediction (or equivalent measures) on the tributaries, the overall long-term average impact on diversions and increase in tributary flows from these rules is equivalent to 368 GL/year from Cap conditions. This includes an extra 184 GL/year from tributaries and 184 GL/year from reduced diversions on the Murray.

750 GL – C

A number of structural and operational changes have been made on the Murray which allow further improvements to the base list of environmental assets, plus the Chowilla floodplain, the Lower Darling and the Great Darling Anabranch, as follows:

When planning releases from Dartmouth to Hume for the rest of the season, the maximum target for transfers between December and March is reduced from 10,000 ML/d to 5,000 ML/d, to reduce the impact of erosion on the Mitta Mitta River. In addition, 30 % of the natural *year-round* inflows to Dartmouth Dam are released from the Dam, to try and restore some of the natural flow variability to the river;

Releases downstream of Hume are adjusted as per the 350GL-C scenario, and aim to improve wetting of wetlands from Hume dam to the Barmah choke;

The Barmah-Millewa Forest allocation is adjusted so that it can not spill, and the medium-size flood target is increased from 21,000 ML/day to 31,000 ML/day for a month every three years to achieve larger floods in the forest on a regular basis;

The additional dilution flow of 3,000 ML/d when Menindee Lakes storage is above 1,300 GL, is replaced with a release of 35,000 ML/d in September and October (if no similar flood was received last year), to increase the frequency of small flood events at the Chowilla floodplain;

The replenishment releases to Great Darling Anabranch are replaced with piped supply, saving 35 GL/yr and the Anabranch Weirs are removed allowing a more natural flow regime to be reinstated; and

The Lower Lakes are operated between 0.6m AHD and 0.9m AHD to supply 2,000 ML/d over the barrages whenever possible, to keep the Murray Mouth open.

When combined with a 10% Cap reduction (or equivalent measures) on the tributaries, the overall long-term average impact on diversions and increase in tributary flows from these rules is equivalent to 739 GL/year from Cap conditions. This includes an extra 423 GL/year from tributaries and 316 GL/year from reduced diversions on the Murray.

1500 GL – C

A number of structural and operational changes have been made on the Murray which allow further improvements to the base list of environmental assets, plus the Chowilla floodplain, the Menindee Lakes, Lower Darling and the Great Darling Anabranch, as follows:

Releases from Dartmouth to Hume are adjusted as per the 750GL-C scenario to reduce the impact of erosion on the Mitta Mitta River and restore some of the natural flow variability to the river. In addition, the Dartmouth Power Station is permitted to generate when the Dam is spilling and the flow at Tallandoon is greater than 10,000 ML/d, resulting in peakier floods in the Mitta Mitta River;

Releases downstream of Hume are adjusted as per the 350GL-C scenario, and aim to improve wetting of wetlands from Hume dam to the Barmah choke;

Contributions to the Barmah-Millewa Forest allocation by NSW and Victoria are increased from up to 75 GL/year each, to up to 200 GL/year each. The account is allowed to accumulate to 900 GL in size and can not spill. Further, the Barmah-Millewa medium-size flood target is increased from 21,000 ML/day to 31,000 ML/day for a month every three years to achieve larger floods in the forest on a regular basis;

Additional dilution flows are adjusted as per the 1500GL-B scenario, to increase the frequency of small flood events at the Chowilla floodplain;

The use of flow at Euston to trigger releases from Lake Victoria and Menindee Lakes, as per the 1500GL-B scenario, is included to increase the peak flow and extent of flooding of the Chowilla floodplain;

The replenishment releases to Great Darling Anabranch are replaced with piped supply, saving 35 GL/yr and the Anabranch Weirs are removed allowing a more natural flow regime during high flows to be reinstated;

Lake Menindee in the Menindee Lakes is decommissioned and its capacity set to 0 GL. This is an initial scoping exercise to assess the potential benefits that the more natural flow regime, reduced evaporation, and increased the flow bypassing the Menindee Lakes system would provide to the Lakes themselves, the Lower Darling and Anabranch and the Lower Murray. Further modelling should be undertaken in which Lake Menindee is reverted to a natural lake and allowed to wet and dry under a natural regime; and

South Australia's entitlement flow is increased by 2,000 ML/d from January to May, and the Lower Lakes are operated between 0.6m AHD and 0.9m AHD, to supply 2,000 ML/d over the barrages whenever possible to keep the Murray Mouth open.

When combined with a 20% Cap reduction (or equivalent measures) on the tributaries, the overall long-term average impact on diversions and increase in tributary flows from these rules is equivalent to 1532 GL/year from Cap conditions. This includes an extra 773 GL/year from tributaries and 759 GL/year from reduced diversions on the Murray.

Appendix 4. Summary of localities and weightings used by each REG

The process of providing simple measures of relative ecological condition demands a means of amalgamating or agglomerating individual measurements and observations into 'scores' that are meaningful, and equitable across the components of the ecosystem and across the whole river system, and that provide a sensitive, comparative, metric. One step in achieving this is to address the issue of weightings. This provides the means of emphasising (or de-emphasising) the relative significance of:

- Any component (eg species or life stage) within any of the five modules
- Any of the modules within an individual REG
- Any one zone in establishing a 'whole-of-river' assessment.

The last is addressed in Section 6 of this report. This appendix describes agreed weightings at the remaining two levels of organisation.

A4.1 Weightings between ecological modules, within zones.

These are the weights used by each of the REGs when providing a zone-wide habitat index.

Table 1. Weightings between ecological models, within a zone.

Zone	Fish	Waterbirds	Floodplain veg	Wetland veg	Algal blooms
A (Mitta Mitta)	1.0	0.5	1.0	1.0	0
B (Hume to Yarrawonga)	1.0	1.0	1.0	1.0	0
C (Yarrawonga to wakool Jn)	1.0	1.0	1.0	1.0	0
D (Wakool Jn. to lock 11)	1.0	1.0	1.0	1.0	1.0
E (Lock 11 to Lock 3)	1.0	1.0	1.0	1.0	1.0
F (lower darling)	1.0	1.0	1.0	1.0	0
G (Lock 3 to Wellington)	1.0	1.0	1.0	1.0	1.0
H (Lower Lakes/Coorong)					
I (Goulburn)					
J (Murrumbidgee)	1.0	1.0	1.0	1.0	0

Notes;
Algal blooms were given zero weighting in zone A, B, and C since algal blooms are extremely unlikely in the reaches considered in these zones (Zones A, B, and C contain large reservoirs but flow manipulations of the type considered in this study would be sufficient to influence algal blooms in those water bodies)
Algal blooms were given weighting of zero in zones F and J (In zone F algae were not modelled, and in zone J algae were modelled but not included in overall assessment)
Waterbirds in zone A were given a lower weighting since there are no major breeding grounds in this zone.
An overall zone index was not calculated for zone H.

A4.2 Weightings within ecological modules and zones.

Tables 2 to 6 present the weightings for calculating amalgamated indices for each module of MFAT and which were established by individual REGs and endorsed by the SRP. The rationale for these decisions is presented in the REG reports (Appendix ~).

Table 2. Weightings used by REGs for fish assessments

Zone	locality	Locality weight	Fish group weightings						
			1	2	3	4	5	6	7
A	Upper mitta	0.9	0	1	0.5	0	1	1	0
	Lower mitta	1	1	1	1	0	1	1	1
B	Richardsons bend	1	1	1	1	1	1	1	1
	Croppers lagoon	1	1	1	1	1	1	1	1
C	Yarrawonga to Tocumwal	1	1	0	0	0	0	1	0
	Edward River	1	2	0	0	2	0	2	1
D	Colignan R	1	1.5	0.2	1	0.2	1	1	1
	Wakool River	1	1.5	0.2	1	0.2	1	1	1
E	Lock 7	1	1	0	0.5	1	1	1	1
	Mullaroo Ck	1	2	0	0	0	0	5	0
F	Darling anabranch weir 32	1	2	0	0	1	1	2	1
	Northern lower darling - wycot	1	2	0	0	1	1	2	1
G	Maize island to overland corner	1	1	0	0	0	0	1	0
	Lock 1 to Nildottie river	1	1	0	0	0	0	1	0
H									
I									
J	Tumut River conf to 10km downstream	1	1	3	2	0	3	3	2
	Redbank weir and 10km downstream	1	1	0.2	1	1	1	1	1

Table 3. Weightings used by REGs for waterbird assessments

Zone	locality	Locality weighting	CNW	W&G
A	Lower mitta	1	0	1
B	Quat Quatta	1	1	1
	St Leonards bend	1	1	1
C	Barmah-Millewa	2	1	0
	Gunbower	1	1	0
D	Hattah lakes	1	1	1
E	Lindsay island	1	0	1

	Merreti clover	2	1	1
	Spectacle lakes	1	0	1
F	Northern anabranch lakes and channels	1	1	1
	Southern anabranch lakes	1	1	1
	Northern lower darling billabongs	1	1	1
	Unregulated menindee lakes	1	1	1
G	Banrock complex	1	0	1
	Brenda park complex	1	0	1
H				
I				
J	Yarradda complex	1	1	1
	Piggery lake complex	1	1	1

Table 4. Weightings used by REGs for wetland vegetation assessments

Zone	locality	Locality weight	Cumb	Phrag	mud gr	GRush	Ribbon W
A	Lower mitta bong1	1	0	1	0	1	1
	Lower mitta bong 2	1	0	1	0	1	1
	Lower mitta bong3	1	0	1	0	1	1
B	Quat Quatta	1	0	1	0	1	1
	Croppers lagoon	1	0	1	1	1	1
C	Barmah bong 1	1				1	
	Barmah bong 2	1			1		
	Werai bong 1	0.5		1			
	Werai bong 2	0.5		1			
	Gunbower bong 1	1		1			
	Gunbower bong 2	1					1
D	Hattah 1	1	0.5	0.5	2	1	2
	Hattah 2	1	0.5	0.5	2	1	2
	Hattah 3	1	0.5	0.5	2	1	2
	Belsar island 1	1	1	1	2	1	2
E	Lindsay island bong 1	1	0	0	0	0	1
	Werta wert bong (Chowilla)	1	0	0	0	0	1
	Werta wert lake (Chowilla)	1	0	0	0	0	1
	Spectacle lakes bong 1	1	1	0	0	0	1

	Spectacle lakes bong 2	1	0	0	0	0	1
	Spectacle lakes bong 3	1	0	0	0	0	1
F	Popio lake	1	0	0	0	0	1
	Billabongs nth lower	1	0	0	0	0	1
G	Banrock lagoon	1	0	1	0	0	3
	Overland corner lagoon	1	0	1	0	0	0
	Nigra lagoon	1	0	1	0	0	3
	Schillers lagoon	1	0	1	0	0	0
	Brenda park lagoon	1	0	1	0	0	3
H							
I							
J	Yarradda lagoon	1	0	1	1	0	1
	Narrandera lagoon	1	0	1	1	0	1
	Berry jerry lagoon	1	1	0	0	0	0

Table 5. Weightings used by REGs for floodplain vegetation assessments

Zone	locality	Locality weight	RGF	RGW	BBX	Lig	RTC
A	Upper mitta	0.3	1	0	0	0	0
	Lower mitta	0.7	0	1	0	0	0
B	Quat Quatta floodplain	0.5	1	0	0	0	0
	Croppers floodplain	0.5	1	0	0	0	0
C	Barmah/Millewa FP 2	1	1				
	Barmah/Millewa FP 3	1		1			
	Barmah/Millewa FP 4	1			1		
	Gunbower 1	1		1			
	Gunbower 2	1			1		
	Gunbower 3	1	1				
	Koondrook/Pericoota 1	1	1				
D	Hattah FP 1	1	0	2	1	1	2
	Hattah FP2	1	0	2	1	1	2
	Hattah FP3	1	0	2	1	1	2
	Belsar Island 1	1	1	1	1	1	1
	Belsar island 2	1	0	1	2	2	1

E	Lindsay island FP1	2	0	0	0	1	1
	Lindsay island FP3	1	0	1	0	0	0
	Werta Wert FP1 (Chowilla)	2	0	0	1	1	1
	Werta Wert FP2 (Chowilla)	1	0	0	1	0	0
	Merreti FP1	2	0	0	0	1	1
	Merreti FP2	1	0	0	0	1	1
	Merreti FP3	1	0	1	0	0	0
	Spectacle Lakes FP1	2	0	1	0	1	0
	Spectacle lakes FP2	1	0	0	0	1	0
	Werta Wert FP4 (Chowilla)	1	0	1	0	0	0
F	Gluepot FP	1	0	0	1	1	0
	Popio halo FP	1	0	0	1	0	0
	Nearie halo FP	1	0	0	1	0	0
	Billabong halo nth FP	1	0	1	0	0	0
	Emu lake halo FP	1	0	0	1	1	0
G	Banrock fp1	1	0	1	0	0	1
	Overland corner fp	1	0	1	0	1	0
	Nigra fp	1	0	0	1	1	0
	Brenda park fp	1	0	1	0	0	1
H							
I							
J	Cuba State Forest	1	1	0	0	0	0

Table 6. Weightings used by REGs for algal bloom assessments

Zone	Locality	Locality Weighting	comment
A			No assessment made
B			No assessment made
C			No assessment made
D	Mildura weirpool	1	
E	Lock 5 weirpool	1	
F			No assessment made
G	Lock 2 to lock 1	1	
	Lock 1 to wellington	1	
H			
I			
J	Maude weirpool	1	

Appendix 5. Initial Sensitivity Analysis of the Murray Flow Assessment Tool (MFAT)

Report to the Murray-Darling Basin Commission
Living Murray Initiative
August 2003

By; John Louis (Farrer Centre, Charles Sturt University) and Arthur Read (Spatial Analysis Unit, Charles Sturt University)

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1. INTRODUCTION

The Murray Flow Assessment Tool (MFAT) is decision support software package developed by CSIRO Land & Water and the CRC for Freshwater Ecology for the Murray-Darling Basin Commission. This software package has formed the primary modelling tool in a study commissioned by the Murray-Darling Basin Ministerial Council in 2003 to investigate the likely ecological impact of implementing a number of hydrological flow scenarios within the River Murray System and the Goulburn and Murrumbidgee Rivers. A sub-component of this study was an initial assessment of the sensitivity of the MFAT model to variations in the adjustable model preference curves and weighting parameters. The results of this initial sensitivity analysis form the basis for this report.

2. THE MFAT MODEL

The MFAT model computes ecological habitat indices for a range of environmental factors including waterbirds, fish, floodplain vegetation, wetland vegetation and algae. In computing these indices the MFAT decision support software captures and uses expert ecological knowledge captured as parameters in the form of preference curves and weightings.

There are two standard sets of these parameters used in this study. The Scientific Reference Panel (SRP) parameters are the MFAT model default parameters. The second set is the Regional Evaluation Group (REG) parameters. This is the set of parameters that were finally chosen by each regional evaluation group to best capture the expert ecological knowledge for their region.

The second major input to the MFAT analysis consisted of a river hydrological scenario. For the sensitivity analysis, two hydrological scenarios were examined; the "current" scenario and the "1500 GL-Cap scenario".

The ecological habitat indices predicted by the MFAT will depend on both the choice of the expert panel parameters and the hydrological scenario chosen. The following analysis examines the sensitivity of the MFAT predictions to variations in both of these model inputs.

3. SENSITIVITY ANALYSIS

The sensitivity analysis of the MFAT was carried out on two levels. Firstly a standard assessment was undertaken to investigate the changes in the model response between the default SRP parameter setting and the final REG parameter settings. This assessment was carried out for every zone and every ecological model.

The second part of the study consisted of a number of additional assessments to investigate the sensitivity of the MFAT to a range of changes in floodplain hydrology conditions, and ecological model preference curves and weightings.

4. STANDARD ASSESSMENT

The standard assessment investigates the response of the MFAT results to the changes made to each ecological module by each REG. The results from the MFAT, as set up by each REG, were compared to the results obtained using the default MFAT settings, as developed by the SRP with feedback from the REGs.

The default MFAT configurations were derived from the REG settings by resetting all parameters to the SRP defaults. In cases where the parameter was locality specific, the settings determined by the REG were maintained. Weightings were handled somewhat differently. For weighting of sites and groups, any that a REG had included in their analysis were weighted evenly; any that a REG had not included were weighted out. Within some modules (eg fish) there are weightings for different parts of the model, for example AHC to RHC. In cases where these weightings were specifically stated as having a default value then these were used. If a default was not stated then an even weighting was used.

Table 4.1 indicates the assessments that were investigated in this sensitivity analysis. Zone / Assessment combinations where the REG had made no changes from the default SRP setting were not assessed and are indicated as NC in Table 1.

Table 4.1 Summary of standard assessments

	Ecological Model Level Indices **('All' localities)**					**Locality Level Indices**
River Zone	***Floodplain Vegetation Habitat Condition***	***Wetland Vegetation Habitat Condition***	***Waterbird Habitat Condition***	***Native Fish Habitat Condition***	***Algal Growth***	***Icon sites in zone only***
Zone A	✓	✓	NC	✓	NA	
Zone B	✓	✓	NC	✓	NA	
Zone C	✓	✓	NC	✓	NA	✓
Zone D	✓	✓	NC	✓	✓	✓
Zone E	✓	✓	✓	✓	✓	✓

Zone F	✓	✓	NC	✓	NA	
Zone G	✓	✓	✓	✓	✓	
Zone J	✓	✓	✓	✓	✓	

NA=not assessed   NC = no change (the REG didn't make changes from default)

Locality Level Indices:

REG C: Barmah Forest complex configuration,

REG C: Gunbower Forest complex configuration,

REG C: Koondrook/Pericoota complex

REG D: Hattah complex configuration

REG E: Werta Wert configuration (to represent Chowilla Floodplain)

Each of the Zone / Assessment combination in Table 4.1 was assessed for sensitivity using the following two flow scenarios.

a) "Current" scenario (2)

b) "1500GL-Cap" scenario (6)
(Note: for Zone J the 20% scenario (7) was used in the absence of the 1500GL scenario)

For each assessment the **arithmetic mean** and **% years above median natural** were calculated using the REG and SRP settings and exported from the MFAT.

(Note: That the % years above median of natural is actually the % *above and equal to* median of natural). For each of these measures a simple measure of change was calculated as the difference between the REG and SRP results.

Appendix 1 tabulates the change in each of these condition index measures. The Zone / Assessment combinations were categorised into small, moderate and large change between the mean REG and mean SRP results according to the following rules.

Table 4.2 Classification boundaries for the mean differences

$0.00 \leq \lvert REG - SRP \rvert < 0.05$	Small
$0.05 \leq \lvert REG - SRP \rvert < 0.10$	Moderate
$0.10 \leq \lvert REG - SRP \rvert \leq 1.00$	Large

An * on the category indicates that the % years above median natural has changed by 10 or more.

The boundary points in Table 4.2 were chosen to give a reasonable spread of small, moderate & large degrees of change and reflect the fact that a change in the mean of 0.2 was as large as any observed between flow scenarios in the zone J report, including comparisons with natural flow conditions.

The standard assessment provides an indication as to the general areas of the MFAT that may be sensitive to parameter changes; however it doesn't allow us to pinpoint those parameters that are causing the sensitivity. This is due to the wide variety of changes that each REG may have made to the default settings. Classification into broad change categories does allow an initial assessment as to which river zone and ecological sub model combinations may be exhibiting some sensitivity.

The principal sensitivity observations for each ecological model can be summarised as;

a) **Floodplain vegetation**: The indices for the REG assessments varied widely from those calculated under the SRP default settings, with the difference ranging from 0.05 to 0.34. The habitat condition indices under the REG A and REG F settings were considerably larger than those under the SRP default settings.
b) **Wetland vegetation**: 10 of the 16 assessments resulted in a small difference, 4 had a moderate difference and only two (the REG E assessments) resulted a large difference from indices calculated under the SRP default settings.
c) **Waterbird**: All assessments showed small or moderate differences from SRP default (all less than 0.06 difference from SRP index)
d) **Native fish**: 14 of the 16 assessments has a small or moderate difference from SRP default (differences between REG and SRP index 0.08 or less), however both of the REG C assessments had large differences from the SRP index (greater than 0.19 difference).
e) **Algae**: 6 of the 8 assessments had a small or moderate difference to SRP default (difference was 0.07 or less), however REG E had a large difference from SRP default (0.2)

f) **Icon sites**: The Gunbower and Werta Wert Wetland both exhibited large change from the default SRP floodplain and wetland vegetation indices (0.14 – 0.22). The Hattah and Koondrook sites both exhibited small change (0.00 – 0.04), while the Barmah Forest exhibited large change in the floodplain vegetation index and moderate to small change in the wetland vegetation index.

Note also that the changes that REG E made to the default parameters has resulted in relatively large ecological index changes, in comparison with the other REGs. The parameter changes to floodplain vegetation have caused large changes in this index in all REGs. Also of interest is that the locality specific assessments tend to be more sensitive. This is could be due to there being one less level of combining of index values involved (i.e. the index is less diluted by the influence of other localities).

5. ADDITIONAL ASSESSMENTS

A range of additional assessments have been made to investigate the sensitivity of the MFAT model to preference curve and weighting adjustments that have been made by the regional evaluation groups. A range of individual parameter variations from the SRP default preference curves and weightings have been tested. As with the standard assessments the degree of change in the mean level of the index has been rated small, medium & large according to Table 4.2 and parameter changes that lead to a 10% change or more in the percentage of years above natural have been marked by an asterisk.

6. MFAT FLOODPLAIN HYDROLOGY MODEL

The floodplain hydrology model was tested for the Cuba State Forest and the Piggery Lake Complex in zone J.

6.1 Cuba State Forest

For Cuba State Forest, Pmin of the inlet pipe was varied by ±10 and ±20%. The value for Pmax was not investigated as this was set to be larger than the maximum flood and thus does not have a bearing on the results. Cuba State Forrest is a shedding floodplain and hence there are no outlet pipe parameters to vary. Floodplain volume was not tested as the floodplain has a volume greater than the largest daily flow. Floodplain areas of ±10 and ±20% were tested.

The volume area curve for the floodplain was tested by moving the points indicated in Figure 6.1. The output of the floodplain vegetation model was assessed for sensitivity to each parameter change. These assessments are summarised in Appendix 2.

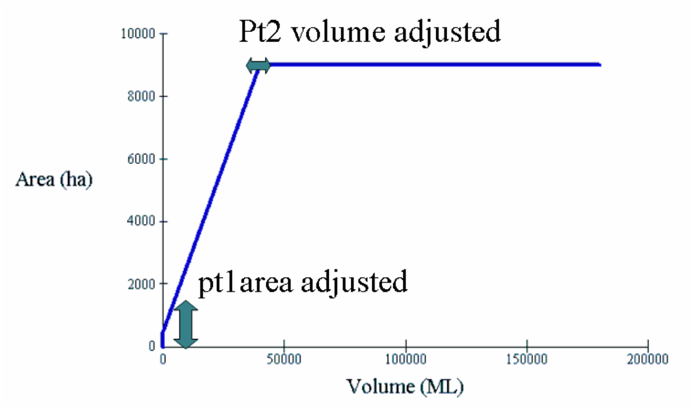

Figure 6.1 Volume area curve changes for Cuba State Forest floodplain

In general the changes made little difference to the output for the floodplain vegetation model. Pmin, the parameter that controls the river stage at which inundation occurs is moderately sensitive, particularly to raising the level of Pmin (ie reduced floodplain connection).

6.2 Piggery Lake Complex

The Piggery Lake complex was chosen to test the sensitivity of the waterbird model. This floodplain complex has two inlet pipes, one of which is turned off for the natural scenario as it models input from a weir. A number of Pmin values were tested for each inlet pipe. Pmax was tested only for one pipe, as the other has a value set by the REG in excess of the floodplain capacity. Decay rate, floodplain volume and area were tested. Two changes to the volume area curves were assessed; a slight raising of the lower tip of the curve for both floodplain elements and a straight volume/area curve, see figure 6.2.

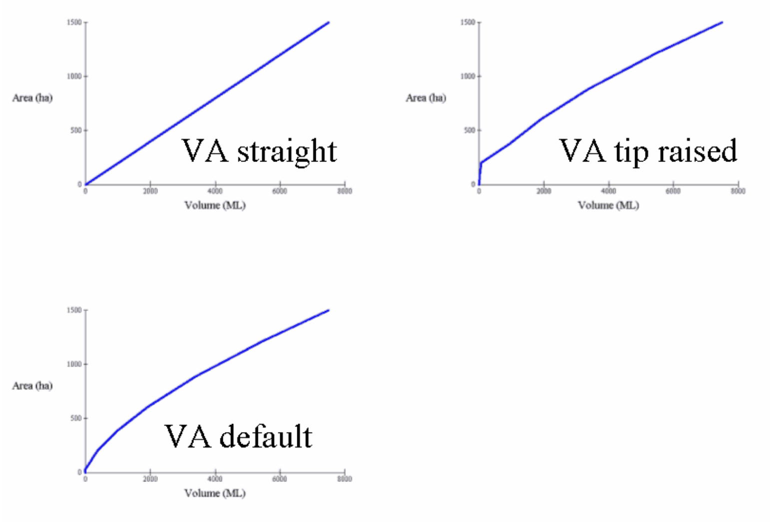

Figure 6.2 Volume area curves assessed at Piggery Lake and Tarwillie Floodplain.

The waterbird habitat condition had low sensitivity to most of the assessed changes tabulated in Appendix 2. As in the Cuba State Forest assessment, one of the inlet pipes for Piggery Lake was sensitive to the changes made to Pmin. The straightening of the volume/area curve exhibited moderate sensitivity.

7. MFAT ECOLOGICAL ASSESSMENT MODELS

7.1 Native Fish Habitat Condition Model

The native fish habitat condition index was tested at zone E. Various weighting configurations were tested between groups, as well as for Groups 1 and 6 independently. The SRP defaults for the weightings between sections of the model called for higher weightings on some sections of the model. The sensitivity of these recommendations was tested by setting the weightings back to a 1:1 ratio. A range of settings for the adult habitat locality parameters were tested. As there were no defaults specified for these parameters and a large candidate set of possible settings, only a few changes were tested, usually the extreme settings.

There were many changes made to the fish model by the REGs. A large number of these were site specific and hence not investigated. The most common change made by the REGs was to spawning time. The spawning timing of REG B (a small reduction in the number of months spawning can occur for most species) and REG J (large reduction in the spawning timing due to cold water pollution) were tested at zone E.

The principal results of the fish sensitivity analysis were (see Appendix 3);

a) The group 1 and group 6 only assessments resulted in large changes to the mean and % years above median of natural. This is not surprising as the model is changed substantially by removing all the other groups.

b) The relative weights of different parts of the model (i.e. the RHC weights) resulted in minimal change in the mean although there was a greater change in the % years above median of natural.
c) The adult habitat locality parameter changes resulted in low levels of sensitivity despite some of the more extreme settings being tested. Each REG has made numerous changes in this area. The investigation of the sensitivity of each REG's configuration is beyond the scope of this report.
d) The extreme changes in spawning timing made by REG J to simulate reduced spawning due to cold water pollution moderately reduced the mean when tested at zone E.

7.2 Waterbird Habitat Condition Model

For the waterbird habitat model the following tests were carried out using the following variations to the standard SRP parameters;

a) Waterfowl and Grebes tested using REG E inundation values
b) REG G and J breeding habitat condition weights
c) Adjustments to relative breeding and foraging habitat weights
d) Adjustments to relative weightings between the two waterbird groups

All of the tests conducted showed a very low level of sensitivity (mean < 0.04) to these changes at zone F (Appendix 4). It is interesting to note that the parameter sets used by zone E and J resulted in a moderate level of sensitivity in the standard assessment, while zone G exhibited low sensitivity in the standard assessment.

7.3 Floodplain Vegetation Habitat Condition Model

Floodplain vegetation habitat model assessments were carried out using the following variations to the standard SRP parameters for zone C;

a) Independent testing of a range of parameters that the REGs have changed within the model
b) Varying two parameters at time to check if the changes add linearly
c) Testing two inundation depths used by other REGs at zone C
d) Adjustments to the relative adult and recruitment weights. AHC 80% and RHC 20% was specifically tested as this was a ratio used by many REGs
e) Adjustments to relative weightings between vegetation groups. Zone C only ran 3 groups, each on a different floodplain, so the weightings between these floodplains were varied to make this assessment.

Most of the tests reported in Appendix 5 have resulted in a minimal change to the index. Of particular interest is the small change that resulted from varying the AHC/RHC weights. Many REGs altered these weights, yet it doesn't appear to be sensitive. In the standard assessment, however, floodplain vegetation has shown large changes in habitat index between runs with the REG and SRP settings. This additional assessment has not provided a definitive indication as to which part of the model is driving this sensitivity. The test in which multiple parameters were changed did indicate that the changes appeared to be cumulative. It is possible, therefore, that it is the combination of changes that the REGs have made that has led to the sensitivity displayed in the standard assessment.

7.4 Wetland Vegetation Habitat Condition Model

The wetland vegetation habitat model was tested for two zones, as each zone only used a small number of vegetation groups. The following variations to the standard SRP parameters were tested;

a) The changes that REG E made to the model were each tested independently (at REG E)
b) Two of the inundation depth settings used by the REGs were tested at zone C
c) Adjustments to relative adult and recruitment weights at zone C
d) Adjustments to relative weightings between vegetation groups at zone C

A number of the tests resulted in a large change in the mean, see Appendix 6. Of particular interest are the large changes that resulted from the tests varying the AHC/RHC weights. Many of the REGs altered these weights.

REG E made substantial changes to the model in their zone; however when each change is assessed individually, only depth duration causes a large change to the mean.

7.5 Algal Growth Model

The locality parameter settings for the algal assessment were taken as the zone D REG values. Of the algae species parameters; growth rate, decay rate, seed population and maximum population were tested. The values used by the other REGs were used as a guide for the range of parameters tested. Locality parameters such as air temperature and wind speed were not tested.

The mean values for algae are of limited use due to the high proportion of years where algal growth is absent. The % of years above natural median results in Appendix 7 suggests that algal growth rate and seed population are sensitive parameters. It is possible that decay rate and maximum population could also be sensitive parameters in situations where there was a higher algal response than for the SRP default model run at zone D.

8. CONCLUSIONS

The results presented in this report do not represent a comprehensive sensitivity analysis for the MFAT model, but rather a limited investigation of the likely magnitude of the changes in the environmental condition indices that result from limited variation of the model parameters from the SRP defaults. In the case of the standard assessments, it is also possible the magnitude of the change is as much to do with how many parameters were varied by each REG, in addition to the magnitude of those variations and the sensitivity of the model response.

What this report does show is that there are a number of areas within the various segments of MFAT that exhibit a high level of sensitivity. In some cases the model appears to have a greater sensitivity to the parameter settings then to the different flow scenarios.

In general the two flow scenarios for which sensitivity was investigated responded with a similar level of sensitivity to a given change. This indicates that there is not much interaction between flow scenarios and the choice of specific model parameters.

9. ACKNOWLDGEMENTS

The authors would like to acknowledge the useful ecological insights to this analysis provided by Dr Robyn Watts and Dr David Roshier. Thanks to Anthony Scott (CRC FE), Bronwyn Rennie (CRC FE) and Sarah Cartwright (MDBC) for their support of this study. The facilities and support of the Spatial Analysis Unit at Charles Sturt University is also acknowledged.

Appendix 1 Standard REG compared with SRP parameter settings

zone	assessment	scenario	mean REG	mean SRP	change mean	abs change mean	category	natural median REG	natural median SRP	% years above natural median REG	% years above natural median SRP	change %
a	floodplain vegetation	2	0.35	0.01	0.34	0.34	large*	0.48	0.00	6	100	-94
a	floodplain vegetation	6	0.35	0.01	0.34	0.34	large*	0.48	0.00	7	100	-93
b	floodplain vegetation	2	0.35	0.25	0.10	0.10	moderate*	0.48	0.46	32	21	11
b	floodplain vegetation	6	0.40	0.29	0.11	0.11	large*	0.48	0.46	44	23	21
c	floodplain vegetation	2	0.38	0.27	0.11	0.11	large	0.56	0.48	14	13	1
c	floodplain vegetation	6	0.42	0.32	0.10	0.10	moderate	0.56	0.48	20	21	-1
d	floodplain vegetation	2	0.28	0.23	0.05	0.05	moderate	0.44	0.41	15	14	1
d	floodplain vegetation	6	0.31	0.26	0.05	0.05	moderate	0.44	0.41	18	18	0
e	floodplain vegetation	2	0.34	0.19	0.15	0.15	large	0.46	0.42	22	13	9
e	floodplain vegetation	6	0.37	0.23	0.14	0.14	large*	0.46	0.42	30	20	10
f	floodplain vegetation	2	0.38	0.11	0.27	0.27	large	0.42	0.19	34	29	5
f	floodplain vegetation	6	0.38	0.11	0.27	0.27	large	0.42	0.19	35	28	7
g	floodplain vegetation	2	0.29	0.20	0.09	0.09	moderate	0.45	0.36	14	15	-1
g	floodplain vegetation	6	0.32	0.24	0.08	0.08	moderate	0.45	0.36	20	24	-4
j	floodplain vegetation	2	0.31	0.19	0.12	0.12	large	0.50	0.31	37	32	5
j	floodplain vegetation	7	0.37	0.22	0.15	0.15	large	0.50	0.31	42	40	2
a	wetland vegetation	2	0.48	0.46	0.02	0.02	small	0.59	0.57	20	15	5

a	wetland vegetation	6	0.48	0.45	0.03	0.03	small	0.59	0.57	23	20	3
b	wetland vegetation	2	0.50	0.47	0.03	0.03	small	0.71	0.66	18	16	2
b	wetland vegetation	6	0.52	0.49	0.03	0.03	small	0.71	0.66	20	17	3
c	wetland vegetation	2	0.60	0.50	0.10	0.10	moderate*	0.68	0.68	35	12	23
c	wetland vegetation	6	0.61	0.52	0.09	0.09	moderate*	0.68	0.68	35	20	15
d	wetland vegetation	2	0.37	0.38	-0.01	0.01	small	0.61	0.63	21	25	-4
d	wetland vegetation	6	0.42	0.43	-0.01	0.01	small	0.61	0.63	25	29	-4
e	wetland vegetation	2	0.11	0.25	-0.14	0.14	large	0.19	0.37	22	22	0
e	wetland vegetation	6	0.13	0.29	-0.16	0.16	large	0.19	0.37	29	30	-1
f	wetland vegetation	2	0.22	0.20	0.02	0.02	small	0.40	0.36	27	31	-4
f	wetland vegetation	6	0.22	0.20	0.02	0.02	small	0.40	0.36	27	30	-3
g	wetland vegetation	2	0.53	0.53	0.00	0.00	small	0.69	0.68	39	38	1
g	wetland vegetation	6	0.57	0.57	0.00	0.00	small	0.69	0.68	46	44	2
j	wetland vegetation	2	0.49	0.44	0.05	0.05	moderate	0.73	0.66	42	36	6
j	wetland vegetation	7	0.55	0.50	0.05	0.05	moderate	0.73	0.66	48	44	4
e	waterbird	2	0.19	0.24	-0.05	0.05	moderate	0.33	0.39	18	19	-1
e	waterbird	6	0.21	0.26	-0.05	0.05	moderate	0.33	0.39	25	25	0
g	waterbird	2	0.44	0.45	-0.01	0.01	small	0.66	0.67	12	14	-2
g	waterbird	6	0.47	0.48	-0.01	0.01	small	0.66	0.67	18	25	-7
j	waterbird	2	0.50	0.56	-0.06	0.06	moderate*	0.70	0.73	25	61	-36

j	waterbird	7	0.55	0.61	-0.06	0.06	moderate*	0.70	0.73	22	49	-27
a	native fish	2	0.61	0.65	-0.04	0.04	small	0.75	0.83	0	0	0
a	native fish	6	0.61	0.65	-0.04	0.04	small	0.75	0.83	0	0	0
b	native fish	2	0.64	0.70	-0.06	0.06	moderate	0.80	0.83	0	0	0
b	native fish	6	0.66	0.70	-0.04	0.04	small	0.80	0.83	0	0	0
c	native fish	2	0.54	0.73	-0.19	0.19	large	0.67	0.82	0	0	0
c	native fish	6	0.53	0.73	-0.20	0.20	large	0.67	0.82	0	0	0
d	native fish	2	0.77	0.80	-0.03	0.03	small	0.78	0.81	24	21	3
d	native fish	6	0.78	0.80	-0.02	0.02	small	0.78	0.81	33	31	2
e	native fish	2	0.75	0.67	0.08	0.08	moderate	0.87	0.77	0	4	-4
e	native fish	6	0.77	0.69	0.08	0.08	moderate	0.87	0.77	5	7	-2
f	native fish	2	0.59	0.61	-0.02	0.02	small	0.63	0.65	20	22	-2
f	native fish	6	0.59	0.61	-0.02	0.02	small	0.63	0.65	22	24	-2
g	native fish	2	0.64	0.65	-0.01	0.01	small	0.73	0.63	11	12	-1
g	native fish	6	0.66	0.67	-0.01	0.01	small	0.73	0.63	18	20	-2
j	native fish	2	0.63	0.62	0.01	0.01	small	0.83	0.81	0	0	0
j	native fish	7	0.66	0.64	0.02	0.02	small	0.83	0.81	0	0	0
d	algal	2	-0.07	0.00	-0.07	0.07	moderate*	0.00	0.00	51	72	-21
d	algal	6	-0.05	0.00	-0.05	0.05	moderate*	0.00	0.00	56	82	-26

e	algal	2	-0.53	-0.33	-0.20	0.20	large	-0.18	-0.03	10	11	-1
e	algal	6	-0.49	-0.29	-0.20	0.20	large	-0.18	-0.03	12	12	0
g	algal	2	0.00	0.00	0.00	0.00	small	0.00	0.00	100	100	0
g	algal	6	0.00	0.00	0.00	0.00	small	0.00	0.00	100	100	0
j	algal	2	-0.02	0.00	-0.02	0.02	small*	0.00	0.00	63	100	-37
j	algal	7	-0.02	0.00	-0.02	0.02	small*	0.00	0.00	72	100	-28
c	Barmah floodplain vegetation	2	0.39	0.25	0.14	0.14	large	0.61	0.53	14	16	-2
c	Barmah floodplain vegetation	6	0.44	0.31	0.13	0.13	large	0.61	0.53	20	16	4
c	Barmah wetland vegetation	2	0.74	0.66	0.08	0.08	moderate*	0.60	0.82	93	28	65
c	Barmah wetland vegetation	6	0.70	0.67	0.03	0.03	small*	0.60	0.82	86	28	58
c	Gunbower wetland vegetation	2	0.45	0.23	0.22	0.22	large	0.79	0.53	9	12	-3
c	Gunbower wetland vegetation	6	0.51	0.29	0.22	0.22	large*	0.79	0.53	12	23	-11
c	Gunbower floodplain vegetation	2	0.35	0.23	0.12	0.12	large	0.52	0.44	12	9	3
c	Gunbower floodplain vegetation	6	0.39	0.27	0.12	0.12	large	0.52	0.44	23	20	3
c	Koondrook floodplain vegetation	2	0.46	0.46	0.00	0.00	small	0.58	0.58	39	39	0
c	Koondrook floodplain vegetation	6	0.47	0.47	0.00	0.00	small	0.58	0.58	42	42	0
d	Hattah wetland vegetation	2	0.34	0.34	0.00	0.00	small	0.63	0.65	18	23	-5
d	Hattah wetland vegetation	6	0.39	0.39	0.00	0.00	small	0.63	0.65	25	25	0
d	Hattah floodplain vegetation	2	0.29	0.25	0.04	0.04	small	0.46	0.42	15	13	2
d	Hattah floodplain vegetation	6	0.31	0.27	0.04	0.04	small	0.46	0.42	17	16	1

e	werta wert floodplain vegetation	2	0.35	0.19	0.16	0.16	large	0.51	0.44	23	15	8
e	werta wert floodplain vegetation	6	0.38	0.23	0.15	0.15	large	0.51	0.44	24	18	6
e	werta wert wetland vegetation	2	0.11	0.25	-0.14	0.14	large	0.19	0.37	22	22	0
e	werta wert wetland vegetation	6	0.13	0.29	-0.16	0.16	large	0.19	0.37	29	30	-1

Appendix 2 Floodplain hydrology assessment

zone	locality	assessment TEST	scenario	mean TEST	mean SRP	change mean	abs change mean	category	natural median TEST	natural median SRP	% years above natural median TEST	% years above natural median SRP	change %
j	cuba	area +10	2	0.31	0.31	0.00	0.00	small	0.5	0.5	36	37	-1
j	cuba	area +10	7	0.36	0.37	-0.01	0.01	small	0.5	0.5	41	42	-1
j	cuba	area +20	2	0.30	0.31	-0.01	0.01	small	0.5	0.5	34	37	-3
j	cuba	area +20	7	0.36	0.37	-0.01	0.01	small	0.5	0.5	39	42	-3
j	cuba	area -10	2	0.31	0.31	0.00	0.00	small	0.5	0.5	37	37	0
j	cuba	area -10	7	0.37	0.37	0.00	0.00	small	0.5	0.5	42	42	0
j	cuba	area -20	2	0.31	0.31	0.00	0.00	small	0.49	0.5	38	37	1
j	cuba	area -20	7	0.37	0.37	0.00	0.00	small	0.49	0.5	43	42	1
j	cuba	pmin +10	2	0.26	0.31	-0.05	0.05	moderate	0.5	0.5	29	37	-8
j	cuba	pmin +10	7	0.32	0.37	-0.05	0.05	moderate	0.5	0.5	36	42	-6
j	cuba	pmin +20	2	0.25	0.31	-0.06	0.06	moderate*	0.5	0.5	26	37	-11
j	cuba	pmin +20	7	0.28	0.37	-0.09	0.09	moderate*	0.5	0.5	29	42	-13
j	cuba	pmin -10	2	0.36	0.31	0.05	0.05	moderate	0.5	0.5	39	37	2
j	cuba	pmin -10	7	0.40	0.37	0.03	0.03	small	0.5	0.5	44	42	2
j	cuba	pmin -20	2	0.39	0.31	0.08	0.08	moderate	0.5	0.5	40	37	3
j	cuba	pmin -20	7	0.47	0.37	0.10	0.10	large*	0.5	0.5	53	42	11
j	cuba	VA pt1 area +10	2	0.31	0.31	0.00	0.00	small	0.5	0.5	37	37	0

j	cuba	VA pt1 area +10	7	0.37	0.37	0.00	0.00	small	0.5	0.5	42	42	0
j	cuba	VA pt1 area +20	2	0.31	0.31	0.00	0.00	small	0.5	0.5	37	37	0
j	cuba	VA pt1 area +20	7	0.37	0.37	0.00	0.00	small	0.5	0.5	42	42	0
j	cuba	VA pt1 area -10	2	0.29	0.31	-0.02	0.02	small	0.5	0.5	34	37	-3
j	cuba	VA pt1 area -10	7	0.36	0.37	-0.01	0.01	small	0.5	0.5	40	42	-2
j	cuba	VA pt1 area -20	2	0.30	0.31	-0.01	0.01	small	0.49	0.5	36	37	-1
j	cuba	VA pt1 area -20	7	0.36	0.37	-0.01	0.01	small	0.49	0.5	41	42	-1
j	cuba	VA pt2 volume +10	2	0.31	0.31	0.00	0.00	small	0.5	0.5	36	37	-1
j	cuba	VA pt2 volume +10	7	0.37	0.37	0.00	0.00	small	0.5	0.5	41	42	-1
j	cuba	VA pt2 volume +20	2	0.31	0.31	0.00	0.00	small	0.49	0.5	37	37	0
j	cuba	VA pt2 volume +20	7	0.36	0.37	-0.01	0.01	small	0.49	0.5	41	42	-1
j	cuba	VA pt2 volume -10	2	0.32	0.31	0.01	0.01	small	0.5	0.5	37	37	0
j	cuba	VA pt2 volume -10	7	0.38	0.37	0.01	0.01	small	0.5	0.5	43	42	1
j	cuba	VA pt2 volume -20	2	0.33	0.31	0.02	0.02	small	0.5	0.5	37	37	0
j	cuba	VA pt2 volume -20	7	0.40	0.37	0.03	0.03	small	0.5	0.5	44	42	2
j	piggery	decay rate -0.002 (REG J setting -0.0002)	2	0.49	0.51	-0.02	0.02	small	0.7	0.72	26	20	6
j	piggery	decay rate -0.002 (REG J setting -0.0002)	7	0.54	0.57	-0.03	0.03	small	0.7	0.72	21	19	2
j	piggery	Piggery Lake area +10%	2	0.50	0.51	-0.01	0.01	small	0.7	0.72	25	20	5
j	piggery	Piggery Lake area +10%	7	0.55	0.57	-0.02	0.02	small	0.7	0.72	24	19	5
j	piggery	Piggery Lake area -10%	2	0.50	0.51	-0.01	0.01	small	0.7	0.72	25	20	5
j	piggery	Piggery Lake area -10%	7	0.55	0.57	-0.02	0.02	small	0.7	0.72	23	19	4

j	piggery	Piggery Lake volume +10%	2	0.51	0.51	0.00	0.00	small	0.7	0.72	25	20	5
j	piggery	Piggery Lake volume +10%	7	0.56	0.57	-0.01	0.01	small	0.7	0.72	22	19	3
j	piggery	Piggery Lake volume -10%	2	0.48	0.51	-0.03	0.03	small	0.7	0.72	24	20	4
j	piggery	Piggery Lake volume -10%	7	0.54	0.57	-0.03	0.03	small	0.7	0.72	22	19	3
j	piggery	pipe204 pmax +10%	2	0.52	0.51	0.01	0.01	small	0.72	0.72	22	20	2
j	piggery	pipe204 pmax +10%	7	0.59	0.57	0.02	0.02	small	0.72	0.72	19	19	0
j	piggery	pipe204 pmax +20%	2	0.53	0.51	0.02	0.02	small	0.72	0.72	22	20	2
j	piggery	pipe204 pmax +20%	7	0.59	0.57	0.02	0.02	small	0.72	0.72	19	19	0
j	piggery	pipe204 pmax -10%	2	0.48	0.51	-0.03	0.03	small	0.72	0.72	19	20	-1
j	piggery	pipe204 pmax -10%	7	0.54	0.57	-0.03	0.03	small	0.72	0.72	17	19	-2
j	piggery	pipe204 pmin +10%	2	0.45	0.51	-0.06	0.06	moderate	0.72	0.72	15	20	-5
j	piggery	pipe204 pmin +10%	7	0.53	0.57	-0.04	0.04	small	0.72	0.72	17	19	-2
j	piggery	pipe204 pmin -10%	2	0.54	0.51	0.03	0.03	small	0.72	0.72	22	20	2
j	piggery	pipe204 pmin -10%	7	0.59	0.57	0.02	0.02	small	0.72	0.72	19	19	0
j	piggery	pipe204 pmin -20%	2	0.56	0.51	0.05	0.05	moderate	0.72	0.72	22	20	2
j	piggery	pipe204 pmin -20%	7	0.60	0.57	0.03	0.03	small	0.72	0.72	20	19	1
j	piggery	pipe205 pmin +10%	2	0.49	0.51	-0.02	0.02	small	0.7	0.72	20	20	0
j	piggery	pipe205 pmin +10%	7	0.54	0.57	-0.03	0.03	small	0.7	0.72	15	19	-4
j	piggery	pipe205 pmin +20%	2	0.49	0.51	-0.02	0.02	small	0.7	0.72	16	20	-4
j	piggery	pipe205 pmin +20%	7	0.53	0.57	-0.04	0.04	small	0.7	0.72	14	19	-5
j	piggery	pipe205 pmin -10%	2	0.51	0.51	0.00	0.00	small	0.7	0.72	28	20	8

j	piggery	pipe205 pmin -10%	7	0.57	0.57	0.00	0.00	small	0.7	0.72	28	19	9
j	piggery	pipe205 pmin -20%	2	0.51	0.51	0.00	0.00	small	0.7	0.72	28	20	8
j	piggery	pipe205 pmin -20%	7	0.57	0.57	0.00	0.00	small*	0.7	0.72	31	19	12
j	piggery	Tarwillie Floodplain area +10%	2	0.50	0.51	-0.01	0.01	small	0.69	0.72	26	20	6
j	piggery	Tarwillie Floodplain area +10%	7	0.54	0.57	-0.03	0.03	small	0.69	0.72	23	19	4
j	piggery	Tarwillie Floodplain area -10%	2	0.51	0.51	0.00	0.00	small	0.7	0.72	29	20	9
j	piggery	Tarwillie Floodplain area -10%	7	0.56	0.57	-0.01	0.01	small	0.7	0.72	25	19	6
j	piggery	Tarwillie Floodplain volume +10%	2	0.51	0.51	0.00	0.00	small	0.7	0.72	26	20	6
j	piggery	Tarwillie Floodplain volume +10%	7	0.56	0.57	-0.01	0.01	small	0.7	0.72	25	19	6
j	piggery	Tarwillie Floodplain volume -10%	2	0.50	0.51	-0.01	0.01	small	0.69	0.72	26	20	6
j	piggery	Tarwillie Floodplain volume -10%	7	0.54	0.57	-0.03	0.03	small	0.69	0.72	23	19	4
j	piggery	VA straight	2	0.44	0.51	-0.07	0.07	moderate	0.64	0.72	22	20	2
j	piggery	VA straight	7	0.49	0.57	-0.08	0.08	moderate	0.64	0.72	22	19	3
j	piggery	VA tip raised	2	0.51	0.51	0.00	0.00	small	0.7	0.72	27	20	7
j	piggery	VA tip raised	7	0.56	0.57	-0.01	0.01	small	0.7	0.72	24	19	5

VA = Volume/Area curve

pmin and pmax 20% adjustments not always tested as they sometimes would close the pipe. (ie pmin becomes greater then pmax)

Appendix 3 Fish habitat assessment

zone	assessment TEST (defaults in brackets)	scenario	mean TEST	mean SRP	change mean	abs change mean	category	natural median TEST	natural median SRP	% years above natural median TEST	% years above natural median SRP	change %
d	Group 1 only	2	0.45	0.79	-0.34	0.34	large*	0.48	0.81	23	13	10
d	Group 1 only	6	0.47	0.79	-0.32	0.32	large*	0.48	0.81	34	24	10
d	Group 6 only	2	0.91	0.79	0.12	0.12	large*	0.92	0.81	77	13	64
d	Group 6 only	6	0.91	0.79	0.12	0.12	large*	0.92	0.81	71	24	47
d	Group 1 weighted double other groups	2	0.74	0.79	-0.05	0.05	moderate	0.76	0.81	20	13	7
d	Group 1 weighted double other groups	6	0.75	0.79	-0.04	0.04	small	0.76	0.81	26	24	2
d	Group 2 weighted double other groups	2	0.77	0.79	-0.02	0.02	small	0.78	0.81	18	13	5
d	Group 2 weighted double other groups	6	0.77	0.79	-0.02	0.02	small	0.78	0.81	27	24	3
d	Group 3 weighted double other groups	2	0.79	0.79	0.00	0.00	small	0.82	0.81	13	13	0
d	Group 3 weighted double other groups	6	0.80	0.79	0.01	0.01	small	0.82	0.81	22	24	-2
d	Group 4 weighted double other groups	2	0.80	0.79	0.01	0.01	small	0.82	0.81	12	13	-1
d	Group 4 weighted double other groups	6	0.80	0.79	0.01	0.01	small	0.82	0.81	23	24	-1
d	Group 5 weighted double other groups	2	0.80	0.79	0.01	0.01	small	0.82	0.81	16	13	3
d	Group 5 weighted double other groups	6	0.81	0.79	0.02	0.02	small	0.82	0.81	25	24	1
d	Group 6 weighted double other groups	2	0.80	0.79	0.01	0.01	small	0.82	0.81	16	13	3
d	Group 6 weighted double other groups	6	0.81	0.79	0.02	0.02	small	0.82	0.81	25	24	1
d	Group 7 weighted double other groups	2	0.80	0.79	0.01	0.01	small*	0.81	0.81	27	13	14

d	Group 7 weighted double other groups	6	0.80	0.79	0.01	0.01	small	0.81	0.81	30	24	6
d	RHC weights SHC 1 : LHC 1 (Group 1 2:1, others 1:5)	2	0.75	0.79	-0.04	0.04	small	0.77	0.81	18	13	5
d	RHC weights SHC 1 : LHC 1 (Group 1 2:1, others 1:5)	6	0.75	0.79	-0.04	0.04	small	0.77	0.81	28	24	4
d	FHC weights AHC 1 : RHC 1 (Group 3 1:1, others 1:5)	2	0.79	0.79	0.00	0.00	small*	0.86	0.81	1	13	-12
d	FHC weights AHC 1 : RHC 1 (Group 3 1:1, others 1:5)	6	0.80	0.79	0.01	0.01	small*	0.86	0.81	2	24	-22
d	spawning timing as per REG B Richardson's Bend	2	0.77	0.79	-0.02	0.02	small	0.8	0.81	9	13	-4
d	spawning timing as per REG B Richardson's Bend	6	0.77	0.79	-0.02	0.02	small*	0.8	0.81	12	24	-12
d	spawning timing as per REG J Tumut R. conf.	2	0.73	0.79	-0.06	0.06	moderate	0.76	0.81	7	13	-6
d	spawning timing as per REG J Tumut R. conf.	6	0.74	0.79	-0.05	0.05	moderate*	0.76	0.81	12	24	-12
d	WD - Few WD (Numerous WD)	2	0.76	0.79	-0.03	0.03	small	0.78	0.81	21	13	8
d	WD - Few WD (Numerous WD)	6	0.77	0.79	-0.02	0.02	small	0.78	0.81	25	24	1
d	WD at natural levels (Numerous WD)	2	0.80	0.79	0.01	0.01	small	0.82	0.81	13	13	0
d	WD at natural levels (Numerous WD)	6	0.80	0.79	0.01	0.01	small	0.82	0.81	25	24	1
d	WT - large thermal pollution (No thermal pollution)	2	0.74	0.79	-0.05	0.05	moderate	0.76	0.81	19	13	6
d	WT - large thermal pollution (No thermal pollution)	6	0.75	0.79	-0.04	0.04	small	0.76	0.81	25	24	1
d	CC absence of macrophyte beds turned off	2	0.79	0.79	0.00	0.00	small	0.81	0.81	13	13	0
d	CC absence of macrophyte beds turned off	6	0.79	0.79	0.00	0.00	small	0.81	0.81	24	24	0
d	FP threshold for effective passage 500 (1000)	2	0.79	0.79	0.00	0.00	small	0.81	0.81	13	13	0
d	FP threshold for effective passage 500 (1000)	6	0.79	0.79	0.00	0.00	small	0.81	0.81	24	24	0

CC = Channel Condition

WT = Water Temperature

WD = Woody Debris

FP = Fish Passage

FHC = Fish Habitat Condition

AHC = Adult Habitat Condition

RHC = Recruitment Habitat Condition

SHC = Spawning Habitat Condition

LHC = Laval - Juvenile Habitat Condition

Appendix 4 Waterbird habitat assessment

zone	assessment TEST	scenario	mean TEST	mean SRP	change mean	abs change mean	category	natural median TEST	natural median SRP	% years above natural median TEST	% years above natural median SRP	change %
f	habitat weights BH 25% FH 75%	2	0.28	0.27	0.01	0.01	small	0.78	0.72	25	26	-1
f	habitat weights BH 25% FH 75%	6	0.28	0.27	0.01	0.01	small	0.78	0.72	27	27	0
f	habitat weights BH 75% FH25%	2	0.26	0.27	-0.01	0.01	small	0.63	0.72	26	26	0
f	habitat weights BH 75% FH25%	6	0.27	0.27	0.00	0.00	small	0.63	0.72	26	27	-1
f	area inundated WG as per zone E	2	0.27	0.27	0.00	0.00	small	0.72	0.72	26	26	0
f	area inundated WG as per zone E	6	0.27	0.27	0.00	0.00	small	0.72	0.72	27	27	0
f	BH weights as per zone G	2	0.26	0.27	-0.01	0.01	small	0.71	0.72	26	26	0
f	BH weights as per zone G	6	0.27	0.27	0.00	0.00	small	0.71	0.72	27	27	0
f	BH weights as per zone J	2	0.24	0.27	-0.03	0.03	small	0.6	0.72	25	26	-1
f	BH weights as per zone J	6	0.25	0.27	-0.02	0.02	small	0.6	0.72	26	27	-1
f	CNW only	2	0.26	0.27	-0.01	0.01	small	0.71	0.72	26	26	0
f	CNW only	6	0.27	0.27	0.00	0.00	small	0.71	0.72	27	27	0
f	WG only	2	0.27	0.27	0.00	0.00	small	0.73	0.72	26	26	0
f	WG only	6	0.28	0.27	0.01	0.01	small	0.73	0.72	27	27	0
f	wg 25% cnw 75%	2	0.27	0.27	0.00	0.00	small	0.72	0.72	26	26	0
f	wg 25% cnw 75%	6	0.27	0.27	0.00	0.00	small	0.72	0.72	27	27	0
f	wg 75% cnw 25%	2	0.27	0.27	0.00	0.00	small	0.72	0.72	26	26	0

f	wg 75% cnw 25%	6	0.28	0.27	0.01	0.01	small	0.72	0.72	27	27	0

W+G = waterfowl and grebes

CNW = colonial nesting waterbirds

BH = breeding habitat

FH = foraging habitat

Appendix 5 Floodplain vegetation habitat assessment

zone	assessment TEST	scenario	mean TEST	mean SRP	change mean	abs change mean	category	natural median TEST	natural median SRP	% years above natural median TEST	% years above natural median SRP	change %
c	HC weights AHC 80% RHC 20%	2	0.22	0.23	-0.01	0.01	small	0.53	0.44	13	9	4
c	HC weights AHC 80% RHC 20%	6	0.28	0.27	0.01	0.01	small	0.53	0.44	21	20	1
c	RRG forest off - RRG woodland and BB woodland only	2	0.15	0.23	-0.08	0.08	moderate	0.4	0.44	11	9	2
c	RRG forest off - RRG woodland and BB woodland only	6	0.21	0.27	-0.06	0.06	moderate	0.4	0.44	22	20	2
c	RRG woodland off - RRG forest and BB woodland only	2	0.27	0.23	0.04	0.04	small*	0.44	0.44	20	9	11
c	RRG woodland off - RRG forest and BB woodland only	6	0.31	0.27	0.04	0.04	small	0.44	0.44	29	20	9
c	BB woodland off - RRG forest and RRG woodland only	2	0.26	0.23	0.03	0.03	small*	0.45	0.44	19	9	10
c	BB woodland off - RRG forest and RRG woodland only	6	0.30	0.27	0.03	0.03	small	0.45	0.44	25	20	5
c	RRG woodland only	2	0.14	0.23	-0.09	0.09	moderate	0.34	0.44	18	9	9
c	RRG woodland only	6	0.21	0.27	-0.06	0.06	moderate*	0.34	0.44	33	20	13
c	RRG forest only	2	0.38	0.23	0.15	0.15	large*	0.57	0.44	23	9	14
c	RRG forest only	6	0.39	0.27	0.12	0.12	large	0.57	0.44	28	20	8
c	BB woodland weighted double other groups	2	0.21	0.23	-0.02	0.02	small	0.42	0.44	10	9	1
c	BB woodland weighted double other groups	6	0.26	0.27	-0.01	0.01	small	0.42	0.44	20	20	0
c	RRG forest weighted double other groups	2	0.26	0.23	0.03	0.03	small	0.46	0.44	16	9	7
c	RRG forest weighted double other groups	6	0.30	0.27	0.03	0.03	small	0.46	0.44	25	20	5
c	RRG woodland weighted double other groups	2	0.20	0.23	-0.03	0.03	small	0.43	0.44	9	9	0

c	RRG woodland weighted double other groups	6	0.26	0.27	-0.01	0.01	small	0.43	0.44	21	20	1
c	RRG woodland FD as per zone J	2	0.23	0.23	0.00	0.00	small	0.54	0.44	12	9	3
c	RRG woodland FD as per zone J	6	0.28	0.27	0.01	0.01	small	0.54	0.44	21	20	1
c	RRG woodland FD as per zone E	2	0.22	0.23	-0.01	0.01	small	0.53	0.44	12	9	3
c	RRG woodland FD as per zone E	6	0.28	0.27	0.01	0.01	small	0.53	0.44	20	20	0
c	RRG woodland DP as per zone E	2	0.21	0.23	-0.02	0.02	small	0.52	0.44	12	9	3
c	RRG woodland DP as per zone E	6	0.27	0.27	0.00	0.00	small	0.52	0.44	20	20	0
c	RRG woodland FT as per zone E	2	0.22	0.23	-0.01	0.01	small	0.53	0.44	12	9	3
c	RRG woodland FT as per zone E	6	0.27	0.27	0.00	0.00	small	0.53	0.44	19	20	-1
c	BB woodland FM increment as per zone E	2	0.22	0.23	-0.01	0.01	small	0.53	0.44	13	9	4
c	BB woodland FM increment as per zone E	6	0.28	0.27	0.01	0.01	small	0.53	0.44	20	20	0
c	BB woodland FM as per zone C	2	0.23	0.23	0.00	0.00	small	0.44	0.44	9	9	0
c	BB woodland FM as per zone C	6	0.27	0.27	0.00	0.00	small	0.44	0.44	20	20	0
c	BB woodland AHC weight as per zone C	2	0.21	0.23	-0.02	0.02	small	0.42	0.44	12	9	3
c	BB woodland AHC weight as per zone C	6	0.25	0.27	-0.02	0.02	small	0.42	0.44	22	20	2
c	BB woodland FD as per zone C	2	0.30	0.23	0.07	0.07	moderate	0.46	0.44	12	9	3
c	BB woodland FD as per zone C	6	0.34	0.27	0.07	0.07	moderate	0.46	0.44	23	20	3
c	BB woodland FD and HC weight as per zone C	2	0.32	0.23	0.09	0.09	moderate	0.48	0.44	16	9	7
c	BB woodland FD and HC weight as per zone C	6	0.36	0.27	0.09	0.09	moderate	0.48	0.44	22	20	2

HC = habitat condition

BB = black box

RRG = river red gum

AHC = adult maintenance condition

RHC = recruitment habitat condition

FD = Inundation Duration (AHC)

FM = flood memory

FT = flood timing

DP = inter flood period

Appendix 6 wetland vegetation habitat assessment

zone	assessment TEST (defaults in brackets)	scenario	mean TEST	mean SRP	change mean	abs change mean	category	natural median TEST	natural median SRP	% years above natural median TEST	% years above natural median SRP	change %
c	100% AHC	2	0.41	0.66	-0.25	0.25	large*	0.89	0.82	17	28	-11
c	100% AHC	6	0.47	0.67	-0.20	0.20	large	0.89	0.82	25	28	-3
c	100% RHC	2	0.90	0.66	0.24	0.24	large*	0.82	0.82	91	28	63
c	100% RHC	6	0.87	0.67	0.20	0.20	large*	0.82	0.82	75	28	47
c	75% AHC 25% RHC	2	0.53	0.66	-0.13	0.13	large	0.85	0.82	24	28	-4
c	75% AHC 25% RHC	6	0.57	0.67	-0.10	0.10	large	0.85	0.82	29	28	1
c	25% AHC 75% RHC	2	0.78	0.66	0.12	0.12	large*	0.81	0.82	40	28	12
c	25% AHC 75% RHC	6	0.77	0.67	0.10	0.10	large	0.81	0.82	35	28	7
c	25% giant rush 75% spiney	2	0.63	0.66	-0.03	0.03	small	0.82	0.82	27	28	-1
c	25% giant rush 75% spiney	6	0.65	0.67	-0.02	0.02	small	0.82	0.82	28	28	0
c	75% giant rush 25% spiney	2	0.68	0.66	0.02	0.02	small	0.82	0.82	30	28	2
c	75% giant rush 25% spiney	6	0.68	0.67	0.01	0.01	small	0.82	0.82	34	28	6
c	Giant Rush only	2	0.71	0.66	0.05	0.05	moderate*	0.82	0.82	47	28	19
c	Giant Rush only	6	0.70	0.67	0.03	0.03	small	0.82	0.82	37	28	9
c	Spiny Mudgrass only	2	0.61	0.66	-0.05	0.05	moderate	0.81	0.82	25	28	-3
c	Spiny Mudgrass only	6	0.63	0.67	-0.04	0.04	small	0.81	0.82	28	28	0
c	inundation depth smaller 10 upper 40 (50:100)	2	0.78	0.66	0.12	0.12	large*	0.69	0.82	85	28	57

c	inundation depth smaller 10 upper 40 (50:100)	6	0.76	0.67	0.09	0.09	moderate*	0.69	0.82	81	28	53
c	inundation depth smaller 70 upper 100 (50:100)	2	0.66	0.66	0.00	0.00	small	0.82	0.82	28	28	0
c	inundation depth smaller 70 upper 100 (50:100)	6	0.67	0.67	0.00	0.00	small	0.82	0.82	28	28	0
e	depth duration as per REG E	2	0.11	0.25	-0.14	0.14	large	0.19	0.37	22	22	0
e	depth duration as per REG E	6	0.13	0.29	-0.16	0.16	large	0.19	0.37	30	30	0
e	innundation timing as per REG E	2	0.23	0.25	-0.02	0.02	small	0.34	0.37	22	22	0
e	innundation timing as per REG E	6	0.27	0.29	-0.02	0.02	small	0.34	0.37	30	30	0
e	rate of depth change as per REG E	2	0.27	0.25	0.02	0.02	small	0.38	0.37	22	22	0
e	rate of depth change as per REG E	6	0.31	0.29	0.02	0.02	small	0.38	0.37	30	30	0
e	recruitment timing as per REG E	2	0.25	0.25	0.00	0.00	small	0.37	0.37	22	22	0
e	recruitment timing as per REG E	6	0.29	0.29	0.00	0.00	small	0.37	0.37	30	30	0
e	water depth as per REG E	2	0.25	0.25	0.00	0.00	small	0.37	0.37	22	22	0
e	water depth as per REG E	6	0.29	0.29	0.00	0.00	small	0.37	0.37	30	30	0

AHC = Adult Maintenance Habitat Condition

RHC = Recruitment Habitat Condition

Appendix 7 Algal growth assessment

zone	assessment TEST (default in brackets)	scenario	mean TEST	mean SRP	change mean	abs change mean	category	natural median TEST	natural median SRP	% years above natural median TEST	% years above natural median SRP	change %
d	decay rate -0.054 (-0.5)	2	-0.01	0.00	-0.01	0.01	small	0.00	0.00	69	72	-3
d	decay rate -0.054 (-0.5)	6	0.00	0.00	0.00	0.00	small	0.00	0.00	78	82	-4
d	decay rate -0.2 (-0.5)	2	0.00	0.00	0.00	0.00	small	0.00	0.00	70	72	-2
d	decay rate -0.2 (-0.5)	6	0.00	0.00	0.00	0.00	small	0.00	0.00	82	82	0
d	decay rate -0.8 (-0.5)	2	0.00	0.00	0.00	0.00	small	0.00	0.00	74	72	2
d	decay rate -0.8 (-0.5)	6	0.00	0.00	0.00	0.00	small	0.00	0.00	85	82	3
d	growth rate 0.2 (0.1)	2	-0.04	0.00	-0.04	0.04	small*	0.00	0.00	60	72	-12
d	growth rate 0.2 (0.1)	6	-0.02	0.00	-0.02	0.02	small*	0.00	0.00	72	82	-10
d	growth rate 0.37 (0.1)	2	-0.07	0.00	-0.07	0.07	moderate*	0.00	0.00	51	72	-21
d	growth rate 0.37 (0.1)	6	-0.06	0.00	-0.06	0.06	moderate*	0.00	0.00	56	82	-26
d	growth rate 0.66 (0.1)	2	-0.11	0.00	-0.11	0.11	large*	-0.01	0.00	18	72	-54
d	growth rate 0.66 (0.1)	6	-0.09	0.00	-0.09	0.09	moderate*	-0.01	0.00	37	82	-45
d	maximum population 20000 (150000)	2	0.00	0.00	0.00	0.00	small	0.00	0.00	72	72	0
d	maximum population 20000 (150000)	6	0.00	0.00	0.00	0.00	small	0.00	0.00	82	82	0
d	maximum population 250000 (150000)	2	0.00	0.00	0.00	0.00	small	0.00	0.00	72	72	0
d	maximum population 250000 (150000)	6	0.00	0.00	0.00	0.00	small	0.00	0.00	82	82	0
d	seed population 10 (1)	2	-0.01	0.00	-0.01	0.01	small*	0.00	0.00	62	72	-10

d	seed population 10 (1)	6	-0.01	0.00	-0.01	0.01	small	0.00	0.00	73	82	-9
d	seed population 100 (1)	2	-0.05	0.00	-0.05	0.05	moderate*	-0.01	0.00	44	72	-28
d	seed population 100 (1)	6	-0.04	0.00	-0.04	0.04	small*	-0.01	0.00	52	82	-30

Appendix 6. Summary statistics (Mean, Median, Coefficient of Variation, Minimum and Maximum annual MFAT habitat condition index)

Overall River Zone Health

Zone	Statistic	Natural	Reference	Current	350cap	350b	350c	750cap	750b	750c	1500cap	1500b	1500c
A	**Mean**	0.58	0.42	0.43	0.44	0.44	0.43	0.43	0.48	0.44	0.44	0.48	0.44
	Median	0.57	0.43	0.43	0.43	0.43	0.43	0.43	0.48	0.43	0.43	0.47	0.44
	CV	0.13	0.14	0.12	0.13	0.12	0.11	0.12	0.11	0.11	0.13	0.11	0.13
	Min	0.37	0.25	0.31	0.28	0.29	0.29	0.28	0.3	0.32	0.29	0.35	0.32
	Max	0.73	0.59	0.6	0.6	0.59	0.58	0.59	0.61	0.58	0.61	0.62	0.59
B	**Mean**	0.62	0.44	0.46	0.46	0.5	0.49	0.47	0.5	0.52	0.49	0.55	0.53
	Median	0.63	0.43	0.44	0.44	0.48	0.46	0.45	0.47	0.48	0.47	0.52	0.51
	CV	0.16	0.22	0.23	0.23	0.24	0.23	0.24	0.23	0.19	0.2	0.18	0.19
	Min	0.39	0.28	0.3	0.3	0.31	0.3	0.31	0.31	0.3	0.31	0.32	0.3
	Max	0.81	0.72	0.7	0.71	0.76	0.75	0.72	0.76	0.75	0.71	0.76	0.75
C	**Mean**	0.65	0.47	0.47	0.48	0.48	0.48	0.48	0.48	0.49	0.50	0.50	0.50
	Median	0.67	0.45	0.46	0.45	0.46	0.47	0.47	0.47	0.47	0.49	0.48	0.48
	CV	0.14	0.26	0.25	0.25	0.25	0.25	0.25	0.26	0.24	0.24	0.23	0.23
	Min	0.30	0.21	0.24	0.22	0.22	0.22	0.24	0.25	0.25	0.26	0.24	0.25
	Max	0.77	0.69	0.70	0.71	0.71	0.71	0.71	0.71	0.72	0.72	0.72	0.72
D	**Mean**	0.61	0.44	0.45	0.45	0.45	0.45	0.46	0.46	0.46	0.48	0.48	0.48
	Median	0.63	0.43	0.44	0.45	0.44	0.45	0.47	0.47	0.45	0.5	0.48	0.49
	CV	0.15	0.37	0.37	0.37	0.36	0.37	0.35	0.35	0.34	0.34	0.33	0.33
	Min	0.26	0.2	0.2	0.2	0.2	0.19	0.19	0.19	0.2	0.19	0.2	0.2
	Max	0.74	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
E	**Mean**	0.58	0.45	0.45	0.46	0.45	0.46	0.46	0.46	0.46	0.47	0.47	0.47
	Median	0.61	0.38	0.38	0.38	0.38	0.38	0.39	0.39	0.41	0.41	0.41	0.43
	CV	0.21	0.25	0.25	0.25	0.25	0.26	0.25	0.26	0.25	0.26	0.26	0.25
	Min	0.38	0.31	0.33	0.33	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34
	Max	0.76	0.73	0.73	0.75	0.75	0.74	0.74	0.75	0.75	0.74	0.75	0.75

F	**Mean**	0.53	0.36	0.37	0.37	0.37	0.36	0.37	0.36	0.37	0.37	0.35	0.47
	Median	0.56	0.24	0.24	0.24	0.25	0.24	0.25	0.24	0.25	0.25	0.24	0.5
	CV	0.26	0.51	0.5	0.5	0.5	0.5	0.49	0.5	0.49	0.5	0.51	0.36
	Min	0.22	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.22
	Max	0.76	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
G	**Mean**	0.6	0.41	0.42	0.43	0.43	0.43	0.44	0.44	0.44	0.46	0.46	0.47
	Median	0.6	0.39	0.39	0.42	0.4	0.4	0.42	0.42	0.42	0.44	0.43	0.46
	CV	0.17	0.37	0.37	0.36	0.36	0.36	0.35	0.35	0.34	0.34	0.34	0.31
	Min	0.29	0.13	0.14	0.16	0.18	0.16	0.16	0.14	0.17	0.2	0.18	0.17
	Max	0.78	0.75	0.74	0.75	0.75	0.76	0.76	0.75	0.75	0.75	0.75	0.76

Zone	**Statistic**	**Natural**	**Current**	**Reference**	**Year 6 WSP**	**10%**	**20%**
J	**Mean**	0.69	0.47	0.5	0.53	0.53	0.55
	Median	0.69	0.5	0.56	0.58	0.57	0.59
	CV	0.13	0.4	0.36	0.33	0.3	0.28
	Min	0.35	0.13	0.15	0.16	0.15	0.16
	Max	0.85	0.8	0.81	0.8	0.81	0.8

Native Fish Habitat Condition

Zone	Statistic	Natural	Reference	Current	350cap	350b	350c	750cap	750b	750c	1500cap	1500b	1500c
A	Mean	0.81	0.55	0.56	0.56	0.56	0.56	0.56	0.59	0.56	0.56	0.58	0.57
	Median	0.82	0.56	0.57	0.57	0.58	0.58	0.58	0.6	0.58	0.57	0.59	0.58
	CV	0.02	0.07	0.08	0.07	0.07	0.08	0.07	0.06	0.06	0.07	0.05	0.07
	Min	0.74	0.42	0.4	0.4	0.4	0.4	0.4	0.42	0.4	0.4	0.43	0.4
	Max	0.86	0.6	0.62	0.61	0.62	0.61	0.62	0.63	0.61	0.62	0.62	0.61
B	Mean	0.85	0.53	0.52	0.53	0.53	0.53	0.52	0.52	0.53	0.55	0.54	0.53
	Median	0.85	0.53	0.52	0.52	0.53	0.53	0.52	0.52	0.52	0.56	0.54	0.52
	CV	0.04	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.1	0.08	0.11	0.1
	Min	0.67	0.43	0.44	0.43	0.43	0.42	0.41	0.41	0.43	0.44	0.42	0.41
	Max	0.91	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.68	0.66	0.66
C	Mean	0.84	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
	Median	0.84	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.62	0.63	0.63	0.63
	CV	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	Min	0.77	0.59	0.58	0.58	0.58	0.59	0.58	0.59	0.58	0.59	0.57	0.59
	Max	0.91	0.68	0.67	0.69	0.67	0.69	0.67	0.67	0.67	0.67	0.67	0.68
D	Mean	0.8	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.76	0.76	0.76
	Median	0.79	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.75	0.75
	CV	0.06	0.04	0.04	0.05	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	Min	0.64	0.7	0.69	0.69	0.71	0.69	0.7	0.7	0.68	0.7	0.71	0.71
	Max	0.91	0.87	0.86	0.86	0.87	0.86	0.87	0.87	0.87	0.87	0.87	0.87
E	Mean	0.86	0.73	0.73	0.74	0.74	0.74	0.74	0.74	0.74	0.75	0.75	0.75
	Median	0.87	0.73	0.74	0.75	0.74	0.74	0.75	0.75	0.74	0.74	0.75	0.74
	CV	0.06	0.06	0.06	0.06	0.06	0.07	0.06	0.06	0.07	0.06	0.07	0.06
	Min	0.63	0.54	0.53	0.62	0.53	0.53	0.65	0.59	0.53	0.66	0.6	0.65
	Max	0.93	0.87	0.85	0.85	0.85	0.88	0.85	0.86	0.87	0.88	0.88	0.86
F	Mean	0.66	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.56	0.55	0.59
	Median	0.63	0.52	0.52	0.52	0.52	0.51	0.52	0.52	0.51	0.52	0.52	0.57
	CV	0.11	0.14	0.14	0.14	0.14	0.14	0.15	0.14	0.15	0.14	0.13	0.14

	Min	0.53	0.47	0.42	0.42	0.42	0.41	0.42	0.42	0.42	0.42	0.48	0.5
	Max	0.86	0.78	0.79	0.79	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
G	**Mean**	0.74	0.59	0.6	0.61	0.61	0.61	0.61	0.61	0.6	0.62	0.61	0.61
	Median	0.72	0.57	0.58	0.58	0.58	0.59	0.58	0.58	0.57	0.58	0.58	0.58
	CV	0.13	0.14	0.14	0.14	0.14	0.13	0.14	0.14	0.14	0.15	0.14	0.15
	Min	0.57	0.45	0.42	0.48	0.43	0.44	0.48	0.47	0.5	0.52	0.53	0.47
	Max	0.94	0.85	0.85	0.85	0.85	0.85	0.86	0.86	0.85	0.86	0.86	0.85
SYSTEM	**Mean**	0.79	0.62	0.62	0.62	0.63	0.62	0.62	0.63	0.62	0.63	0.63	0.63
	Median	0.79	0.61	0.61	0.62	0.62	0.62	0.62	0.62	0.61	0.62	0.63	0.62
	CV	0.03	0.05	0.05	0.05	0.05	0.04	0.05	0.04	0.05	0.05	0.04	0.05
	Min	0.74	0.57	0.58	0.58	0.58	0.57	0.57	0.58	0.58	0.58	0.59	0.59
	Max	0.86	0.72	0.72	0.72	0.73	0.72	0.72	0.73	0.71	0.72	0.73	0.71

Zone	**Statistic**	**Natural**	**Current**	**Reference**	**Year 6 WSP**	**10%**	**20%**
J	**Mean**	0.82	0.63	0.61	0.65	0.64	0.66
	Median	0.83	0.63	0.62	0.66	0.65	0.66
	CV	0.03	0.05	0.06	0.04	0.04	0.04
	Min	0.72	0.54	0.51	0.57	0.58	0.57
	Max	0.86	0.72	0.72	0.73	0.73	0.71

Waterbird Habitat Condition

Zone	Statistic	Natural	Reference	Current	350cap	350b	350c	750cap	750b	750c	1500cap	1500b	1500c
A	Mean	0.4	0.27	0.27	0.27	0.28	0.28	0.27	0.27	0.28	0.28	0.29	0.28
	Median	0.43	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.29	0.28
	CV	0.56	0.5	0.48	0.49	0.45	0.47	0.5	0.57	0.47	0.47	0.53	0.49
	Min	0	0	0	0	0	0	0	0	0	0	0	0
	Max	0.8	0.73	0.73	0.73	0.72	0.71	0.73	0.72	0.71	0.71	0.74	0.71
B	Mean	0.6	0.44	0.46	0.47	0.47	0.45	0.47	0.47	0.46	0.48	0.48	0.46
	Median	0.69	0.38	0.38	0.38	0.4	0.39	0.38	0.4	0.4	0.38	0.43	0.42
	CV	0.32	0.3	0.3	0.31	0.29	0.3	0.32	0.29	0.28	0.31	0.27	0.28
	Min	0	0.28	0.29	0.29	0.3	0.29	0.26	0.29	0.29	0.28	0.29	0.26
	Max	0.83	0.73	0.76	0.76	0.79	0.77	0.74	0.77	0.72	0.74	0.74	0.72
C	Mean	0.56	0.29	0.30	0.31	0.31	0.31	0.32	0.32	0.32	0.35	0.34	0.34
	Median	0.62	0.20	0.21	0.21	0.21	0.21	0.22	0.22	0.23	0.25	0.24	0.26
	CV	0.44	0.84	0.82	0.82	0.82	0.81	0.78	0.82	0.78	0.76	0.76	0.73
	Min	0	0	0	0	0	0	0	0	0	0	0	0
	Max	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
D	Mean	0.63	0.39	0.39	0.39	0.39	0.39	0.41	0.41	0.4	0.43	0.43	0.42
	Median	0.7	0.39	0.37	0.37	0.39	0.39	0.41	0.42	0.41	0.44	0.43	0.42
	CV	0.23	0.75	0.75	0.74	0.74	0.74	0.69	0.69	0.69	0.64	0.63	0.64
	Min	0.08	0	0	0	0	0	0	0	0	0	0	0
	Max	0.78	0.76	0.76	0.77	0.77	0.76	0.76	0.76	0.76	0.77	0.76	0.76
E	Mean	0.34	0.2	0.2	0.2	0.2	0.21	0.21	0.21	0.21	0.22	0.21	0.22
	Median	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.12	0.11	0.1	0.14
	CV	0.65	0.88	0.88	0.88	0.9	0.89	0.86	0.88	0.86	0.85	0.94	0.88
	Min	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.05
	Max	0.85	0.87	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.87
F	Mean	0.42	0.23	0.24	0.24	0.24	0.23	0.24	0.23	0.25	0.24	0.22	0.36
	Median	0.4	0	0.04	0.04	0.04	0.04	0.04	0.01	0.09	0.07	0.01	0.32
	CV	0.59	1.29	1.25	1.24	1.24	1.25	1.23	1.26	1.21	1.24	1.31	0.79

	Min	0	0	0	0	0	0	0	0	0	0	0	0
	Max	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.83
G	**Mean**	0.6	0.33	0.33	0.34	0.34	0.34	0.36	0.36	0.36	0.38	0.38	0.39
	Median	0.62	0.26	0.29	0.32	0.33	0.32	0.33	0.34	0.37	0.37	0.36	0.38
	CV	0.31	0.65	0.63	0.62	0.62	0.63	0.61	0.62	0.59	0.59	0.59	0.55
	Min	0.14	0	0	0.05	0.13	0.05	0.05	0.01	0.04	0.13	0.09	0.06
	Max	0.85	0.77	0.77	0.78	0.78	0.77	0.78	0.77	0.77	0.77	0.77	0.77
SYSTEM	**Mean**	0.50	0.29	0.30	0.30	0.30	0.30	0.31	0.31	0.32	0.33	0.32	0.35
	Median	0.52	0.22	0.23	0.24	0.24	0.24	0.25	0.25	0.27	0.30	0.26	0.32
	CV	0.35	0.64	0.64	0.63	0.63	0.63	0.62	0.62	0.60	0.60	0.59	0.52
	Min	0.05	0.06	0.06	0.07	0.06	0.07	0.07	0.06	0.07	0.08	0.07	0.07
	Max	0.80	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78

Zone	Statistic	Natural	Current	Reference	Year 6 WSP	10%	20%
J	**Mean**	0.69	0.5	0.43	0.5	0.53	0.55
	Median	0.7	0.63	0.56	0.59	0.62	0.63
	CV	0.18	0.56	0.69	0.51	0.46	0.43
	Min	0	0	0	0	0	0
	Max	0.84	0.88	0.85	0.88	0.88	0.88

Floodplain Vegetation Habitat Condition

Zone	Statistic	Natural	Reference	Current	350cap	350b	350c	750cap	750b	750c	1500cap	1500b	1500c
A	**Mean**	0.47	0.34	0.35	0.35	0.35	0.34	0.35	0.39	0.35	0.35	0.39	0.37

	Median	0.48	0.35	0.36	0.36	0.35	0.35	0.36	0.37	0.35	0.36	0.37	0.37
	CV	0.26	0.2	0.21	0.22	0.22	0.22	0.23	0.22	0.21	0.21	0.21	0.23
	Min	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	Max	0.83	0.52	0.62	0.62	0.62	0.56	0.62	0.69	0.56	0.62	0.69	0.65
B	**Mean**	0.42	0.32	0.35	0.34	0.48	0.48	0.37	0.5	0.56	0.4	0.6	0.59
	Median	0.48	0.32	0.35	0.35	0.55	0.55	0.39	0.57	0.57	0.43	0.58	0.57
	CV	0.53	0.67	0.66	0.68	0.57	0.53	0.64	0.54	0.36	0.53	0.34	0.32
	Min	0	0	0	0	0	0	0	0	0.08	0	0.11	0
	Max	0.84	0.97	0.95	0.95	1	0.99	0.95	0.99	1	0.95	1	1
C	**Mean**	0.55	0.38	0.39	0.4	0.4	0.41	0.4	0.4	0.42	0.43	0.43	0.43
	Median	0.56	0.38	0.38	0.38	0.38	0.39	0.39	0.39	0.4	0.42	0.42	0.43
	CV	0.23	0.4	0.41	0.42	0.41	0.41	0.41	0.39	0.39	0.38	0.36	0.37
	Min	0.17	0.1	0.12	0.12	0.12	0.14	0.12	0.12	0.14	0.14	0.12	0.14
	Max	0.77	0.74	0.74	0.76	0.75	0.77	0.77	0.76	0.78	0.79	0.79	0.79
D	**Mean**	0.45	0.28	0.28	0.28	0.28	0.28	0.29	0.29	0.29	0.31	0.31	0.3
	Median	0.44	0.3	0.31	0.31	0.31	0.31	0.31	0.32	0.31	0.33	0.32	0.32
	CV	0.29	0.62	0.62	0.6	0.6	0.6	0.59	0.58	0.57	0.56	0.54	0.55
	Min	0.11	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05
	Max	0.66	0.69	0.69	0.69	0.68	0.69	0.67	0.66	0.67	0.68	0.68	0.67
E	**Mean**	0.49	0.36	0.36	0.37	0.36	0.37	0.37	0.37	0.38	0.39	0.39	0.39
	Median	0.51	0.30	0.30	0.30	0.30	0.30	0.31	0.31	0.31	0.32	0.31	0.33
	CV	0.33	0.40	0.39	0.39	0.38	0.40	0.38	0.39	0.38	0.38	0.38	0.36
	Min	0.21	0.13	0.14	0.14	0.14	0.14	0.14	0.14	0.19	0.17	0.20	0.22
	Max	0.78	0.74	0.73	0.75	0.75	0.77	0.74	0.73	0.72	0.76	0.75	0.75
F	**Mean**	0.43	0.36	0.38	0.38	0.38	0.37	0.38	0.37	0.38	0.38	0.37	0.44
	Median	0.42	0.36	0.37	0.37	0.37	0.36	0.38	0.36	0.37	0.38	0.36	0.43
	CV	0.21	0.28	0.26	0.26	0.26	0.27	0.25	0.27	0.26	0.25	0.28	0.22
	Min	0.18	0.17	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.2
	Max	0.63	0.61	0.61	0.61	0.61	0.62	0.61	0.61	0.61	0.61	0.64	0.67
G	**Mean**	0.47	0.28	0.29	0.29	0.29	0.3	0.3	0.31	0.31	0.32	0.33	0.34
	Median	0.45	0.24	0.26	0.27	0.3	0.35	0.35	0.36	0.3	0.36	0.39	0.39

	CV	0.35	0.71	0.7	0.68	0.67	0.67	0.66	0.65	0.62	0.61	0.61	0.58
	Min	0.09	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Max	0.84	0.83	0.81	0.82	0.82	0.83	0.82	0.78	0.78	0.79	0.81	0.81
SYSTEM	**Mean**	0.48	0.34	0.35	0.35	0.36	0.37	0.36	0.37	0.38	0.38	0.40	0.40
	Median	0.48	0.35	0.34	0.35	0.36	0.36	0.36	0.37	0.37	0.38	0.38	0.39
	CV	0.19	0.34	0.35	0.35	0.35	0.34	0.35	0.33	0.31	0.31	0.30	0.28
	Min	0.21	0.14	0.14	0.14	0.14	0.16	0.14	0.15	0.18	0.15	0.19	0.19
	Max	0.66	0.63	0.67	0.69	0.71	0.70	0.69	0.70	0.70	0.72	0.72	0.69

Zone	**Statistic**	**Natural**	**Current**	**Reference**	**Year 6 WSP**	**10%**	**20%**
J	**Mean**	0.49	0.31	0.32	0.34	0.32	0.37
	Median	0.5	0.25	0.26	0.31	0.26	0.37
	CV	0.48	0.81	0.8	0.77	0.78	0.67
	Min	0	0	0	0	0	0
	Max	1	0.94	0.94	0.95	0.95	0.95

Wetland Vegetation Habitat Condition

Zone	Statistic	Natural	Reference	Current	350cap	350b	350c	750cap	750b	750c	1500cap	1500b	1500c
A	Mean	0.55	0.46	0.48	0.48	0.47	0.48	0.47	0.56	0.48	0.48	0.55	0.48
	Median	0.59	0.45	0.45	0.45	0.44	0.44	0.45	0.6	0.45	0.44	0.59	0.46
	CV	0.21	0.3	0.23	0.24	0.24	0.23	0.24	0.21	0.24	0.25	0.22	0.23
	Min	0.13	0.02	0.16	0.12	0.1	0.14	0.1	0.13	0.17	0.07	0.16	0.17
	Max	0.7	0.7	0.69	0.69	0.69	0.7	0.69	0.71	0.7	0.69	0.71	0.68
B	Mean	0.63	0.48	0.5	0.51	0.52	0.5	0.51	0.53	0.53	0.52	0.56	0.56
	Median	0.71	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.41	0.39	0.63	0.63
	CV	0.25	0.3	0.31	0.31	0.3	0.3	0.31	0.3	0.29	0.3	0.27	0.28
	Min	0.22	0.35	0.36	0.37	0.37	0.36	0.37	0.37	0.36	0.33	0.37	0.36
	Max	0.79	0.75	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.76	0.76	0.77
C	Mean	0.64	0.56	0.57	0.57	0.57	0.57	0.58	0.57	0.59	0.58	0.60	0.60
	Median	0.66	0.60	0.60	0.60	0.60	0.60	0.61	0.61	0.60	0.61	0.61	0.62
	CV	0.15	0.28	0.25	0.25	0.25	0.26	0.24	0.26	0.22	0.22	0.19	0.21
	Min	0.09	0.09	0.19	0.12	0.11	0.10	0.019	0.21	0.20	0.22	0.20	0.21
	Max	0.8	0.81	0.79	0.80	0.78	0.78	0.78	0.78	0.79	0.80	0.78	0.81
D	Mean	0.57	0.37	0.37	0.38	0.38	0.38	0.4	0.4	0.4	0.42	0.41	0.42
	Median	0.61	0.38	0.37	0.43	0.42	0.42	0.45	0.45	0.46	0.47	0.45	0.46
	CV	0.21	0.59	0.6	0.58	0.58	0.58	0.55	0.55	0.53	0.51	0.49	0.49
	Min	0.13	0	0	0	0	0	0	0	0	0	0	0
	Max	0.71	0.72	0.72	0.71	0.72	0.71	0.71	0.72	0.71	0.72	0.72	0.71
E	Mean	0.63	0.5	0.51	0.51	0.51	0.51	0.52	0.52	0.51	0.53	0.53	0.53
	Median	0.66	0.42	0.39	0.41	0.39	0.39	0.46	0.46	0.46	0.47	0.47	0.47
	CV	0.27	0.29	0.29	0.29	0.29	0.3	0.29	0.3	0.29	0.3	0.3	0.29
	Min	0.39	0.29	0.36	0.38	0.39	0.38	0.38	0.37	0.32	0.38	0.39	0.37
	Max	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
F	Mean	0.6	0.29	0.3	0.3	0.3	0.28	0.3	0.28	0.32	0.3	0.27	0.5
	Median	0.76	0	0	0	0	0	0	0	0	0	0	0.71
	CV	0.47	1.24	1.19	1.19	1.2	1.22	1.19	1.22	1.14	1.22	1.3	0.68
	Min	0	0	0	0	0	0	0	0	0	0	0	0
	Max	0.9	0.84	0.85	0.85	0.85	0.85	0.84	0.85	0.85	0.85	0.85	0.87

G	**Mean**	0.59	0.46	0.45	0.46	0.46	0.47	0.48	0.48	0.5	0.5	0.5	0.52
	Median	0.63	0.48	0.46	0.49	0.46	0.51	0.54	0.55	0.58	0.56	0.61	0.61
	CV	0.19	0.55	0.54	0.52	0.54	0.53	0.5	0.49	0.48	0.45	0.48	0.41
	Min	0.1	0.03	0.05	0.06	0.06	0.06	0.06	0.05	0.06	0.06	0.05	0.06
	Max	0.73	0.78	0.77	0.78	0.78	0.78	0.78	0.78	0.78	0.76	0.77	0.79
SYSTEM	**Mean**	0.61	0.45	0.46	0.47	0.47	0.46	0.47	0.48	0.48	0.48	0.49	0.53
	Median	0.63	0.45	0.44	0.44	0.45	0.46	0.46	0.48	0.47	0.47	0.50	0.53
	CV	0.18	0.33	0.32	0.32	0.32	0.32	0.31	0.30	0.29	0.30	0.27	0.24
	Min	0.15	0.18	0.19	0.18	0.19	0.18	0.20	0.21	0.20	0.21	0.21	0.21
	Max	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.75	0.74	0.73	0.74	0.73

Zone	**Statistic**	**Natural**	**Current**	**Reference**	**Year 6 WSP**	**10%**	**20%**
J	**Mean**	0.76	0.57	0.51	0.62	0.62	0.63
	Median	0.81	0.76	0.69	0.79	0.79	0.79
	CV	0.21	0.61	0.71	0.53	0.52	0.49
	Min	0	0	0	0	0	0
	Max	0.91	0.95	0.93	0.94	0.91	0.92