

## **Attachment 9 – REG J Report**

Regional Evaluation Group Assessment of reference point flow scenarios for zone J (The Murrumbidgee River)

# Ecological assessment of flow scenarios in the Murrumbidgee River (Zone J) for the Living Murray Initiative

Final Report to the Murray-Darling Basin Commission  
for the Living Murray Initiative  
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## 1. SUMMARY

The reach of the Murrumbidgee River assessed in this report extends from downstream of Burrinjuck Dam to the confluence with the Murray River. This reach can be subdivided into five distinctive zones based on geomorphic and hydrological characteristics. Localities were selected from four of these river zones. The majority of the localities were from the Lowbidgee and Riverine Plain Palaeo-floodplain as these zones 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.

Seven flow scenarios were evaluated in the Murrumbidgee River:

1. Modelled Natural
2. Modified Current
3. Modified Reference
4. Modified 1<sup>st</sup> year gazetted Murrumbidgee Water Sharing Plan (referred to as WSP1)
5. Modified 6<sup>th</sup> year gazetted Murrumbidgee Water Sharing Plan (referred to as WSP6)  
This scenario is approx equivalent to the 350GL-a scenario assessed by other REGs.
6. 10% reduction of modified current – This scenario is approximately equivalent to the 750GL-a scenario assessed by the other regional evaluation groups
7. 20% reduction of modified current - This scenario is approximately equivalent to the 1500GL-a scenario assessed by the other regional evaluation groups

The Murray Flow Assessment Tool (MFAT) was used to generate waterbird, fish, floodplain vegetation and wetland vegetation habitat condition indices for each of the 108 years of modelled flows. Threshold analysis was used to group these values into five categories: ‘much better’ than the reference (greater than 50% increase), ‘better’ than the reference (between 5 and 50% increase), ‘same’ as the reference (including 5% either side of the reference index), ‘worse’ than the reference (index between 5 and 50% less than the reference) and ‘much worse’ than the reference (less than 50% of the reference index). Several additional assessments were undertaken in the Murrumbidgee River: assessment of operational changes to Yanga Regulator at Piggery Lake; assessment of partial mitigation of cold water pollution at Gundagai; an assessment of a billabong that is regularly connected to the river during irrigation flows; and assessment of Cumbungi and Algae (nuisance taxa).

*Waterbird results:* The waterbird habitat condition index increased with increasing environmental flow allocations, with a greater improvement in the index under the 10% and 20% flow scenarios than under the WSP1 or WSP6 scenarios. Changing the operation of the Yanga regulator at Piggery Lake in the Lowbidgee combined with increased environmental flow allocations resulted in a small further increase in the waterbird habitat condition index.

*Fish results:* Increased environmental flow allocations resulted in an increase in the habitat condition index of fish at Gundagai, but little change in the index at Redbank Weir. Partial mitigation of cold water pollution improved fish habitat conditions at Gundagai more than by increasing environmental flow allocations alone. Murray Cod habitat condition would benefit considerably from increased environmental flow allocations and benefit even further if the flow allocations were in conjunction with partial mitigation of cold water pollution. Several other factors are known to impact on fish populations in the Murrumbidgee River and these factors would need to be addressed to ensure that the improvement in fish habitat condition predicted in this report would actually result in healthier fish populations.

*Floodplain vegetation results:* Increased environmental flow allocations generally resulted in an increase in the habitat condition index of floodplain vegetation at Cuba Forest. As the health of river red gums is highly influenced by flood duration this reflects the larger number of overbank flows that would eventuate from higher environmental flow allocations.

*Wetland vegetation results:* Increased environmental flow allocations resulted in an increase in the habitat condition index of wetland vegetation. Cattle grazing and poor land management practises in the riparian zone and around wetlands would significantly reduce the potential for improvement in the condition of wetland plants. These factors would need to be addressed to ensure that the improvement in wetland plant habitat condition predicted in this report would result in healthier wetland plant populations.

*Algae results:* The algal assessment predicts that there will be a reduction in the number of algal blooms at Maude Weir under the 20% flow scenario.

*Detrimental outcomes of flow scenarios:* The only detrimental outcome predicted is that the health of the nuisance wetland plant species Cumbungi could improve relative to current conditions under increased environmental flow allocations. As Cumbungi does not currently occur in any of the lagoons assessed in this report, this negative outcome is only hypothetical and could be minimised with a targeted weed management plan. It is likely that common carp may also benefit from changed flow scenarios, however an assessment of carp was not undertaken in this report, as there is no capability to assess carp in the MFAT.

*Comparison of flow scenarios:* Most habitat condition indices showed an improvement at least once every twenty years, however considerably fewer indices showed an improvement at least once every five years. Most of the improvements observed at least once every five years under the WSP1 and WSP6 flow scenarios were those that resulted from the combined effects of operational changes and increased flow allocations. In contrast, under the 10% and 20% flow scenarios five indices showed improvement solely in response to the increased environmental water allocations and three were improved due to the combined effects of operational changes and increased flow allocations. If the community considers it acceptable to have 'better' or 'much better' river health in one out of every twenty years, then the model predicts that many indices are likely to show improvement under all of the flow scenarios. However, if the community expects to observe 'better' or 'much better' river health in one out of every five years then this is unlikely to be realised for many indices under the WSP1 or WSP6 scenarios and will only be attained under the 10% or 20% flow scenarios.

*Constraints:* The main limitation of this assessment is that only one flow delivery strategy was modelled for each of the flow scenarios. Furthermore, under the 10% and 20% flow scenarios, water was delivered to the environment according to the 'current' flow rules. Therefore the flow scenarios that were assessed in this report are not likely to produce the most beneficial ecological outcomes for the volume of water. The MDBC has undertaken to develop additional hydrological scenarios for the Murrumbidgee River that optimise environmental outcomes whilst minimising impacts on existing water users. When these additional scenarios are available it will be possible to determine if additional ecological benefit can be achieved in the Murrumbidgee River from different flow delivery strategies. A further constraint on this assessment was that only a small number (eight) of localities in could be included in this assessment. Future assessments of flow scenarios in the Murrumbidgee River should assess the habitat condition index of each group (e.g. fish) in each of the five geomorphic zones that have been identified downstream of Burrinjuck Dam.

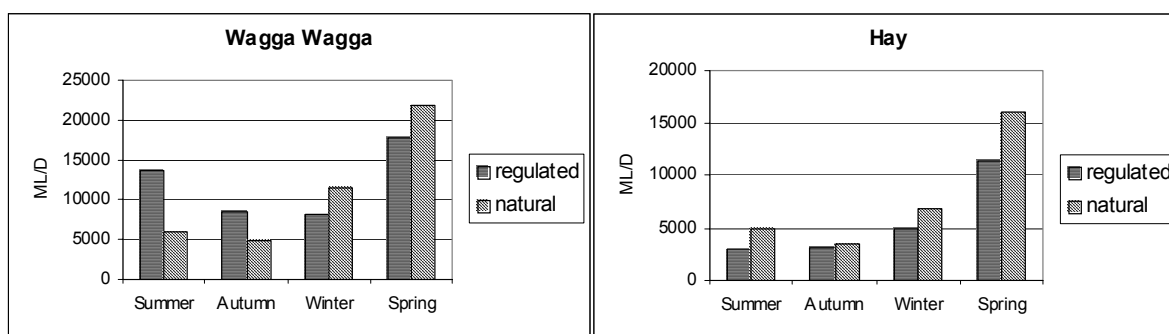
## 2. INTRODUCTION

The Murrumbidgee River is an approximately 1600 km long tributary of the Murray River in southern NSW with a total catchment area of 84000 km<sup>2</sup> (DLWC 1995). It rises in a region of high annual precipitation in the Snowy Mountains and then flows west across the semi-arid Riverine Plain before joining the Murray River near Balranald. The Murrumbidgee River supplies large irrigation areas downstream of Narrandera. There was an average annual flow diversion of 2506 GL from the river between 1988 and 1994 (23.5 % of all surface water extractions from the Murray-Darling Basin) (MDBMC 2002). Only 30 per cent of the pre-irrigation flows reach the Murray River (MDBMC 2002). Environmental flows have been implemented in the Murrumbidgee River since 1998.

The flow regime of the Murrumbidgee River is regulated by two storage reservoirs; Burrinjuck Dam on the Murrumbidgee River and Blowering Dam on the Tumut River. Modelling of flows by the NSW Department of Land and Water Conservation has shown that reservoir construction, flow augmentation and water diversion for irrigation have combined to alter the natural flow regime (Read 2001). Between 1970 and 1998 average historical flows reach a maximum 12737 MLd<sup>-1</sup> at Wagga Wagga and reduced downstream to 4232 MLd<sup>-1</sup> at Balranald. The diversion of water for irrigation is the principal cause of this difference, but losses to evaporation, distributaries and floodplain storage also play a part.

In the reach upstream of the major irrigation off-takes, average flows in the period 1970 to 1998 were increased by diversions of approximately 550,000 ML per year from the Snowy Mountain Scheme (DLWC 1996). The impact of irrigation and flow augmentation is evident in a comparison of historical and modelled natural flows. At Wagga Wagga, average flows have been increased by 11.3%, whereas at the most downstream gauge, Balranald, there has been a 46% reduction in flows. Modelled natural flows show a strong seasonal redistribution of flows in the reach upstream of irrigation off-takes (Figure 1). At Wagga Wagga, summer and autumn flows have been increased while winter and spring flows have been reduced (Figure 1). Downstream of major irrigation diversions (e.g. at Hay) the seasonal distribution of flows is similar to that before regulation but with the magnitude of all flows reduced (Figure 1). Burrinjuck Dam has a modest mitigating effect on large floods but strongly mitigates floods with an average frequency of occurrence of less than five years (DLWC 1996). Reservoir construction has halved the frequency of floodplain inundation between Gundagai and Balranald in the period 1970 to 1998 (Read 2001).

The main threats to the ecology of the Murrumbidgee River include alterations to the natural timing of flows, reduced connections between the river and floodplain, reduced frequency of flooding, cold water pollution, in-stream barriers, snag removal, clearing, grazing by domestic livestock, and the introduction of exotic species (Hillman *et al.* 2000). The Murrumbidgee River and its associated floodplain contain several significant sites and supports important ecological communities and nationally listed threatened species. The mid-Murrumbidgee wetlands are listed in the Directory of Important Wetlands (ANCA 1996) and the Lowbidgee area supports large populations of breeding waterbirds (Kingsford & Thomas 2001). The freshwater fish community in the Murrumbidgee River includes the threatened Trout Cod, Silver Perch and Macquarie Perch and the icon species Murray Cod (Lugg 2000, Hartley and Rayner 2002). One species of frog and three species of birds associated with floodplain habitats on the Murrumbidgee River are listed as threatened in NSW (NSW Threatened Species Conservation Act 1995, updated 2002).



**Figure 1.** Mean seasonal flows in the Murrumbidgee River under historical regulated and modelled natural regimes at Wagga Wagga and Hay (1970-1998). Historical regulated flows at Wagga Wagga have been augmented by approximately 550,000 ML per year from the Snowy Mountain Scheme (DLWC 1996).

### 3. METHODS

#### 3.1 Selection of localities

The reach of the Murrumbidgee River assessed in this report extends from downstream of Burrinjuck Dam to the confluence with the Murray River. This reach of the Murrumbidgee River can be subdivided into 5 distinctive zones based on geomorphic and hydrological characteristics (Page & Nanson 1996) (Table 1). Localities were selected from four of these river zones (Table 2). No localities were selected from the Carrathool to Hay zone because it has very few wetlands (Page & Nanson 1996; Frazier, unpublished data). The majority of the localities were from the Lowbidgee and Riverine Plain Palaeo-floodplain as these zones have substantial floodplain and wetland development. Localities were selected if they was near to a river gauging site, typical of that zone, and if there were good hydrological data and ecological data available for that locality. Two river reaches, four wetlands, one weir-pool and one floodplain were selected for assessment (Table 2).

**Table 1.** Geomorphic reaches of the Murrumbidgee River below Burrinjuck Dam after Page & Nanson (1996).

River Zone	Reach	Features
Burrinjuck Dam to Malebo Range	Confined Valley	Narrow floodplain confined by bordering hills (floodplain width 2 to 5 km)
Malebo Range to Narrandera	Wide Valley	Wider floodplain with little topographic confinement – some large meander scars and anabranches (floodplain width up to 10 km)
Narrandera to Carrathool	Riverine Plain Palaeo-floodplain	Substantial floodplain development with large meander cut-offs from palaeo-river (floodplain width 2 to 6 km)
Carrathool to Hay	Riverine Plain Confined floodplain	Narrow floodplain with no palaeo-channel remnants and few wetlands (floodplain width < 1.5 km)
Hay to Murray River	Lowbidgee	Very flat expansive modern floodplain with extensive marginal swamps (floodplain width reaches a maximum of 45 km before narrowing to less than 3 km below Balranald)

**Table 2.** Rationale for selection of localities assessed in Murrumbidgee River.

<b>Localities</b>	<b>River zone</b>	<b>Assessments undertaken</b>	<b>Reasons for selection</b>
Gundagai	Burrinjuck Dam to Malebo Range	Fish	This reach was selected to enable an assessment of the fish community that occurs in reaches affected by cold water pollution. NSW Fisheries data were available for this locality.
Berry Jerry Lagoon	Malebo Range to Narrandera	Wetland vegetation	This lagoon was selected to represent billabongs that are regularly connected to the river during summer irrigation flows. Information on commence to flow, cross sectional area, length of time to drying and IMEF vegetation data were available.
Narrandera Forest Lagoon	Narrandera to Carrathool	Wetland vegetation	This wetland is typical of the meander cut-off type of billabongs that are part of the mid-Murrumbidgee wetland complex listed in the Directory of Important Wetlands (DIW) (ANCA 1996). Information on commence to flow, cross sectional area, length of time to drying and IMEF vegetation survey data were available.
Yarradda Lagoon Complex	Narrandera to Carrathool	Waterbirds and wetland vegetation	This wetland is typical of the palaeochannel type of billabongs that are part of the mid-Murrumbidgee wetland complex listed in the DIW (ANCA 1996). Information on commence to flow, cross sectional area, length of time to drying, IMEF vegetation data and NPWS bird survey data available.
Cuba State Forest	Narrandera to Carrathool	Floodplain vegetation	This floodplain is typical of the red gum forests that occur in the mid-Murrumbidgee River and is habitat for the threatened superb parrot. Floodplain cross-section surveys (Carden et al. 1999) and floodplain vegetation surveys (Jansen unpublished data) have been undertaken at this locality.
Maude Weirpool	Hay to Murray River	Algae	Algal blooms have been reported at Maude Weir (e.g. Jones 1994). DLWC database on algal cell counts was available for this weir.
Downstream of Redbank Weir	Hay to Murray River	Fish	This reach was selected to enable an assessment of the fish community that occurs in reaches downstream of irrigation diversions. It has been listed as a fish hotspot. NSW fisheries and IMEF fish survey data were available.
Piggery Lake Complex	Hay to Murray River	Waterbirds	This wetland complex was selected to represent the important waterbird breeding sites in the Lowbidgee. Hydrological data and NPWS bird survey data were available.

### 3.2 Description of floodplain configurations and wetlands

Floodplain configurations were produced for input to the Murray Flow Assessment Tool (MFAT). Data required to set up the configurations were wetland commence to flow (CTF), wetland area, wetland volume, area-volume relationship and wetland seepage rate. Descriptions of the floodplain configurations are presented in Table 3.

**Table 3.** Descriptions of floodplain configurations used in Murrumbidgee River assessment

Floodplain configuration	Description of wetlands
Berry Jerry Lagoon	Berry Jerry Lagoon is a 6.6 ha (117 ML) meander cut-off lagoon located approx 30km west of Wagga Wagga on the north side of the river. It is connected to the river by overbank flows and CTF at 16,700 MLd <sup>-1</sup> at the Wagga gauge (Maguire 1998). The dominant wetland vegetation is <i>Eleocharis acuta</i> (common spike rush), with <i>Ludwigia peploides</i> (water primrose), <i>Paspalidium jubiflorum</i> (Warrego summer grass), <i>E. sphacelata</i> (Large spike rush) and <i>Psuedoraphis spinescens</i> (spiny mudgrass) being relatively abundant (Hardwick unpub. data).
Narrandera Forest Lagoon	Narrandera Forest Lagoon is a 5.6 ha (67 ML) meander cut-off lagoon located approximately 2 km west of Narrandera on the north side of the river. It is connected to the river by overbank flows and its CTF is 26,800 MLd <sup>-1</sup> at the Narrandera gauge (Maguire 1998). The lagoon is surrounded by river red gum and has an <i>E. acuta</i> understorey. It is typified by extensive <i>P. spinescens</i> stands when inundated (Hardwick unpublished data).
Yarradda Lagoon Wetland Complex comprising Yarradda Lagoon and Yarradda halo floodplain	Yarradda Lagoon is a 128 ha (1,525 ML) palaeo-channel cut-off of the Gum Creek system located approximately 16 km west of Darlington Point on the south side of the river. It is connected to the river by overbank flows and its CTF is 16,000 MLd <sup>-1</sup> at the Darlington Point gauge (Maguire 1998). The lagoon is surrounded by river red gum with <i>E. acuta</i> understorey. When inundated the lagoon vegetated with <i>P. spinescens</i> , <i>Triglochin procera</i> (water ribbons), <i>Eleocharis sphacelata</i> (Tall spike rush), <i>Ludwigia peploides</i> (water primrose) and various other species (Hardwick unpublished data).
Cuba State Forest	Cuba floodplain is characterised by large meander scars of the Gum Creek palaeo-channel system (Page et al. 1996) and varies in width from 3 to 6 km. The river flats adjacent to the channel carry dense stands of mature river red gums, with an understorey dominated by exotic annual grasses and herbs (Jansen, unpublished data). The CTF of the floodplain is 23,000 MLd <sup>-1</sup> at the Darlington Point gauge.
Piggery Lake Wetland Complex comprising Piggery Lake and Tarwillie Floodplain	Piggery Lake is a roughly circular natural floodplain depression in the Lowbidgee Swamp, located approximately 2km east of the Murrumbidgee channel and 6 km downstream of the Yanga regulator in Redbank Weir. It is fed by controlled releases from the regulator with a CTF of 4,764 MLd <sup>-1</sup> at the gauge within Redbank Weir. It is also connected to the river by overbank flows with a CTF of 9,500 MLd <sup>-1</sup> at the gauge downstream of Redbank Weir. Tarwillie Swamp (area 200 ha) is fed by overflow from Piggery Lake to the southeast. The dominant vegetation in these wetlands is river red gum.

### ***3.3 Verification of floodplain configurations***

Verification of each floodplain configuration was undertaken using the natural flow scenario and details of floodplain verification data are provided in Appendix 1. The verification was undertaken using the following steps:

1. The daily hydrograph of the inflow pipes to the partitioning storages was examined and was checked for years of known large floods (e.g. 1925, 1956, 1974/75) and droughts (e.g. 1940/41, 1980/81)
2. The volume of the partitioning storage was checked to ensure it was zero at the end of each day
3. The inflow pipe to each wetland was checked to ensure that it peaked at the pipe capacity set in the floodplain configuration
4. The frequency of filling of wetlands as compared to local knowledge
5. The length of the drying period in each wetland was checked against DLWC data logger information (Hardwick unpublished data)
6. The rate of filling of each wetland was compared to local knowledge

For Piggery Lake complex an additional verification step was undertaken because this configuration has two partitioning storages that receive inflows from different hydrological nodes. The configuration for the natural and current scenarios were checked: a) with inflows coming only from the Yanga regulator on Redbank weir; b) with inflows coming only from overbank flows using downstream Redbank Weir gauge; and c) with inflows coming from a combination of the Yanga regulator and overbank flows. Inflow from only over-bank flows was used for the natural scenario, whereas inflows from both the Yanga regulator and overbank flows were used for all other scenarios.

### ***3.4 Hydrological scenarios examined***

The Department of Infrastructure Planning and Natural Resources Integrated Quantity and Quality Model (IQQM) generated the flow files used in this assessment. The IQQM represents the major hydrologic and water management processes that occur in the river basin. It simulates many processes including streamflow, reservoir operation and irrigation demands. Seven flow scenarios produced for assessment were:

1. Natural - this scenario is a calibrated 'Current' model without Burrinjuck Dam or Blowering Dam, without irrigation diversions, with a natural Yanco Ck outflow, without any river weirs, and with the same tributary inflows, rainfall, and evaporation as the current system
2. Modified Current – based on the sort of crop areas seen in 97/98 to 99/00 (with adjustment for allocation). The model uses entitlements as they were in 99/00 including adjustment for intra and inter valley trade
3. Modified Reference – This model is used for MDBC 'cap' auditing purposes and is based on the sort of crop areas and entitlements in 1993/94 with adjustment for allocation.
4. Modified 1<sup>st</sup> year gazetted Murrumbidgee Water Sharing Plan (referred to as WSP1)
5. Modified 6<sup>th</sup> year gazetted Murrumbidgee Water Sharing Plan (referred to as WSP6) This scenario is approximately equivalent to the 350GL-a scenario assessed by the other regional evaluation groups
6. 10% reduction of modified current – This scenario is approximately equivalent to the 750GL-a scenario assessed by the other regional evaluation groups
7. 20% reduction of modified current - This scenario is approximately equivalent to the 1500GL-a scenario assessed by the other regional evaluation groups

The flow scenarios generated for the Murrumbidgee zone were different from those assessed by the other regional evaluation groups. In the Murrumbidgee River only one flow delivery strategy was modelled for each of the test scenarios. A project to undertake integrated modelling of the Murrumbidgee and Murray Rivers has been recently initiated by the Murray-Darling Basin Commission to develop further the hydrological modelling in the Murrumbidgee River. One of the objectives of this project is to explore opportunities to optimise environmental outcomes whilst minimising impacts on existing water users by improved integration of environmental flows in the Murrumbidgee and Murray River systems. The outcomes of the integrated project will be additional hydrological scenarios that can be incorporated into future ecological assessments. When these additional scenarios are available it will be possible to determine if additional ecological benefit can be achieved in the Murrumbidgee River from different flow delivery strategies.

### 3.5 Zone level ecological assessments

The Murray Flow Assessment Tool (MFAT) was used to assist the ecological assessment of flow scenarios in the Murrumbidgee River. Table 4 summarises the ecological assessments that were undertaken to calculate the overall zone level indices. If more than one locality was used in an assessment each was weighted equally in the analysis.

**Table 4.** Summary of ecological assessments used to calculate the overall zone level indices for the Murrumbidgee River.

Ecological assessments	Localities	Groups assessed
Waterbirds	Yarradda Lagoon Complex Piggery Lake Complex	Colonial nesting waterbirds and waterfowl and grebes were assessed these localities as they have been recorded at both localities (Maher 1990; Briggs et al. 1997; Kingsford & Thomas 2001).
Fish	Gundagai Downstream of Redbank weir	All fish groups except group 4 (catfish) were included in the assessment at Gundagai as this locality is outside the range of freshwater catfish (Pollard <i>et al.</i> 1996). All fish groups were included in the assessment at downstream of Redbank Weir because they have the potential to occur at this locality (Lugg 2000).
Floodplain vegetation	Cuba State Forest	Only river red gum forest was assessed at Cuba State Forest because it is the dominant species at this locality.
Wetland vegetation	Narrandera Forest Lagoon Yarradda Lagoon	Spiny mudgrass and ribbon weed were assessed because they occur at these localities (Hardwick, unpub. data) and they were the taxa modelled in the MFAT that best represent the wetland plant communities in these lagoons. Although <i>Phragmites australis</i> does not occur in these wetlands it was assessed because it occurs in these areas and may have disappeared from the wetlands with overgrazing by cattle.

### 3.6 Amendments to default MFAT settings

The Scientific Reference Panel default preference curves, settings and weightings were used in all assessments with the exception of those indicated in Tables 5 and 6. Details of the rationale for the changes to preference curves and weightings, together with the relevant information sources, are embedded in the ecological modules of the MFAT for zone J.

**Table 5.** Preference curves or settings amended from SRP default curves.

<b>Module</b>	<b>Preference curve or settings amended</b>
Fish	<ul style="list-style-type: none"> <li>● Model weights modified for each group</li> <li>● Cold water pollution set to none for the natural scenario and high for all other scenarios</li> <li>● Fish Passage parameters adjusted for groups 1, 2 and 6</li> <li>● Channel conditions parameters set based on each locality</li> <li>● Spawning timing at Gundagai was adjusted for all fish groups (except wetland specialists) for all scenarios (except natural) to simulate reduced spawning success due to cold water pollution</li> <li>● Substrate condition, flood magnitude, and inundation area were adjusted based on local hydrology</li> </ul>
Floodplain vegetation	<ul style="list-style-type: none"> <li>● AHC - changed flood memory to increment 6: decrement 1 based on locality specific hydrological data</li> <li>● Modified inundation duration curve for adults and recruits so they reach a maximum at 11 days based on locality specific hydrological data</li> <li>● Changed zero point at zero inundation duration to 0.1</li> </ul>
Algae	<ul style="list-style-type: none"> <li>● Growth rate constant changed to 0.37/day</li> <li>● Decay constant set at -0.2</li> <li>● Seed population set to 1</li> </ul>

**Table 6.** Changes to within locality weightings from SRP default.

<b>Module</b>	<b>Weights changed</b>
Waterbirds	The following weightings were used for both colonial nesting birds and waterfowl/grebes: FD 0.8, RF 0, DP 0.05, NV 0.15
Fish	Gundagai: G1=1, G2=3, G3=2, G4=0, G5=3, G6=3, G7=2 Redbank: G1=1, G2=0.2, G3=1, G4=1, G5=1, G6=1, G7=1
Wetland vegetation	Weighting for Phragmites set to AHC 80: RHC 20

### 3.7 Species level assessments

One species level assessment was undertaken in the Murrumbidgee zone. The icon species Murray Cod was assessed at each river locality (Gundagai and downstream of Redbank weir). The effect of partial mitigation of cold water pollution on Murray Cod was also assessed at Gundagai. Partial cold water mitigation was simulated by changing the cold water pollution setting from high to medium. The monthly spawning timing values were increased from 0.01 from September to January (see Table 5) to a value that was half of the value set in scientific reference panel default preference curve, to simulate partial improvement in the likelihood of successful spawning.

### 3.8 Additional Assessments

The additional assessments undertaken in the Murrumbidgee River were operational changes to infrastructure, an assessment of a billabong that is regularly connected to the river during summer irrigation flows, and assessment of nuisance taxa (Table 7).

**Table 7.** Summary of additional ecological assessments for the Murrumbidgee River

Assessment and locality	Focus group	Details of assessment
Changed operation of Yanga regulator at Piggery Lake	Waterbirds	Yanga regulator is normally opened between August and November (Tom Davy, pers comm). Assessments of the waterbird condition index in Piggery Lake were undertaken with the regulator opened from July to November and from June to November.
Partial mitigation of cold water pollution at Gundagai	Fish	This assessment was undertaken to examine the response of fish to the partial mitigation of cold water pollution that could be brought about by the installation of a multilevel off-take on either Burrinjuck or Blowering Dam. Partial cold water mitigation was simulated by changing the cold water pollution setting from high to medium. The monthly spawning timing values were also increased
Assessment of a wetland (Berry Jerry Lagoon) that is currently often inundated by summer irrigation flows	Wetland vegetation	As this lagoon does not have a typical commence to flow of billabongs in this zone (Maguire 1998), it was reported as an additional assessment rather than including it in the zone level assessment.
Nuisance plant species (Cumbungi rushland) at Berry Jerry Lagoon, Narrandera Forest Lagoon and Yarradda Lagoon	Wetland vegetation	Cumbungi does not currently occur in any of these wetlands (Hardwick, unpublished data). It was assessed at these localities because it is a highly invasive plant that could potentially become a nuisance in wetlands where there is permanent water.
Nuisance algal species ( <i>Anabaena circinalis</i> ) at Maude Weirpool	Algae	Algal blooms have been reported at Maude Weir (e.g. Jones 1994). This assessment was included as an additional assessment (not a zone level assessment) because algal blooms are not common in the Murrumbidgee River but can be a problem in weirs.
Nuisance fish species - carp	Fish	Carp are extremely abundant in the Murrumbidgee River. There is no capability to assess this species in the MFAT, so a brief manual assessment was undertaken.

### 3.9 Data analyses

The MFAT was used to undertake the ecological assessments in this report. The condition indices all range between zero, representing an unhealthy condition, and one, representing a healthy condition. The mean condition index, median condition index and coefficient of variation were calculated for each hydrological scenario for each of the assessments.

Four types of threshold analyses were undertaken using the MFAT:

1. The percent of years greater than the mean of the range of the natural scenario was calculated for each scenario for waterbirds, fish, floodplain vegetation, wetland vegetation and river health, where:  $\text{mean of range} = \frac{\text{min} + (\text{max} - \text{min})}{2}$
2. S/R (ratio of test scenario to reference scenario) was calculated for waterbirds, fish, floodplain vegetation, wetland vegetation and river health. The MFAT was used to generate an index for each of the 108 years of modelled flows. Threshold analysis grouped these values into five categories: much better than the reference, better than the reference, similar to the reference, worse than the reference and much worse than the reference. These were calculated using the following formulae:
  - a) **Much better** = percent of years much better than reference, defined as those years with a greater than 50% increase over the reference index. ( $\% \text{ years} \geq \text{threshold } 1.51$ )
  - b) **Better** = percent of years better than reference, defined as those years with greater than 5% but less than 50% increase over the reference.  
( $\% \text{ years} \geq \text{threshold } 1.06$ ) – ( $\% \text{ years threshold} \geq \text{threshold } 1.51$ )
  - c) **Same** = percent of years similar to the reference, defined as those years having between 5% lower value and 5% greater value than the reference.  
( $\% \text{ years} \geq \text{threshold } 0.98$ ) – ( $\% \text{ years} \geq \text{threshold } 1.06$ )
  - d) **Worse** = percent of years worse than reference, defined as those years with less than 5% but not greater than 50% reduction over the reference.  
( $\% \text{ years} \geq \text{threshold } 0.75$ ) – ( $\% \text{ years threshold} \geq \text{threshold } 0.98$ )
  - e) **Much worse** = percent of years much worse than reference, defined as those years with more than 50% reduction over the reference index.  
 $100 - (\% \text{ years} \geq \text{threshold } 0.75)$
3. S/C (ratio of test scenario on current scenario) was calculated for waterbirds, fish, floodplain vegetation, wetland vegetation and river health using the same approach as outlined in point 2 (above) but using the current scenario as the denominator.
4. For the nuisance algae assessment the number of times the algal count reached the low alert (2,000 cells), medium alert level (15,000 cells) or the high alert level (100,000 cells) was recorded manually from the cell counts in the algae.mdb using in the database viewer of the MFAT.

## 4. RESULTS

### 4.1 Zone level assessments

#### *Waterbirds*

The mean waterbird habitat condition index ranged from 0.43 for the reference scenario to 0.55 for the 20% flow scenario (natural 0.69; Table 8), and the median ranged from 0.56 for the reference to 0.63 for the 20% flow scenario (natural 0.70; Table 9). The waterbird habitat condition index generally had a large coefficient of variation, which indicates that the waterbird breeding habitat conditions were fluctuating between being highly suitable and highly unsuitable for breeding.

The waterbird habitat condition index generally increased with higher environmental flow allocations. For all flow scenarios (WSP1, WSP6, 10% reduction of current, 20% reduction of current) there were at least 23% of the years in which the waterbird habitat condition index was ‘much better’ than the index under reference conditions and at least 9% of the years when it was ‘much better’ than the index under the current flow scenario (Figure 2). There were only small differences in the percentage of ‘much better’ years between the WSP1, WSP6 and 10% scenarios. However, the 20% flow scenario resulted in a considerable increase in the percent of years when the waterbird condition index was ‘much better’ than reference or current conditions (Figure 2). There were many years in which the waterbird habitat condition index was ‘worse’ than the index under the current scenario (Figure 2). This is probably not as important for waterbirds as for other groups (e.g. vegetation) because when conditions are unsuitable for birds they move to other breeding locations. The most important part of the threshold analysis for waterbirds is the percentage of years when the condition index is ‘better’ or ‘much better’ than current or reference.

#### *Fish*

The mean fish habitat condition index ranged from 0.61 for the reference flow scenario to 0.66 for the 20% flow scenario (natural 0.82; Table 8), and the median ranged from 0.62 for the reference to 0.66 for the 20% flow scenario (natural 0.83; Table 9). The fish habitat condition index had a very small coefficient of variation for all scenarios, which indicates that the fish habitat condition index varied very little between years. The percent of years when the condition index was greater than the mean of the range of the natural scenario was zero for all flow scenarios. This is due to the very low variation around the mean values and reflects the poor state of the fish habitat in the Murrumbidgee River.

The fish habitat condition index showed only a small response to the increased environmental flow allocations. There were no years in which the condition index was ‘much better’ than the current or reference conditions (Figure 3). In most years the condition index was generally the ‘same’ as the index under the current scenario. There were no years in which the index was ‘much worse’ than current and only a small percentage of years in which the index was ‘worse’ than under reference or current conditions. The WSP1 flow scenario resulted in very little improvement in the condition index compared to that under current flow conditions. However, for the WSP6, 10% and 20% flow scenarios there were at least 19% of years in which the index was ‘better’ than the current flow scenario.

### *Floodplain vegetation*

The mean floodplain vegetation habitat condition index was generally lower than the index values for the birds, fish or wetland vegetation (Table 8). The mean floodplain vegetation habitat condition index ranged from 0.31 for the current and WSP1 flow scenarios to 0.37 for the 20% flow scenario (natural 0.49; Table 8). The median ranged from 0.25 for the current and WSP1 flow scenarios to 0.37 for the 20% flow scenario (natural 0.50; Table 9). The floodplain habitat condition index had a very large coefficient of variation for all scenarios, which reflects the large fluctuations in condition index between good years when there were overbank flows and poor years when there were no overbank flows. The coefficient of variation decreased with increased environmental flow allocations.

The WSP1 and the 10% flow scenarios resulted in only a very small percentage of years when the floodplain habitat condition index was 'better' or 'much better' than the index under current or reference scenarios (Figure 4). The WSP6 flow scenario resulted in 8-10% of years when the floodplain habitat condition index was 'much better' than the index under reference or current conditions. The 20% flow scenario resulted in 14-15% of years when the floodplain habitat condition index was 'much better' than the index under reference or current conditions (Figure 4). There were very few years in which the index was 'much worse' or 'worse' than the index under current conditions.

### *Wetland vegetation*

The mean wetland vegetation habitat condition index ranged from 0.51 for the reference flow scenario to 0.63 for the 20% flow scenario (natural 0.76; Table 8), and the median ranged from 0.69 for the reference to 0.79 for the 20% flow scenario (natural 0.81; Table 9). The wetland vegetation habitat condition index generally had a large coefficient of variation, which suggests that the habitat conditions were fluctuating between being highly suitable and unsuitable for wetland vegetation.

The wetland vegetation habitat condition index generally increased with higher environmental flow allocations. For all flow scenarios (WSP1, WSP6, 10% reduction of current, 20% reduction of current) there were at least 21% of the years in which the wetland vegetation habitat condition index was 'much better' than the index under reference conditions and at least 12% of the years when it was 'much better' than the index under the current flow scenario (Figure 5). There were only small differences in the percentage of 'much better' years between the WSP1, WSP6 and 10% flow scenarios. However, the 20% flow scenario resulted in a further small increase in the percent of years when the wetland vegetation condition index was 'much better' than the reference or current conditions (Figure 5). For all scenarios there were considerably more years when the condition index was 'better' rather than 'worse' than the reference scenario. The wetland vegetation habitat condition index was 'much worse' than the index under the current flow scenario in less than 6% of the years (Figure 5).

### *River Health*

The mean river health index ranged from 0.47 for the reference flow scenario to 0.55 for the 20% flow scenario (natural 0.69; Table 8), and the median ranged from 0.50 for the reference flow scenario to 0.59 for the 20% flow scenario (natural 0.69; Table 9).

The river health index generally increased with higher environmental flow allocations. The index was ‘much better’ than reference for 11% of years under the WSP1 flow scenario and ‘much better’ than reference for 18% of the years under the 20% flow scenario. The index was ‘much better’ than current for 4% of years under the WSP1 flow scenario and ‘much better’ than current for 9% of years under the 20% flow scenario. The percent of worse years and better years was similar for the WSP1, WSP6 and 10% scenarios. However, the 20% scenario resulted in a greater percentage of years when the river health index was ‘better’ or ‘much better’ rather than ‘worse’ or ‘much worse’ than current conditions (Figure 6).

**Table 8.** Mean (coefficient of variation) of the waterbird habitat condition index, fish habitat condition index, floodplain vegetation habitat condition index, wetland vegetation habitat condition index and overall river health condition index under different flow scenarios.

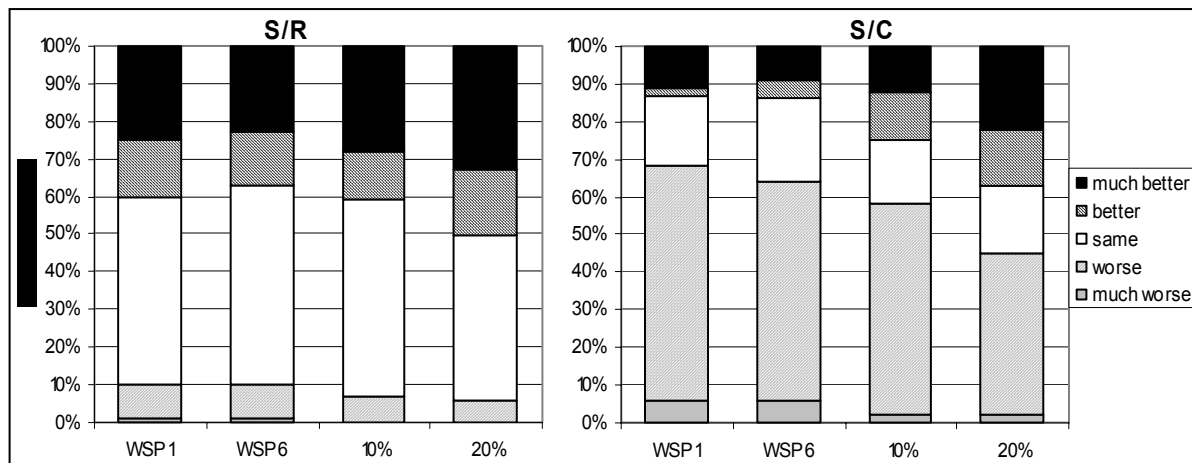
Scenario	Birds	Fish	Floodplain vegetation	Wetland vegetation	River Health
Natural	0.69 (0.18)	0.82 (0.03)	0.49 (0.48)	0.76 (0.21)	0.69 (0.13)
Current	0.50 (0.56)	0.63 (0.05)	0.31 (0.81)	0.57 (0.61)	0.50 (0.36)
Reference	0.43 (0.69)	0.61 (0.06)	0.32 (0.80)	0.51 (0.71)	0.47 (0.40)
Yr1WSP	0.50 (0.51)	0.63 (0.04)	0.31 (0.82)	0.61 (0.54)	0.51 (0.34)
Yr6WSP	0.50 (0.51)	0.65 (0.04)	0.34 (0.77)	0.62 (0.53)	0.53 (0.33)
10%	0.53 (0.46)	0.64 (0.04)	0.32 (0.78)	0.62 (0.52)	0.53 (0.30)
20%	0.55 (0.43)	0.66 (0.04)	0.37 (0.67)	0.63 (0.49)	0.55 (0.28)

**Table 9.** Median values of the waterbird habitat condition index, fish habitat condition index, floodplain vegetation habitat condition index, wetland vegetation habitat condition index and overall river health condition index under different flow scenarios.

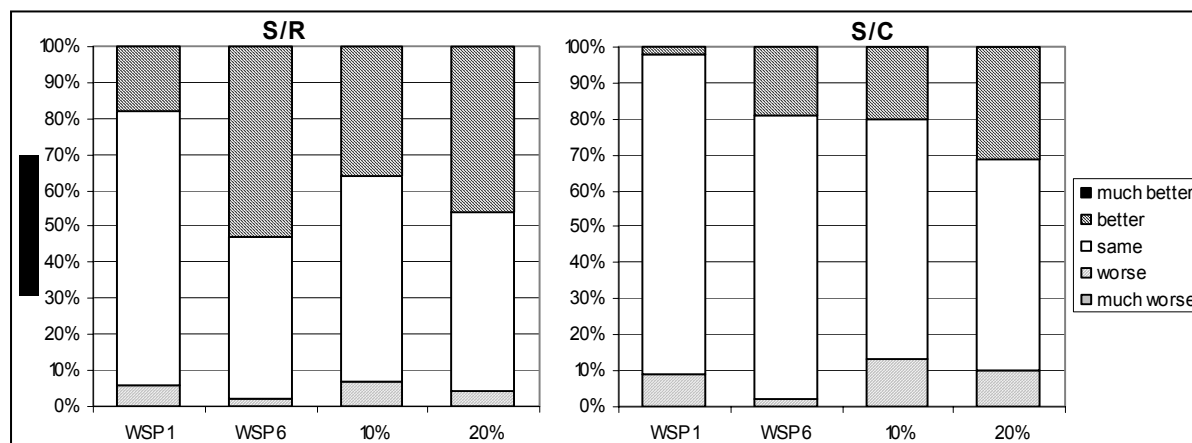
Scenario	Birds	Fish	Floodplain vegetation	Wetland vegetation	River Health
Natural	0.70	0.83	0.50	0.81	0.69
Current	0.63	0.63	0.25	0.76	0.56
Reference	0.56	0.62	0.26	0.69	0.50
Yr1WSP	0.60	0.64	0.25	0.80	0.57
Yr6WSP	0.59	0.66	0.31	0.79	0.58
10%	0.62	0.65	0.26	0.79	0.57
20%	0.63	0.66	0.37	0.79	0.59

**Table 10.** Percent of years greater than the mean of the range of the natural scenario for the waterbird habitat condition index, fish habitat condition index, floodplain vegetation habitat condition index, wetland vegetation habitat condition index and overall river health condition index under different flow scenarios.

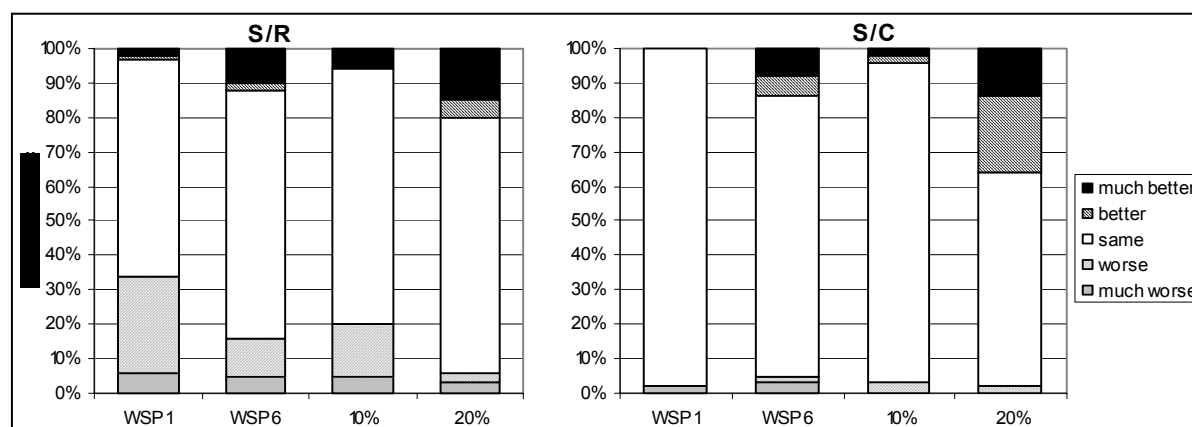
Scenario	Birds	Fish	Floodplain vegetation	Wetland vegetation	River Health
Natural	97	77	50	93	85
Current	63	0	37	64	38
Reference	58	0	37	56	28
Yr1WSP	70	0	37	65	38
Yr6WSP	73	0	39	69	41
10%	75	0	38	66	37
20%	78	0	42	69	48



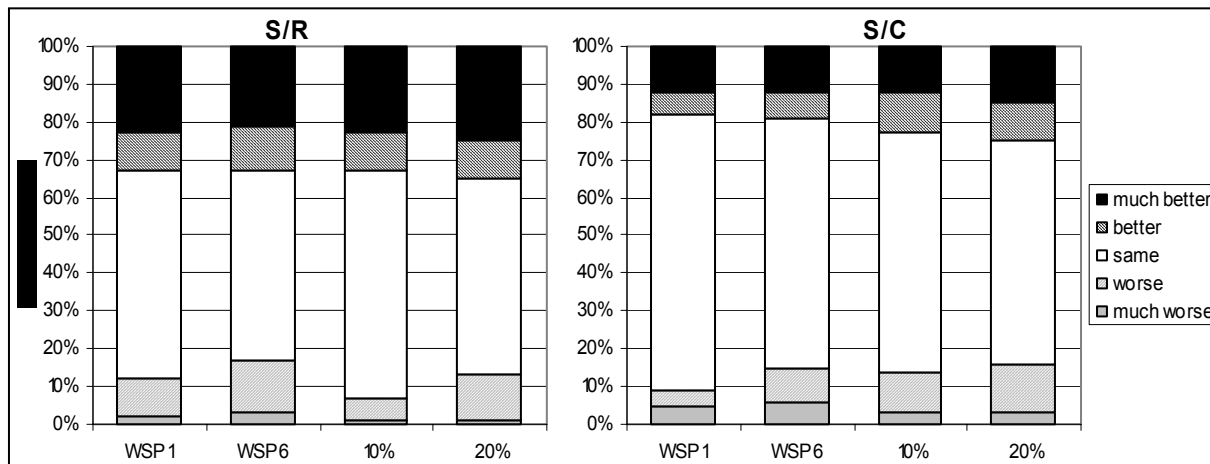
**Figure 2.** Percent of years the waterbird habitat condition index for each flow scenario (WSP1, WSP6, 10% reduction of current, 20% reduction of current) was ‘much better’, ‘better’, ‘same’, ‘worse’ and ‘much worse’ than the index for the reference and current flow scenarios. See section 3.9 for full description of categories.



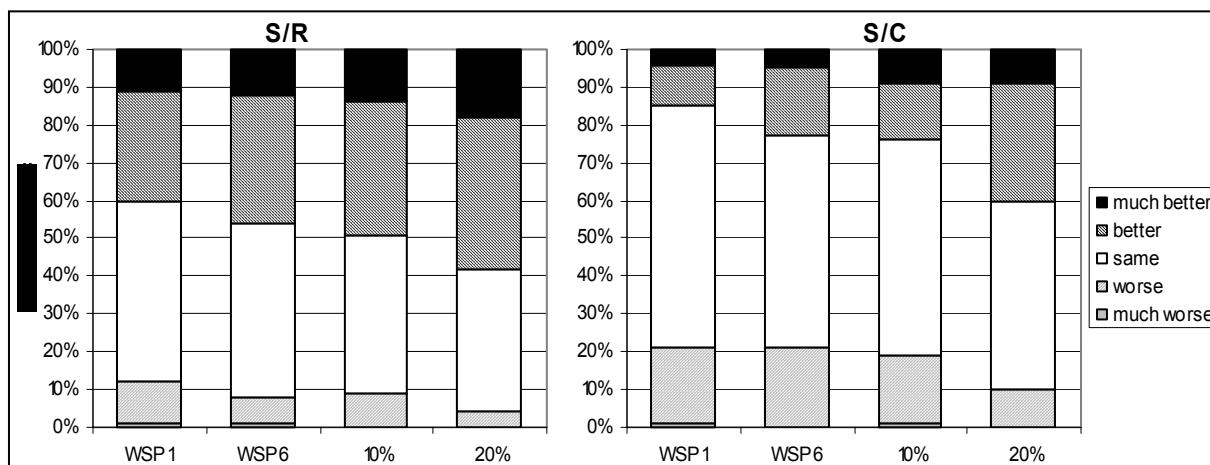
**Figure 3.** Percent of years the fish habitat condition index for each flow scenario (WSP1, WSP6, 10% reduction of current, 20% reduction of current) was ‘much better’, ‘better’, ‘same’, ‘worse’ and ‘much worse’ than the index for the reference and current flow scenarios. See section 3.9 for full description of categories.



**Figure 4.** Percent of years the floodplain vegetation habitat condition index for each flow scenario (WSP1, WSP6, 10% reduction of current, 20% reduction of current) was ‘much better’, ‘better’, ‘same’, ‘worse’ and ‘much worse’ than the index for the reference and current flow scenarios. See section 3.9 for full description of categories.



**Figure 5.** Percent of years the wetland vegetation habitat condition index for each flow scenario (WSP1, WSP6, 10% reduction of current, 20% reduction of current) was ‘much better’, ‘better’, ‘same’, ‘worse’ and ‘much worse’ than the index for the reference and current flow scenarios. See section 3.9 for full description of categories.



**Figure 6.** Percent of years the river health habitat condition index for each flow scenario (WSP1, WSP6, 10% reduction of current, 20% reduction of current) was ‘much better’, ‘better’, ‘same’, ‘worse’ and ‘much worse’ than the index for the reference and current flow scenarios. See section 3.9 for full description of categories.

## 4.2 Species level assessments

### *Icon species – Murray cod*

The Murray Cod habitat condition index was very different at the two river localities. The mean indices at Gundagai under cold water pollution conditions were approximately half the values obtained for the natural flow scenario (Table 11). In contrast, the mean habitat condition index for Murray Cod was high at the locality downstream of Redbank Weir. With the exception of the 20% flow scenario, the index at Redbank was more than double the index for the same flow scenario at Gundagai (Table 11).

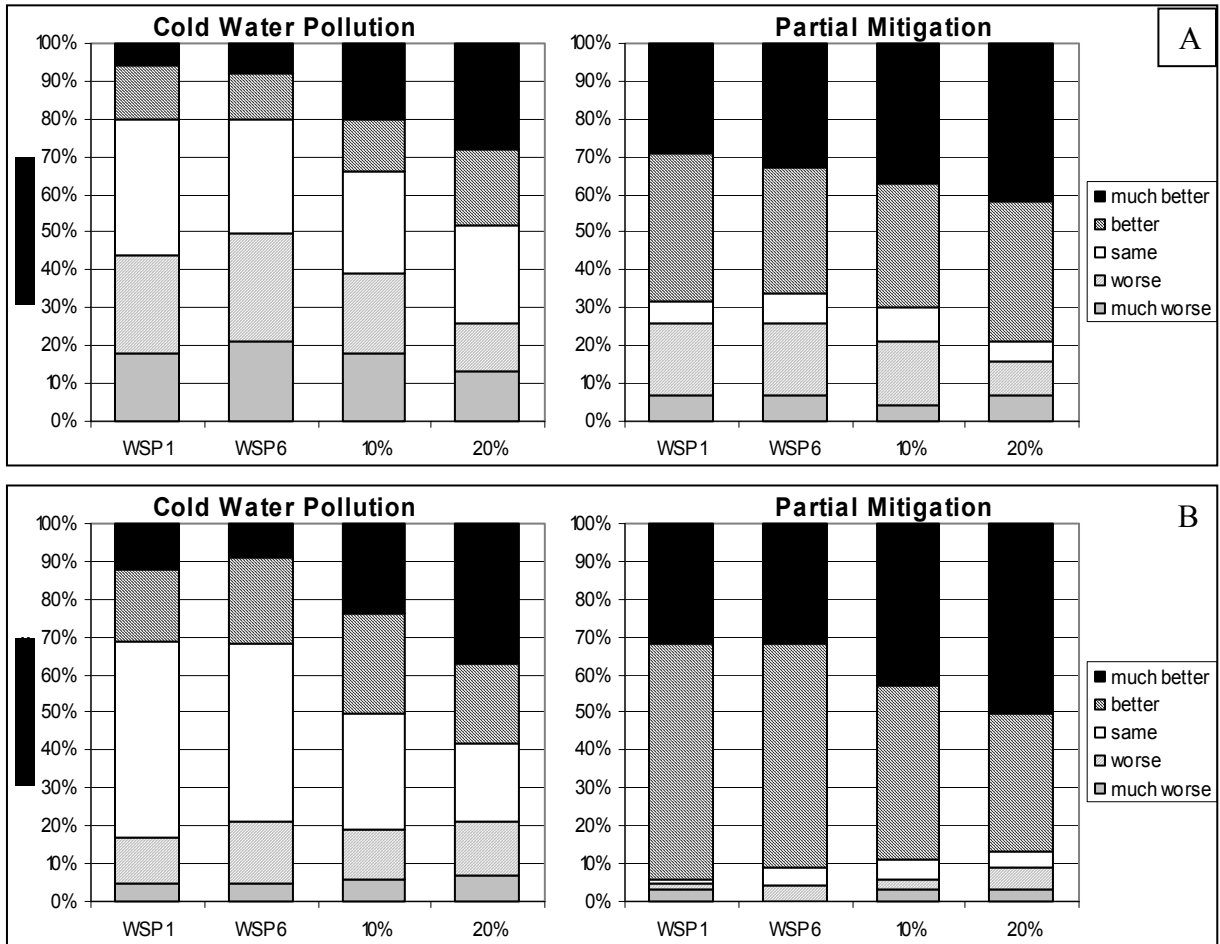
Under cold water pollution conditions at Gundagai there was an increase in the Murray Cod habitat condition index with increased environmental flow allocations (Table 11). The mean habitat condition index increased from 0.31 for the current flow scenario to 0.45 for the 20% flow scenario. Under cold water pollution conditions the 10% flow scenario resulted in a 34% increase and the 20% flow scenario resulted in a 48% increase in the years in which the index was of ‘better’ or ‘much better’ than the index under the reference scenarios (Figure 7). Under cold water pollution conditions the 10% flow scenario resulted in a 50% increase and the 20% flow scenario resulted in a 58% increase in the years in which the index was of ‘better’ or ‘much better’ than the index under the current scenarios (Figure 7).

Partial mitigation of cold water at Gundagai resulted in a considerable increase in the mean and median habitat condition index under all scenarios (Table 11). With partial cold water mitigation there was at least 70% of years in which the habitat condition index was ‘better’ or ‘much better’ than reference and 90% of years in which the index was ‘better’ or ‘much better’ than under current conditions (Figure 7).

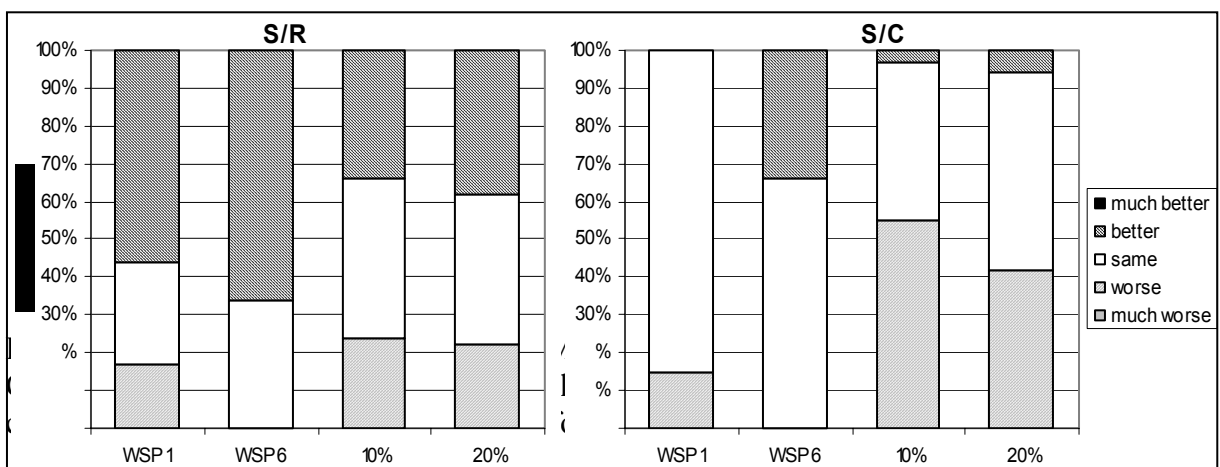
At the locality downstream of Redbank Weir there was virtually no change in the mean habitat condition index with increased environmental flow allocations (Table 11) and there were no years in which the habitat index was ‘much better’ than under reference or current scenario at this locality (Figure 8). This is because Murray Cod have a relatively high mean habitat condition index at the Redbank Weir locality under reference and current scenarios.

**Table 11.** Mean and coefficient of variation (CV) of the Murray Cod habitat condition index under different flow scenarios. No data are presented for the natural, current and reference scenarios for partial cold water mitigation at Gundagai as this change is relevant for only future flow scenarios.

Scenario	Gundagai		Gundagai (partial cold water mitigation)		Downstream of Redbank Weir	
	mean (CV)	median	mean (CV)	median	mean (CV)	median
Natural	0.83 (0.06)	0.86	no data	no data	0.89 (0.06)	0.92
Current	0.31 (0.60)	0.31	no data	no data	0.83 (0.05)	0.85
Reference	0.36 (0.57)	0.37	no data	no data	0.79 (0.08)	0.78
Yr1WSP	0.34 (0.57)	0.34	0.42 (0.46)	0.42	0.83 (0.05)	0.84
Yr6WSP	0.34 (0.55)	0.35	0.42 (0.45)	0.43	0.87 (0.02)	0.87
10%	0.40 (0.50)	0.40	0.48 (0.42)	0.48	0.81 (0.06)	0.81
20%	0.45 (0.47)	0.45	0.53 (0.40)	0.53	0.82 (0.06)	0.82



**Figure 7.** Comparison of the effects of cold water pollution and partial mitigation of cold water pollution on the Murray Cod habitat condition index at Gundagai. Graph shows the percent of years the fish habitat condition index attained under each flow scenario was 'much better', 'better', 'same', 'worse' and 'much worse' than the index under A) the reference scenario and B) the current scenario.



**Figure 8.** Murray Cod habitat condition index at Redbank: Percent of years the index attained under each flow scenario (WSP1, WSP6, 10% reduction of current, 20% reduction of current) was 'much better', 'better', 'same', 'worse' and 'much worse' than the index attained under the reference and current flow scenarios.

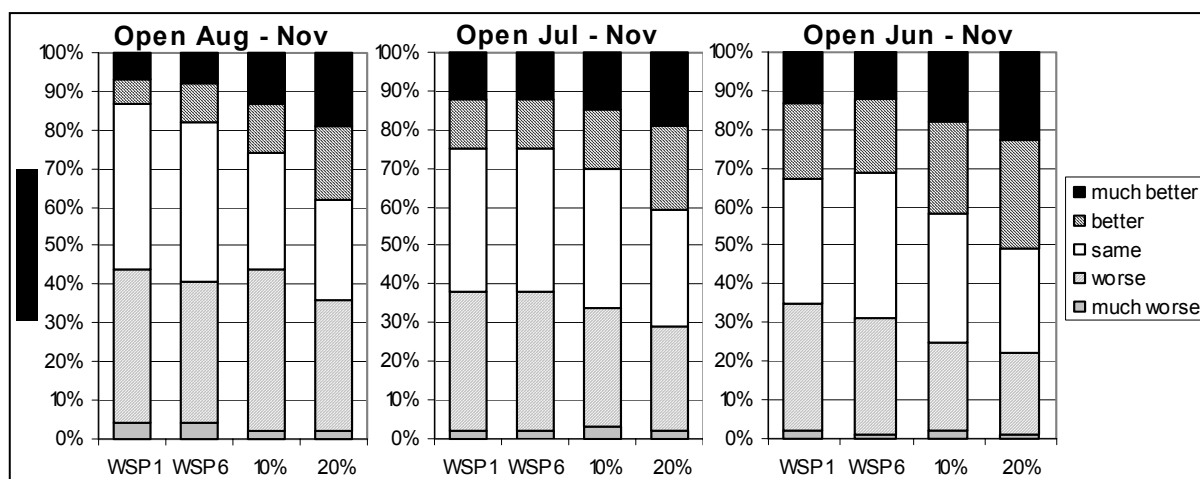
### 4.3 Additional assessments

#### *Effects of changed operation of Yanga regulator at Piggery Lake*

There were small increases in the mean and median values of the waterbird habitat condition index at Piggery Lake when the Yanga regulator was modelled to be open for an additional one or two months compared to its normal operation (Table 12). When the regulator was open from July to November the percentage of years in which the index was ‘much better’ than the index was similar to that when the regulator is under normal operation (Figure 9). However, when the regulator was open from June to November there was a further small increase in the percentage of years in which the index was ‘much better’ than the current scenario (Figure 9).

**Table 12.** Mean and coefficient of variation (CV) of the waterbird habitat condition index in Piggery Lake comparing three operational arrangements of the Yanga regulator under different flow scenarios. No data are presented for the natural, current and reference scenarios as for the changed operation of Yanga regulator as the changes are relevant for only future flow scenarios.

Scenario	Yanga regulator open Aug to Nov (normal operation)		Yanga regulator open July to Nov		Yanga regulator open June to Nov	
	mean (CV)	median	mean (CV)	median	mean (CV)	median
Natural	0.71 (0.17)	0.72	no data	no data	no data	no data
Current	0.51 (0.55)	0.62	no data	no data	no data	no data
Reference	0.43 (0.69)	0.58	no data	no data	no data	no data
Yr1WSP	0.51 (0.52)	0.59	0.53 (0.48)	0.63	0.55 (0.46)	0.66
Yr6WSP	0.51 (0.52)	0.58	0.54 (0.47)	0.6	0.55 (0.46)	0.65
10%	0.54 (0.43)	0.60	0.56 (0.42)	0.64	0.58 (0.39)	0.68
20%	0.57 (0.40)	0.65	0.58 (0.39)	0.68	0.61 (0.36)	0.70



**Figure 9.** Comparison of the effects of changing the operation of the Yanga regulator on the waterbird habitat condition index at Piggery Lake in the Lowbidgee. Results of threshold analysis of waterbird condition index when Yanga regulator was open a) August to November, and b) July to November and c) June to November. Graph shows the percent of years the condition index attained under each flow scenario was ‘much better’, ‘better’, ‘same’, ‘worse’ and ‘much worse’ than the index under the current scenario.

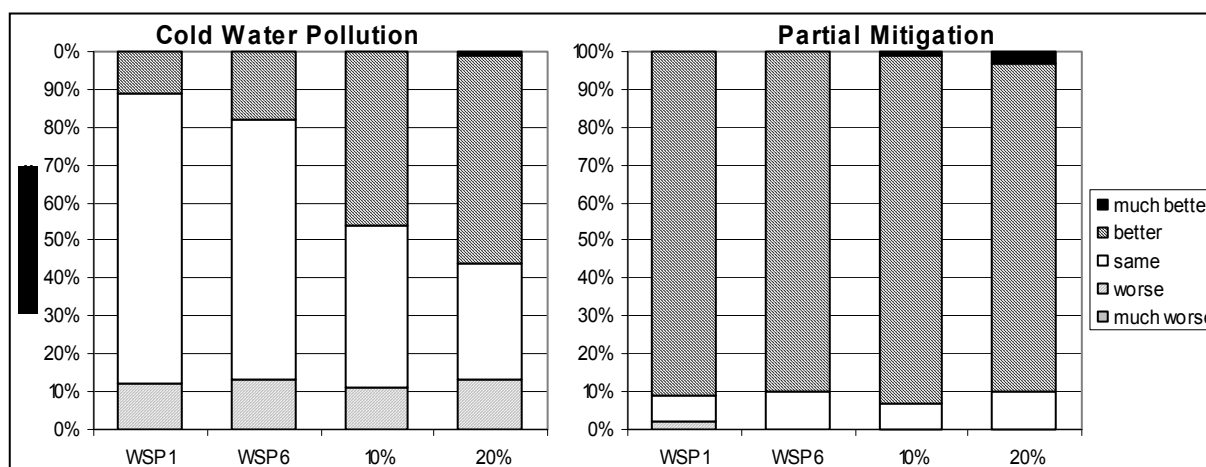
*Partial mitigation of cold water pollution in the upper catchment*

Under the existing cold water pollution conditions at Gundagai there was an increase in the fish habitat condition index with increased environmental flow allocations (Table 13). The mean condition index increased from 0.53 for the current flow scenario to 0.58 for the 20% flow scenario. Under cold water pollution conditions there were considerable increases in the percent of years in which the index was of ‘better’ than the index under the current scenarios. However, for the WSP1, WSP6 and 10% flow scenarios there were no years in which the index was ‘much better’ than that under the current scenario (Figure 10).

Partial cold water mitigation at Gundagai resulted in a considerable increase in the mean and median fish habitat condition index under all flow scenarios (Table 13). The mean condition index increased from 0.53 for the current scenario to 0.64 for the 20% flow scenario. For all flow scenarios, with partial cold water mitigation there was approximately 90% of years in which the habitat condition index was ‘better’ than under current conditions (Figure 10). The partial mitigation of cold water pollution produced a better outcome for fish than the 20% flow scenario under existing cold water pollution conditions.

**Table 13.** Mean and coefficient of variation (CV) of the fish habitat condition index at the Gundagai locality under cold water pollution (existing conditions) and partial mitigation of cold water pollution. No data are presented for the natural, current and reference scenarios for partial cold water mitigation as the changes are relevant for only future flow scenarios.

Scenario	Cold water pollution (existing conditions)		Partial mitigation of cold water pollution for test scenarios	
	mean (CV)	median	mean (CV)	median
Natural	0.79 (0.03)	0.80	no data	no data
Current	0.53 (0.10)	0.53	no data	no data
Reference	0.54 (0.13)	0.55	no data	no data
Yr1WSP	0.54 (0.11)	0.54	0.60 (0.09)	0.61
Yr6WSP	0.54 (0.10)	0.54	0.60 (0.09)	0.61
10%	0.57 (0.10)	0.57	0.63 (0.08)	0.63
20%	0.58 (0.10)	0.58	0.64 (0.09)	0.64



**Figure 10.** Comparison of the effects of cold water pollution and partial mitigation of cold water pollution on the fish habitat condition index at Gundagai. Graph shows the percent of years the fish habitat condition index attained under each flow scenario was ‘much better’, ‘better’, ‘same’, ‘worse’ and ‘much worse’ than the index under the current scenario.

*Assessment of a lagoon that is frequently inundated by irrigation flows*

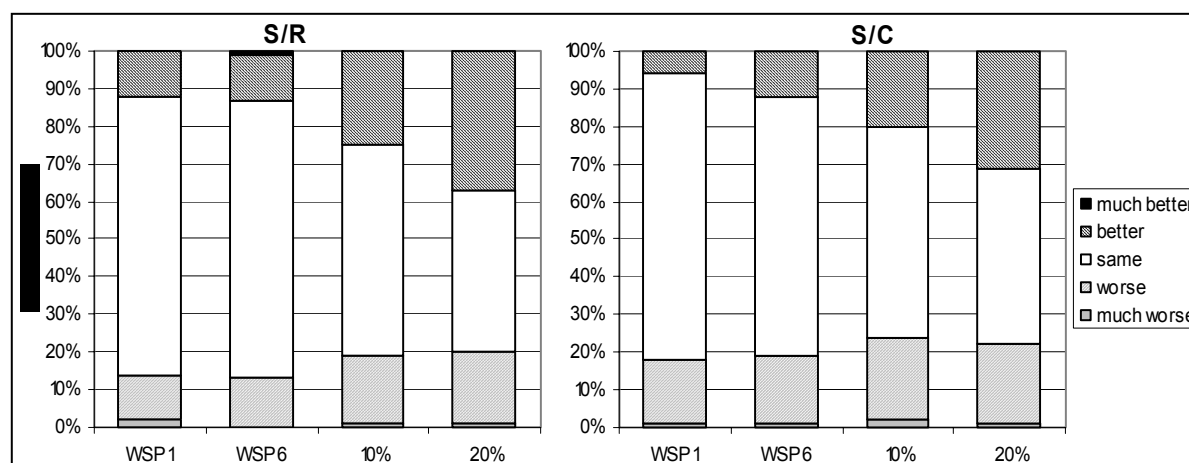
The mean wetland vegetation habitat condition index for submerged plants at Berry Jerry Lagoon was extremely high, ranging between 0.98 and 0.99 (Table 14). As this wetland is almost always full of water, the conditions are highly suitable for submerged plants such as ribbon weed.

The mean wetland vegetation habitat condition index for edge plants ranged from 0.58 for the reference flow scenario to 0.62 for the 20% flow scenario (natural 0.68)(Table 14). There was no variation in the median index between flow scenarios.

The wetland vegetation habitat condition index generally increased with higher environmental flow allocations. There were only small differences between the WSP1 and WSP6 scenarios in the percentage of years when the index was ‘better’ than under the reference flow scenario (Figure 11). However, the 10% and 20% flow scenarios resulted in further increases in the percent of years when the wetland edge vegetation condition index was ‘better’ than under reference or current conditions (Figure 11).

**Table 14.** Mean and coefficient of variation (CV) of the wetland vegetation habitat condition index for edge plants (*Phragmites australis* and Spiny mudgrass grassland combined) and submerged plants (ribbon weed) at Berry Jerry Lagoon under different flow scenarios.

Scenario	<i>Phragmites australis</i> and spiny mudgrass grassland		Ribbon weed herbland	
	mean (CV)	median	mean (CV)	median
Natural	0.68 (0.19)	0.69	0.99 (0)	0.99
Current	0.59 (0.13)	0.59	0.98 (0.10)	0.99
Reference	0.58 (0.08)	0.59	0.99 (0)	0.99
Yr1WSP	0.59 (0.14)	0.59	0.98 (0.10)	0.99
Yr6WSP	0.60 (0.09)	0.59	0.99 (0)	0.99
10%	0.60 (0.12)	0.59	0.99 (0)	0.99
20%	0.62 (0.14)	0.59	0.99 (0)	0.99



**Figure 11.** Wetland edge plants (*Phragmites australis* and Spiny mudgrass grassland combined) habitat condition index at Berry Jerry lagoon: Percent of years the index under each flow scenario (WSP1, WSP6, 10% reduction of current, 20% reduction of current) was ‘much better’, ‘better’, ‘same’, ‘worse’ and ‘much worse’ than the index under the reference and current flow scenarios.

*Nuisance fish species – Common carp*

Common carp are widespread and are the most abundant large fish in the Murrumbidgee River (Harris and Gehrke 1997). There is no capability to assess the effect of the flow scenarios on carp in the MFAT. However, as carp are capable of recruiting after only 5 to 14 days of floodplain inundation at any time between September and February (Stuart and Jones 2002) they are likely to benefit from any flow scenario that increases the duration of floodplain inundation.

*Nuisance wetland plant species - Cumbungi rushland*

Cumbungi does not currently occur in any of the lagoons assessed in this report (Hardwick, unpublished data). It was assessed at these localities because it is a highly invasive plant that could potentially become a nuisance in wetlands where there is permanent water.

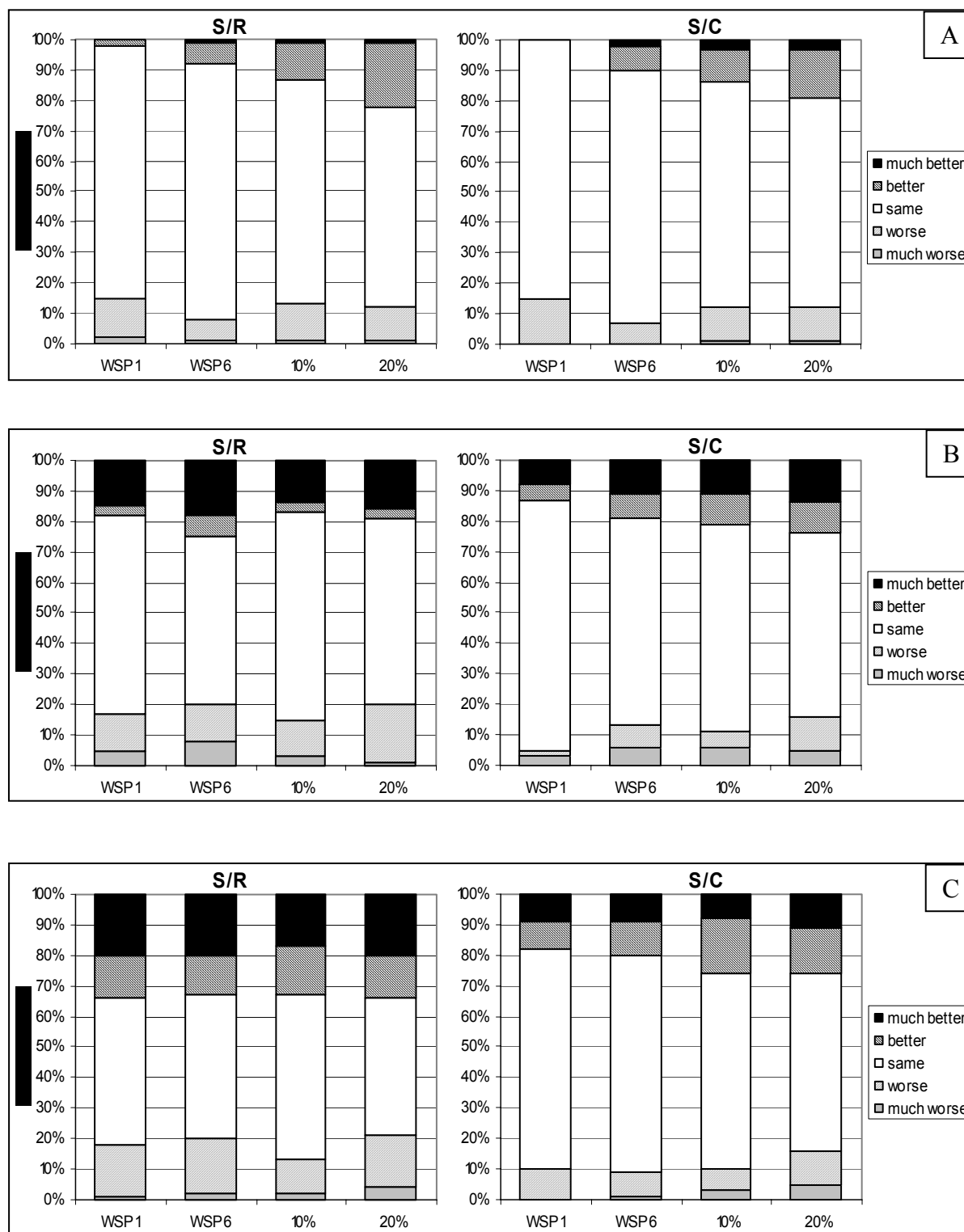
The mean habitat condition index for Cumbungi was higher at Berry Jerry lagoon than at Narrandera Forest Lagoon or Yarradda Lagoon (Table 15). This reflects the higher level of inundation of Berry Jerry Lagoon compared to the other two wetlands. Narrandera Forest Lagoon and Yarradda Lagoon had large coefficient of variation values, which suggests that the conditions for Cumbungi were fluctuating between being highly suitable and unsuitable in these wetlands.

Higher environmental flow allocations resulted in less change in the condition index of Cumbungi at Berry Jerry Lagoon than at Narrandera or Yarradda Lagoons. At Berry Jerry Lagoon there were very few years in which the condition index was ‘much better’ than under reference or current conditions. However, higher environmental flow allocations resulted in an increase in the number of years the index was ‘better’ than under reference or current flow conditions at this lagoon (Figure 120).

The most significant change in the Cumbungi habitat condition index was observed in Narrandera and Yarradda Lagoons which are not as low on the floodplain as Berry Jerry Lagoon. In these lagoons for all flow scenarios there was approximately 15-20% of years in which the Cumbungi condition index was ‘much better’ than under reference flow conditions. For all flow scenarios there was approximately 10% of years in which the Cumbungi condition index was ‘much better’ than under current conditions (Figure 12).

**Table 15.** Mean and coefficient of variation (CV) of the habitat condition index for the nuisance species Cumbungi at three wetlands.

Scenario	Berry Jerry Lagoon		Narrandera Forest Lagoon		Yarradda Lagoon	
	mean (CV)	median	mean (CV)	median	mean (CV)	median
Natural	0.73 (0.14)	0.74	0.66 (0.36)	0.75	0.74 (0.22)	0.78
Current	0.69 (0.13)	0.71	0.49 (0.70)	0.68	0.55 (0.62)	0.72
Reference	0.69 (0.08)	0.71	0.46 (0.81)	0.47	0.49 (0.75)	0.63
Yr1WSP	0.68 (0.13)	0.71	0.54 (0.64)	0.77	0.61 (0.52)	0.77
Yr6WSP	0.70 (0.05)	0.71	0.55 (0.64)	0.77	0.61 (0.52)	0.77
10%	0.71 (0.07)	0.71	0.54 (0.64)	0.77	0.61 (0.53)	0.77
20%	0.71 (0.08)	0.71	0.55 (0.60)	0.76	0.62 (0.50)	0.77



**Figure 12.** Cumbungi habitat condition index at A) Berry Jerry Lagoon, B) Narrandera Forest Lagoon and C) Yarradda Lagoon: Percent of years the index attained under each flow scenario (WSP1, WSP6, 10% reduction of current, 20% reduction of current) was ‘much better’, ‘better’, ‘same’, ‘worse’ and ‘much worse’ than the index attained under the reference and current flow scenarios.

*Nuisance algal species - Anabaena circinalis*

Algal blooms reached low alert and medium alert levels at Maude Weir in the Murrumbidgee River under all flow scenarios but never reached the high alert level (Table 16). The scenarios for the 1<sup>st</sup> year and 6<sup>th</sup> year of the Murrumbidgee water sharing plan resulted in a similar number of blooms as the current scenario. There was a reduction in the number of medium algal blooms predicted under the 20% scenario when compared to the current scenario (Table 16).

**Table 16.** Number of times in 108 years that the algal cell count was simulated to reach a medium and high alert at Maude Weir under different flow scenarios.

Scenario	No. of times reaches low alert (over 2,000 cells)	No. of times reaches medium alert (over 15,000 cells)	No. of times reaches high alert (over 100,000 cells)
Natural	1	2	0
Current	9	24	0
Reference	5	35	0
Yr1WSP	6	25	0
Yr6WSP	10	23	0
10%	3	24	0
20%	5	19	0

## 5. DISCUSSION

### 5.1 Discussion of ecological assessments and confounding factors

#### *Waterbirds*

There was an increase in the waterbird habitat condition index with increasing environmental flow allocations. There was a greater increase in the index under the 10% and 20% flow scenarios than under the WSP1 and WSP6 flow scenarios. As the breeding success of waterbirds is highly influenced by flood duration, this reflects the increase in flooding events that would eventuate from higher environmental flow allocations. The results of the MFAT assessment suggests that waterbird breeding success would improve under increased environmental flow allocations. This could partially reverse the decline in the condition of waterbird habitat that has been observed in recent years in the Lowbidgee (e.g. Kingsford and Thomas 2001), however would be unlikely to fully reverse the decline because of the continued influence of other factors (e.g. levee banks).

Changing the operation of the Yanga regulator at Piggery Lake in the Lowbidgee combined with increased environmental flow allocations resulted in a small further increase in waterbird habitat condition index. Opening the regulator from July to August (additional one month to normal operation) resulted in an increase in the waterbird habitat index under the WSP1 and WSP2 flow scenarios but there was little change to the index under the 10% and 20% flow scenarios. Opening the regulator from June to November (additional 2 months to normal operation) resulted in an increase in the waterbird habitat index under all flow scenarios. These assessments suggest that operational changes to wetland management in the Lowbidgee can improve the likelihood of waterbird breeding success. Other operational changes to wetland management should be explored to gain the most benefit from increased environmental flow allocations.

### *Fish*

Increased environmental flow allocations resulted in an increase in the habitat condition index of fish at Gundagai, but little change in the index at Redbank Weir. A greater response is to be expected at Gundagai, because the fish habitat in this part of the Murrumbidgee River is considerably more degraded than in the reach downstream of Redbank Weir (Lugg 2000). The assessments undertaken in this report suggest that partial mitigation of cold water pollution is likely to result in a greater improvement in fish habitat conditions at Gundagai than simply increasing environmental flow allocations alone. There were no flow scenarios under which the overall zone fish habitat condition index was 'much better' than the current scenario. This is because the zone assessment combines the large response observed at Gundagai with the small response observed for the locality downstream of Redbank Weir.

The assessment of Murray Cod habitat condition index showed that this species could benefit considerably from increased environmental flow allocations and benefit further if the flow allocations were made in conjunction with partial mitigation of cold water pollution.

The MFAT assessment predicts the likely improvement in fish habitat condition with increased environmental flow allocation in the Murrumbidgee River. Several other factors are known to impact on fish populations in the Murrumbidgee River (e.g. desnagging, predation and competition with introduced species, barriers to fish migration)(Lugg 2000). These factors would also need to be addressed to ensure that the improvement in fish habitat condition predicted in this report would actually result in healthier fish populations.

### *Floodplain vegetation*

Increased environmental flow allocations generally resulted in an increase in the habitat condition index of floodplain vegetation at Cuba Forest. The WSP1 flow scenario did not result in any improvement in the habitat condition of floodplain vegetation at this locality. The WSP6 and 10% flow scenarios resulted in minor improvement, and the 20% flow scenario resulted in considerable improvement in the habitat condition of floodplain vegetation. As the health of river red gums is highly influenced by flood duration this pattern reflects the increase in over-bank flows that would eventuate from higher environmental flow allocations. However, recruitment of river red gums and health of the understorey vegetation associated with river red gums is strongly influenced by cattle grazing in the riparian zone (Jansen and Robertson 2001, Robertson and Rowling 2000), reducing the beneficial effects of increased water allocations.

### *Wetland vegetation*

Increased environmental flow allocations resulted in an increase in the habitat condition index of wetland vegetation. The increase was due to improvement in both edge wetland vegetation (e.g. spiny mudgrass) and submerged wetland vegetation (e.g. ribbon weed). The MFAT assessments can predict the likely improvement in wetland habitat condition but do not directly predict the improvement in wetland vegetation health. Cattle grazing and poor land management practises in the riparian zone and around wetlands would significantly reduce the potential for improvement in the condition of wetland plants (Jansen and Healey 2002) regardless of increased environmental flow allocations. These factors would need to be addressed to ensure that the improvement in wetland plant habitat condition predicted in this report would actually result in healthier wetland plant populations.

The MFAT predicted an increase in the habitat condition index of Cumbungi with increased environmental flows. A wetland that is regularly connected to the river during irrigation flows (Berry Jerry Lagoon) had a particularly high Cumbungi habitat condition index. Although Cumbungi does not currently occur in any of the lagoons assessed in this report (Hardwick, unpublished data), the results suggests that if this species were to colonise these wetlands it may increase rapidly under favourable conditions.

### *Algae*

Algal blooms have been recorded in Maude Weir (e.g. Jones 1994) and in Tombullen Storage in the Murrumbidgee River. The results indicate that there has been a considerable reduction in the likelihood of algal blooms under current conditions relative to MDBC-cap reference conditions. The assessments predict that there will be a further reduction in the number of algal blooms that reach a low or medium alert level with increased environmental flow allocations. A reduction in incidence of algal blooms, relative to the current flow scenario, was minimal under the WSP1, WSP6 and 10% flow scenarios, but the 20% flow scenario resulted in a further reduction in likelihood of blooms at Maude Weir.

### ***5.2 Predicted improvement in condition indices relative to current flow scenario***

The results of the assessments can be interpreted in different ways, depending on how frequently the community desires to see an improvement in river health. In this section of the report the improvement in condition of the indices will be summarised in two ways. We will identify which indices showed improvement at least once every twenty years and which showed improvement at least once every five years relative to the current flow scenario. For the assessment of improvement once every twenty years, the habitat condition indices were classified as ‘much better’ than under the current flow scenario if at least once every 20 years they were in that category. They were classified as ‘better’ if the combined values of the ‘better’ and ‘much better’ categories occurred at least once every 20 years. All other indices were classified as ‘no improvement’ relative to the current scenario. The same approach was taken to identify the indices that were expected to show improvement once every five years.

#### *Improvements expected at least once every twenty years*

The only detrimental change predicted is that the habitat of the nuisance species Cumbungi could improve relative to current conditions under all flow scenarios (Table 17). As Cumbungi does not currently occur in any of the lagoons assessed in this report this negative outcome is hypothetical and could be minimised with a targeted weed management plan. It is likely that common carp may also benefit from flow scenarios that increase the duration of floodplain inundation. However, the effect of the flow scenarios on the habitat condition of carp was not assessed in this report, as there is no capability to assess carp in the MFAT.

Under the WSP1 flow scenario there were four indices that showed ‘no improvement’ relative to the current flow scenario (Table 17). This scenario also had the least number of indices that had a ‘much better’ condition relative to the current flow scenario.

The WSP6 flow scenario is approximately equivalent to the 350GL-a scenario assessed by the other regional evaluation groups. Under this scenario only nuisance algae had a condition index that showed ‘no improvement’ relative to the current flow scenario (Table 17). Most

indices were classed as having a ‘much better’ condition once every twenty years under this flow scenario.

The 10% flow scenario is approximately equivalent to the 750GL-a scenario assessed by the other regional evaluation groups. The floodplain vegetation habitat index decreased from ‘much better’ to ‘better’ and the Murray Cod habitat index at Redbank Weir decreased from ‘better’ to ‘no improvement’ when compared to the WSP6 scenario (Table 17). The reduction in condition for these two indices may be due to the water delivery routine of the 10% flow scenario. Under the 10% flow scenario water is delivered to the environment according to the ‘current’ flow rules whereas the WSP6 flow scenario includes routines that are specifically aimed to improve environmental outcomes. Most indices were classed as having a ‘better’ or ‘much better’ condition once every twenty years under this flow scenario (Table 17)

The 20% scenario is approximately equivalent to the 1500GL-a scenario assessed by the other regional evaluation groups. Most indices were classed as having a ‘much better’ condition relative to the current flow scenario (Table 17). There was a predicted decrease in likelihood of algal blooms under this flow scenario.

#### *Improvements expected at least once every five years*

Under the WSP1 flow scenario most indices showed ‘no improvement’ relative to the current flow scenario (Table 18). Under this scenario three of the four indices that showed improvement were those that resulted from the combined effects of operational changes and increased flow allocations. Only Murray Cod at Gundagai showed improvement solely in response to the increased environmental water allocations.

The WSP6 flow scenario is approximately equivalent to the 350GL-a scenario assessed by the other regional evaluation groups. Under this scenario most indices showed ‘no improvement’ relative to the current flow scenario (Table 18). Under this scenario three of the six indices that showed improvement were those that resulted from the combined effects of operational changes and increased flow allocations. Murray Cod at Gundagai and Redbank as well as the overall river condition index showed improvement solely in response to the increased environmental water allocations.

The 10% flow scenario is approximately equivalent to the 750GL-a scenario assessed by the other regional evaluation groups. The Murray Cod (Redbank Weir) index decreased from ‘better’ to ‘no improvement’ when compared to the WSP6 flow scenario (Table 18) and for more than half of the years this index was ‘worse’ than under the current flow scenario (Figure 8). The reduction in condition for this index may be due to the water delivery routine of the 10% flow scenario. Under the 10% flow scenario water is delivered to the environment according to the ‘current’ flow rules whereas the WSP6 flow scenario includes routines that are specifically aimed to improve environmental outcomes. Most indices were classed as having a ‘better’ condition once every five years under this flow scenario.

The 20% scenario is approximately equivalent to the 1500GL-a scenario assessed by the other regional evaluation groups. All indices were classed as ‘better’ or ‘much better’ than under the current flow scenario at least once every five years except Murray cod at Redbank Weir (Table 18). There was a predicted decrease in likelihood of algal blooms under this flow scenario.

**Table 17.** Summary of improvement in condition indices expected at least once every twenty years under each flow scenario relative to the current scenario. Habitat condition indices were classified as ‘much better’ than under the current flow scenario if at least once every 20 years they were in that category. They were classified as ‘better’ if the combined values of the ‘better’ and ‘much better’ categories occurred at least once every 20 years. All other indices were classified as ‘no improvement’ relative to the current scenario.

Scenario	No improvement relative to current scenario	Better condition relative to current scenario	Much better condition relative to current scenario
WSP1	Fish (zone) Cod (Redbank) Floodplain veg (zone) <i>Algal blooms</i>	Fish (mitigate CWP) Edge plants (BJ) River (zone) <i>Cumbungi</i>	Cod (Gundagai) Cod (mitigate CWP) Waterbirds (zone) Waterbirds (Piggery) Wetland veg (zone)
WSP6	<i>Algal blooms</i>	Fish (zone) Cod (Redbank) Fish (mitigate CWP) Edge plants (BJ) <i>Cumbungi</i>	Cod (Gundagai) Cod (mitigate CWP) Waterbirds (zone) Waterbirds (Piggery) Wetland veg (zone) Floodplain veg (zone) River (zone)
10%	Cod (Redbank) <i>Algal blooms</i>	Fish (zone) Fish (mitigate CWP) Floodplain veg (zone) Edge plants (BJ) <i>Cumbungi</i>	Cod (Gundagai) Cod (mitigate CWP) Waterbirds (zone) Waterbirds (Piggery) Wetland veg (zone) River (zone)
20%	<i>Algal blooms</i>	Fish (zone) Cod (Redbank) Edge plants (BJ) <i>Cumbungi</i>	Cod (Gundagai) Cod (mitigate CWP) Fish (mitigate CWP) Waterbirds (zone) Waterbirds (Piggery) Wetland veg (zone) Floodplain veg (zone) River (zone)

Abbreviations: mitigate CWP = partial mitigation of cold water pollution; BJ = Berry Jerry Lagoon; Piggery = Piggery Lake; Redbank = downstream of Redbank Weir. *Algal blooms* and *Cumbungi* are shown in italics as they are both nuisance taxa.

**Table 18.** Summary of improvement in condition indices expected at least once every five years under each flow scenario relative to the current scenario. Habitat condition indices were classified as ‘much better’ than under the current flow scenario if at least once every five years they were in that category. They were classified as ‘better’ if the combined values of the ‘better’ and ‘much better’ categories occurred at least once every five years. All other indices were classified as ‘no improvement’ relative to the current scenario.

Scenario	No improvement relative to current scenario	Better condition relative to current scenario	Much better condition relative to current scenario
WSP1	Waterbirds (zone) Fish (zone) Cod (Redbank) Wetland veg (zone) Edge plants (BJ) Floodplain veg (zone) River (zone) <i>Cumbungi</i> <i>Algal blooms</i>	Fish (mitigate CWP) Cod (Gundagai) Waterbirds (Piggery)	Cod (mitigate CWP)
WSP6	Waterbirds (zone) Fish (zone) Wetland veg (zone) Edge plants (BJ) Floodplain veg (zone) <i>Cumbungi</i> <i>Algal blooms</i>	Cod (Redbank) Fish (mitigate CWP) Cod (Gundagai) Waterbirds (Piggery) River (zone)	Cod (mitigate CWP)
10%	Waterbirds (zone) Cod (Redbank) Floodplain veg (zone) <i>Algal blooms</i>	Fish (zone) Fish (mitigate CWP) Waterbirds (Piggery) Wetland veg (zone) Edge plants (BJ) River (zone) <i>Cumbungi</i>	Cod (mitigate CWP) Cod (Gundagai)
20%	Cod (Redbank) <i>Algal blooms</i>	Fish (zone) Fish (mitigate CWP) Wetland veg (zone) Edge plants (BJ) Floodplain veg (zone) River (zone) <i>Cumbungi</i>	Cod (mitigate CWP) Cod (Gundagai) Waterbirds (zone) Waterbirds (Piggery)

Abbreviations: mitigate CWP = partial mitigation of cold water pollution; BJ = Berry Jerry Lagoon; Piggery = Piggery Lake; Redbank = downstream of Redbank Weir. *Algal blooms* and *Cumbungi* are shown in italics as they are both nuisance taxa.

### ***5.3 Comparison of the ecological benefits of different flow scenarios***

Most habitat condition indices showed an improvement at least once every twenty years (Table 17), however considerably fewer indices showed an improvement at least once every five years (Table 18).

Most of the improvements that were observed at least once every five years under the WSP1 and WSP6 flow scenarios were those that resulted from the combined effects of operational changes and increased flow allocations (Table 18). However the habitat condition index for Murray Cod at Gundagai and Redbank as well as the overall river condition index showed improvement solely in response to the increased environmental water allocations. In contrast, under the 10% and 20% flow scenarios five of the indices showed improvement solely in response to the increased environmental water allocations and three were improved due to the combined effects of operational changes and increased flow allocations.

In summary, the results of the habitat condition index assessments can be summarised in different ways. In this report the improvement in habitat condition indices expected at least every twenty years was compared to that expected at least every five years. If the community considers it acceptable to have ‘better’ or ‘much better’ river health in one out of every twenty years, then the model predicts that many of these indices are likely to show improvement under each of the flow scenarios. However, if the community expects to observe ‘better’ or ‘much better’ river health in one out of every five years then this is unlikely to be realised for many indices under the WSP1 or WSP6 scenarios and will only be attained under the 10% or 20% flow scenario.

### ***5.4 Constraints of this assessment***

One of the main limitations of this assessment was that only one flow delivery strategy was modelled for each of the flow scenarios in the Murrumbidgee River. Furthermore, under the 10% and 20% flow scenarios, water was delivered to the environment according to the ‘current’ flow rules. This modelling approach will limit the benefit that can be achieved from a given volume of water. Therefore the hydrological models that were assessed in this report are not likely to produce the most beneficial ecological outcomes that could be achieved from the volume of water assessed.

It is well acknowledged that additional ecological benefit can be achieved by delivering environmental water according to rules that are based on ecological knowledge and principles. The Murray-Darling Basin Commission has acknowledged the limitation of the current hydrological models developed for the Murrumbidgee River and has undertaken to further develop the models for this river by instigating an integrated modelling project for the Murrumbidgee and Murray Rivers. One of the objectives of this project is to explore opportunities to optimise environmental outcomes whilst minimising impacts on existing water users by improved integration of environmental flows in the Murrumbidgee and Murray River systems. The outcomes of the integrated project will be additional hydrological scenarios that can be incorporated into future ecological assessments. When these additional scenarios are available it will be possible to determine if additional ecological benefit can be achieved in the Murrumbidgee River from different flow delivery strategies.

A further constraint on this assessment was that the Murrumbidgee River was classed as a single zone for the Living Murray Initiative. Consequently only a small number (eight) of localities in the Murrumbidgee River could be included in this assessment. Because of this constraint this report was unable to comprehensively assess the diversity of habitats present in the Murrumbidgee River. An assessment of a larger number of localities would ensure a more comprehensive assessment of the likely impacts of the flow scenarios on the habitat condition of this river system. The reach of the Murrumbidgee River assessed in this report (downstream of Burrinjuck Dam to the confluence with the Murray River) has been subdivided into 5 distinctive zones based on geomorphic and hydrological characteristics (Page & Nanson 1996) (Table 1). Future assessments of flow scenarios in the Murrumbidgee River should assess the habitat condition index of each group (e.g. fish) in each of these geomorphic zones.

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