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1 Introduction

EM (Ecology Management) Pty Ltd (EM) was commissioned by Murray Irrigation Limited (MIL) in late May 2003 to undertake a review of the key scientific information behind the Living Murray Initiative of the Murray Darling Basin Commission (MDBC).

The MIL project brief basically represented a means by which MIL could become better informed before taking part in the environmental flows debate. MIL recognised that as a large private stakeholder, with a board responsible to shareholders, reactive responses to Government or agency outputs was not good enough, and they needed a firm foundation for any reasoned position they may take in the debate. MIL should be strongly commended for its willingness to question and learn, for seeking a reasoned position and for being prepared to take part in debate on behalf of its members. Simon Molesworth, President of the Environment Institute of Australia and New Zealand wrote (EIANZ Newsletter 40, August 2003) "*The low level of water in rivers and dams throughout Australia has been given a new twist by the metropolitan media. Rather than focus on ways that people have been able to minimise water loss during a drought, unbalanced and sensational articles have not reflected the concern that rural people have for their environment*."

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Key actions within the project Brief were:

1. Desktop review of the research that forms the basis of the "*Snapshot of the Murray Darling Basin River Condition*" report and other identified studies of importance, including relevant data available, the analyses applied and conclusions reached – i.e. – review the scientific foundation of the research, the interpretation of the data and the significance of the results.
2. Identify gaps and/or inadequacy of the data and research methods and identify implications of any inadequacy to decision making.
3. Assist MIL to understand the key indicators of river health used by the scientific reference panel and the Living Murray including the weightings applied and identify strengths, weaknesses and validity of these indicators and weightings.
4. Identify, if applicable, other more relevant indicators of river health.
5. Assist MIL understand the trade-offs between environmental values along the river.
6. Assist MIL understand the relative importance of flows (compared to other aspects of river management and landscape and riparian management).
7. Identify potential non-flow options for improving river health.
8. Review the Murray Flow Assessment Tool (MFAT) being developed to assess the river condition – its strengths, weaknesses and limitations.

In fulfilling the intent of the Brief, the reviewers concentrated on the certainty of any conclusions or predictions made and thus the decision-making risk attached to the documents reviewed. As provision of flows for environmental benefit is often regarded as having significant negative social and economic consequences (eg Roy Green, Foreword, "Snapshot") the decision-making risks associated with any such provision should be clear. This report only addresses such risk associated with the ecological inputs to decision-making. The report is written for MIL, an irrigation group whose core business centres on their rights to access volumes of water. The impact of the environmental flows process can therefore by critical and this is why their Brief to EM looks for means to address river health issues through actions other than those related solely to volume.

There is a plethora of literature on the Murray Darling Basin and the River Murray itself. Over the last 20 years particularly there has been a large number of research projects, investigations, reports, workshops and conferences directed at various aspects of the environment. It was not the intent of this project to become familiar with that entire body of work in the three month timeframe of the review. The intent was to review the core documents, their key supporting references and any particularly relevant earlier reports. If comments within this review would have altered if some other piece of information had been found, then that is a regrettable but unavoidable outcome of the process. It also represents a component of decision-making risk associated with use of this report.

This report is primarily the work of Dr Lee Benson, for EM, with significant contributions with respect to geomorphology from Dr Andy Markham and on fish by Dr Ross Smith. Dr Markham and Dr Smith also reviewed a draft of the report. A full draft was independently reviewed by Dr Bruce Chessman and his full review is attached as Appendix A. MIL also reviewed the same full draft. Choices with respect to if or how to take the comments of reviewers into account were made by Dr Benson.

The core documents reviewed are those most often referenced in Living Murray literature as of importance to decision-making. They are (in chronological order):

1. *Report of the River Murray Scientific Panel on Environmental Flows. River Murray – Dartmouth to Wellington and the Lower Darling River*. June 2000. Thoms *et al* for the MDBC. ("SRP report")
2. *Snapshot of the Murray Darling Basin River Condition*. September 2001. Norris *et al* for the MDBC. ("Snapshot")
3. *Independent report of the Expert Reference Panel on Environmental Flows and Water Quality Requirements for the River Murray System*. February 2002. Jones *et al* for the MDBC. ("ERP report").

The review of each of these documents is presented in separate chapters of this report. Many other documents were read and have been used in the reviews, the description of the current situation and discussion of indicators of aquatic health, trade-offs or approaches to system management.

Documents 1 and 3 above are examples of Expert Panel approaches, as is the River Murray Barrages Environmental Flows study (Jensen *et al* 2000) and the current use of the Regional Evaluation Groups. As the expert panel approach is a significant component of decision-making risk associated with the use and interpretation of ecological information, a discrete review of the process is presented first.

1.1 The Expert Panel Process and it's implications

The process of data collection in the MDB was very deliberate in the 1980s, including programs specific to water quality, macroinvertebrates, phytoplankton, wetlands and riparian zones. The decade of the 90s seems to have been filled with various targeted research projects, some gap filling based on shortfalls identified in the earlier studies and on development of planning strategies (wetlands, fish, carp etc). The current decade, and to some extent the latter part of the last decade, has seen much greater emphasis on "Expert Panel" reports aiming to quickly provide the basis for major decisions with respect to environmental flows. This change is not only restricted to the Murray or the MDBC but has been widespread in Australia.

The reasons put forward for use of Expert Panels rather than specific data collection programs generally relate to the perceived need for rapid decisions and actions, the presumption or recognition that available useful data is limited so an expert opinion is all that is possible and the assumption that collection of field data is expensive and time consuming. The Brief for the SRP, dated March 1996, notes the timeframe for decisions – environmental flow regimes (EFRs) for the River Murray and Lower Darling were to be resolved before cap arrangements could be finalised, and this was scheduled for June 1997. An expert panel approach was used because of the short timeframe. However the report of the expert panel was not published till June 2000 and in 2003, 7 years after the Brief was issued, we still have no EFR's. One argument used by management bodies, including the MDBC specifically in this instance, is that the need for action is so urgent that they don't have the time to undertake significant data gathering. This is not substantiated by history with respect to the speed of implementation of an EFR for the Murray or in fact for any catchment in Australia for which this reviewer has knowledge.

Pressey (1990) noted with respect to wetlands of the Murray "*On a chronological scale from pristine to completely ruined, it is not "five minutes to midnight" but still before lunch time*". There was time for better informed decision-making at that stage, and there still is.

On page 17 of the SRP report the expert panel process is described as "*a series of observations made…in a systematic and rigorous manner and these are combined with current and historical data*…" This statement suggests the process is far more scientific than it really is, which is a group of qualified scientists jointly reviewing whatever data are available and overlaying their experience on it. Brief visits to sites along the river are usually included, as they were in the case of the SRP for the Murray. However in that report there is no obvious record of any systematically recorded rigorous observations and given the brief nature of the site visits any interpretations made on the basis of those visits must be expert, rather than data based, and would probably vary depending on conditions at the time of inspection. Rapid appraisals of habitat would be possible on such visits and this may add to the available data from other sources but the expert panel process is fundamentally about interpretation of existing data, not generating significant new data.

The SRP report also noted the expert panel method "*is adaptive and iterative, based upon the river under consideration, the composition of the scientific team and the requirements of the water managers*." It also notes it "*is not necessarily a reproducible analysis*". What this means is that the conclusions might be different depending on the make up of the panel. This sort of vagueness in the outputs may suffice as a preliminary planning tool but if this represents the best science available for extremely important decisions, then the best simply isn't good enough. In the case of the SRP report, a study of river flows, it is surprising that there was no independent hydrologist on the team. The Centre for Water Policy Research concluded from their review of the Expert Panel process that "*at best, is seen as a partial or preliminary approach to determination of environmental flows*" (Pigram, 1996).

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The key limitation of the expert panel approach is that it acknowledges by its very existence that we do not fully understand the linkages between flow and ecology. This is acknowledged in the SRP report; "*there is limited information upon which to make quantitative links between hydrology and the ecological health of the river and floodplain*" and "*Knowledge of species ecology is woefully defective in many key areas and is hampered by lack of historical information*". If you don't have knowledge then you have to rely on opinion and opinion is subjective. Unfortunately it appears there is a trend for Governments and management agencies to use the Precautionary Principle as the justification and the Expert Panel as the means, to implement policy rather than to gather relevant data for use in informed decision-making. In the Lower Balonne the local stakeholders were able to reasonably argue their case because they actually funded the necessary data collection and completely disproved the assertions of the Expert Panel with respect to ecology (Cullen, Marchant and Mein, 2003). The best scientific information is not necessarily good enough and experts don't always get it right.

As noted earlier, the outcomes from an Expert Panel process will in part be determined by the composition of the Panel. Those used in the Murray have largely been drawn from academic institutes or government funded research organizations and this is the norm with such panels. Professor Gary Jones of the CRC for Freshwater Ecology and Chair of the ERP, stated in a MFAT workshop in June 2003 that advocacy of conservation related outcomes by scientists advising managers was appropriate and in fact it had been done in the expert panel reports for this process. This is partly unavoidable because as Prof Jones pointed out, ecologists tend to be conservation minded so the subjective opinions they impose on an Expert Panel process will tend to the conservation side. However it is not appropriate if the managers, stakeholders or readers of such reports thought they were receiving independent and unbiased authoritative advice, which is usually what is sought from scientists. There already exist any number of conservation advocacy groups and they are quite able to take the scientific reports and use them for advocacy purposes.

The credibility of the science is far more important than the advocacy of the scientists. Mitchell (1996) stated with respect to the role of limnologists in the water debate "*the ultimate decision-makers in the use of most water are rural landholders who often have little understanding of limnology and no sympathy with "academic greenies*". Also, "*Many pronouncements from limnologists thus far have been far too self serving*". Stakeholders will listen and take action if the advice is credible; they won't if it is not.

Gippel (2002), in reviewing the impacts of flow regulation on the Murray, ranked information from expert panels below that from scientific journal articles, conference papers or trade journals, consulting reports or internal (government agency) reports. The author stated "*While the Scientific panel reports are well written and they have lengthy bibliographies, they do contain some unsupported and / or apparently speculative statements*".

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The factor which should drive water resource planning is environmental risk, or the risk of environmental harm. The volume of water extracted from a system is only one risk aspect related to water use. In determining the planning effort which should be expended on environmental flows *per se*, and then on the different attributes of flow (including volume), managers should assess the following steps:

1. the relative risk to the aquatic environment from water use *per se* (ie, water use relative to land use, urbanisation, industrialisation, direct habitat or geomorphological alteration (e.g. de-snagging, sediment extraction, river engineering etc)
2. the relative risk to the aquatic environment from various aspects of water use (non-flow related aspects: dams and their impacting attributes, levees, regulators; flow-related aspects: extraction, regulation, discharge from particular activities)
3. the relative risk to the aquatic environment from aspects of the flow regime where that is seen as the most significant component of risk (non-volumetric aspects: seasonality, variability, constancy; volumetric aspects: reduced flooding frequency and duration)
4. those ecologically significant components of the aquatic environment at most risk from specific flow regime changes (mid-level floodplain, fringing aquatic vegetation, riparian zone, fish, birds etc).

This stepwise risk assessment and targeting of management responses does not appear to have occurred to date in the Living Murray process. It is acknowledged that the MDBC and the States have a number of programs in place which address many of the non-flow issues but they have not been clearly incorporated into the Living Murray process and therefore not comparatively weighted against flow issues with respect to their ability to counteract apparently declining river health. Some expert panel reports do actually address parts of the above process but it was not core to their Terms of Reference. In fact the Terms of Reference often specifically restricted the panels to flow issues only.

Some level of assessment and then decision-making has apparently taken place because “The Living Murray” discussion paper (MDBMC, July 2002) noted “*summer irrigation flows will remain a feature of the river between Hume Dam and Yarrawonga*” and “*In the Lower Murray, the locks, weirs and barrages will remain in place for irrigation and navigation*”. These attributes of river management are probably one of, if not <u>the</u> major cause of impact in their respective regions of the river and it has already been decided that they will remain so. The latter is clearly not a volumetric impact of flow and the former is primarily a question of seasonality of flow. How much of the remaining impact can be corrected by adjusting volumetric aspects of flow?

Where are the reports from expert panels which were not restricted to flow related impacts? Where is the report from an expert panel which was specifically directed to address <u>only</u> non-flow related impacts or non-volumetric aspects of flow? How did volume become the core issue without such analyses having taken place? If such reports exist somewhere else in the MDBC Natural Resource Management Strategy then they should have been specifically referenced in the core literature for the Living Murray and it’s environmental flows initiatives.

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Gippel and Blackham (2002) define Environmental Flows thus; "*Environmental flows ensure that the key chemical, geomorphological, and ecological processes necessary for (a) healthy river ecosystem keep functioning*". This sort of definition is part of the problem with the focus on flow. Environmental flows in their own right are very unlikely to "ensure" the processes keep functioning simply because they are not the sole source of impact on the processes. At best they can be set so as to not be a limiting factor on the functioning of the processes.

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Crabb (1997) noted "*The role of the Murray Darling Basin Commission is to promote integrated natural resource management across State borders and on a catchment wide basis to ensure sustainable use of the resources of the Murray-Darling Basin*". He also noted that the 1902 Interstate Royal Commission on the Murray recommended "*the river and its tributaries must be looked on as one*". The exclusion nearly a century later of tributaries and headwaters from the Terms of Reference of each of the core studies noted above shows that jurisdictional issues still plague integrated natural resource management. The inability of Expert Panels to comment on impacts, or potential solutions, related to tributaries, is a major shortcoming of the process with respect to generating sound ecological outcomes.

It should be stressed that the outcomes of the environmental flows process are extremely important to stakeholders, particularly those with water allocations or whose businesses are linked to irrigated agriculture, because potential volumetric adjustments will be based largely on ecological supposition. The proof that it is supposition lies in the use of the Expert Panel approach rather than the use of field data or proven relationships. The end result directly affects the livelihood of irrigators and the associated communities. If an engineering project were planned and it had the same level of potential consequence, this level of subjectivity would simply not be contemplated but for some reason it passes as acceptable with respect to ecology.

Hart *et al* (1997) noted "*Improved information should ensure that costly management decisions made on a "best guess" basis are minimised and that sensible strategies will be developed to manage this vital Australian river system*." While this statement was made with respect to algal bloom management it is equally applicable to flow management.

Expert panels can be a useful first step in an exercise to identify potential impacts and even their causes, but basing significant decisions primarily on their outputs is very risky, particularly when those used to date in the Living Murray have been so narrowly focussed. The risks are multiplied many-fold when one expert panel largely relies on the outputs of another, as has happened in the Living Murray process a number of times.

2 Report of the River Murray Scientific Panel on Environmental Flows: River Murray – Dartmouth to Wellington and the Lower Darling River. (Thoms *et al* June 2000 MDBC).

2.1 General

The project brief for the scientific panel (SRP) noted the purpose of the project was to "*identify short term actions which would improve the environmental flow conditions of the River Murray*." The major objective was "*to identify changes in river operations for the River Murray and Lower Darling that should result in general improvements in the environmental condition of these river reaches whilst considering the current needs of existing users*". As such, it was not the purpose of the study to review or investigate long-term options, specific improvements in particular areas (other than weirs) or actions outside the ambit of operational river management. The 'current needs of existing users' appears to have been restricted largely to assumptions regarding volume and seasonality of flow and no consultation with users was undertaken. Tributaries were not assessed or reported upon.

The recommendations were intended to "*maintain or restore biodiversity and ecological processes*" (underline added). In the report this term of reference is interpreted as "*Maintain and where possible improve the natural habitats and ecological functions of the Murray and Lower Darling Rivers as they are today*." The idea that maintenance is the first priority, followed by improvement if possible, is in accord with EPA (now called Department of Environment and Conservation), DLWC (now called Department of Infrastructure, Planning and Natural Resources) and MDBC policy as expressed in a number of documents. The SRP report describes many changes to the system which have, supposedly, resulted in changes in ecology, but it does not explicitly discuss, other than with respect to the weir pools on the Great Anabranch of the Darling, if it is appropriate to accept that change or to aim to restore something of the original system. Similarly when making recommendations the report does not state if the recommendation relates to maintenance only or to a level of improvement or restoration. Maintenance of the existing condition does not appear to have really been accepted as a legitimate outcome because the recommendations generally appear to target a level of improvement in any condition where change is identified.

The report also states "*the Panel worked with the premise that it may not be possible to return the rivers to their pristine or pre-European settlement state*." Besides the fact that this was explicitly not the aim of the project, returning to a pristine system would be a totally impractical target so the very contemplation of such a target possibly reflects the strong conservation ethic of the Panel.

The Panel was to assess actions which did and did not require adjustment of allocations (volume) and prioritise the actions according to scale of cost (to users) and benefits to the environment. The outcomes were to be used in trade-off negotiations.

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The Panel excluded the barrages and the Edward Wakool systems from their brief because they were very complex in their own right. The barrages were assessed separately (Jensen *et al* 2000) and the DLWC report by Green (2001) may be intended to serve as the assessment of the Edward-Wakool, though it was not a specific component of the Living Murray process.

On page 17 the SRP report describes the expert panel process as "*a series of observations made….in a systematic and rigorous manner and these are combined with current and historical data*…". There is no obvious record of the systematically recorded observations in the report and as it poorly references its sources it is very difficult to tell if there is any supporting data or if statements are made based solely on observations made during a rapid visit to a site. Similarly, Table 1.1 notes "*sample sites*" whereas the Panel apparently visited some sites for longer than others and some members of the Panel were able to make useful observations while on site and they recorded these observations on a worksheet. No physical "samples" such as fish, macroinvertebrate or water quality samples were apparently collected. The word "inspection" or "observation" would be more appropriate. It is noted that the expert panel for the Barrages chose not to use the worksheets developed by the SRP.

It is very common in the report for the authors to make statements on river condition, or note causes for that condition, and not to support the statement with references. For example, "*The condition of the floodplain upstream of the gorge is poor to fair*" – based on what? In some sections it is clear that some of the condition assessment is based solely on their site visit whereas in others the source of the statement is very unclear. As an example, "*Fish populations were similarly poor and probably dominated by carp*". How can the fish statement be factual ("were") when the carp dominance is an assumption ("probably")? No reference is given anywhere near the statement.

The panel developed three principles which should govern the management of rivers and their floodplains in order to maintain ecosystem complexity and health (integrity):

1. Natural diversity of habitats and biota within the river channel, riparian zone and the floodplain should be maintained
2. Natural linkages between the river and the floodplain should be maintained
3. Natural metabolic functioning of aquatic ecosystems should be maintained.

Habitats, linkages and functioning are sensible categories to address. Given lack of knowledge on definitive relationships between hydrology and ecology, the "*best response is to restore as much of the pre-regulation regime as possible*". This is a logical assumption in a general sense and the "as possible" section brings into play the socio-economic consequences of any such actions. There appears to be an assumption here that "maintenance" is in relation to the natural condition whereas my interpretation of the Terms of Reference is that maintenance refers to the current condition or in the words of the Panel itself, "*as they are today*". Any move towards natural would constitute "an improvement" or "restoration". This fundamental difference in understanding carries through to later documents regarding the healthy working river concept and the idea that a river may be acceptable to stakeholders as "healthy" even though it has changed from natural. Maintenance of that changed system then becomes acceptable and a legitimate target.

Two further hydrological principles were developed by the Panel:

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4. Elements of the natural flow regime, in particular seasonality, should be retained as far as possible
5. Consistent and constant flow and water level regimes should be avoided as much as possible.

These five principles framed the Panels assessments.

The Panel also considered non-flow actions and "*This gives a sense of the significance of flow changes relative to other aspects of river or land management which may be impacting on the ecological values of the river system*." Note that the Panel's consideration only gives a <u>sense</u>. The Panel clearly noted the importance of integrated river restoration management actions - but they only provided the starting point – they did not weigh up or prioritise flow versus non-flow actions except at times when making recommendations within specific river zones. This is not a failing by the Panel because their Brief specifically instructed them to concentrate on flow.

The Panel warns that the operational changes recommended in the report are to improve environmental condition and should not be used to increase extractions. They cite a litany of examples where previous beneficial measures were eventually lost to increased extractions and this history now leaves little room within the current system for operational manoeuvres.

A significant amount of hydrological data is presented in the report and changes in the flow regime are expressed as a percentage departure from natural. The accuracy of the hydrological data or the modelling upon which most of the figures are based is not mentioned anywhere in the report. This is characteristic of reports written by expert ecological panels and it appears as if the hydrological data is assumed to be suitable for use. This is not always correct and both the basic hydrological data and any models developed from it will have considerable errors. For example the accuracy of gauging and statistics generated by modelling for the main stem and for flows which remain within the banks is probably within +/- 5 or 10%, but for overbank flows and floodplain areas it is common for the best of these models (IQQM) to have errors in the estimate of peak flood flows of the order of 30-40% and of flood volumes of 15-25% (Cullen *et al* 2003). As the Panel often makes recommendations regarding flood peaks, durations or magnitudes, noting of the model error rates should be mandatory.

One aspect of the use of hydrological data which is to be commended was the linking of flow statistics to ecologically meaningful attributes. For example the Panel attempted on occasions to determine a flow rate which would inundate a particular river terrace (bench) or reach a certain flood runner. Linking to a real and observable attribute is a much better approach than using generalised flow percentiles or long term average statistics such as the mean or median (Cullen *et al* 2003), as is often practiced by expert panels.

The report initially describes the hydrological and ecological changes in the system to date then addresses the common issues recognised. A more detailed review for each of six recognised river zones is then presented. In doing so, the Panel attempted to link changes in the flow regime to their five principles.

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2.2 Hydrological Changes

The report notes "*flow management effects are not uniform through the system and consequently any attempt to redress detrimental effects will need to be made on a regional reach basis*". This is attempted to an extent in the report by the zone assessment and going to a reach basis would be much more specific again. There are many other reasons why the regional unit is a sensible scale for management and this is discussed further in section 3.1.

In several places the report notes the various physical impacts of dams and weirs, as distinct from changes to the flow regime which result from their operation. This is a very important distinction which is not made in many other reports. Depending on their size these structures can cause complete change in the ecology of the river sections upon which they impact. The pondage behind weirs produces a lake or billabong where there was once a river. Within the pondage the once important river benches are permanently flooded, slump because of sustained water levels or are smothered by sediment. Neighbouring wetlands which may have been occasionally inundated are now permanently flooded, leading to death of the natural vegetation and invasion by weed species. Water quality within the pondage may be affected by stratification, leading to temperature, nutrient and algal problems. The weirs present a physical barrier to movement of fauna, most notably fish. By altering the height of the river and the bed profile at the weir wall, they affect the flood profile in the near vicinity. Flows over a weir cause erosion for some distance downstream due to the reduced sediment load caused by the upstream pondage, and increased sediment transport capacity of the released/over-topping water, followed by deposition in downstream natural pools or the next weir pool. Basically they are a severe disruption to the natural river continuum and the Murray system has a lot of them, particularly in South Australia.

All of the impacts noted above have occurred and will continue to occur irrespective (almost) of the level of extraction. As the Panel notes with respect to overcoming some of these problems, "*Some management actions, such as providing fish passage or appropriate outlets for natural water temperatures, involve financial and engineering decisions only – they will not impact adversely on water allocation or future river operations*."

The same is true of the large number of levees and regulators along the system; "*In essence their effect can override potential flow management issues*". Regulators are basically small weirs and have the same impacts but on a smaller scale. Levees exclude water from areas where it is beneficial to humans to do so but this is often of detriment to the environment.

At Albury, the report noted little change in total annual flow but seasonality is completely reversed, with summer flows now 7-fold greater and late-winter/spring flows only one seventh as great.

Table 4.1 of the SRP report shows all floods between the fiftieth percentile and the tenth have been reduced between 60 and 76% everywhere from Albury to the South Australian border. Given that the system currently receives a net gain from the Snowy system of over 1100GL per year, (including that which enters via the Murrumbidgee) without this transfer the impact on flooding would be even greater. Also at Albury, all flows more common than about the fiftieth percentile are above natural, leading to an overall flow balance when the noted flood reductions are taken into account.

Major extraction occurs from Lake Mulwala (Yarrawonga) so downstream of this point sees much reduced median monthly flows, particularly in winter-spring, and much reduced flood frequency at all levels between about the tenth percentile and the ninety-fifth. Changes in the flow regime are almost the same at Edward River at Deniliquin except the annual flow frequency is similar to natural between about the fifteenth and thirty-fifth percentile. Larger flows to 95% are significantly reduced. Seventy-two percent of extraction from the River Murray occurs in the Albury to Wakool Junction section, including from the Edward and Wakool rivers. From here to the border with South Australia, use is 9% of total use from the system. Major extraction also occurs on the significant tributaries; the Goulburn – Broken and Murrumbidgee.

After the Murrumbidgee enters, seasonality returns to normal but volumes are much reduced throughout the full range of monthly median and annual percentile flows. Reductions are greatest in peak flow months. Lower flow months (Feb-May inclusive) are close or within 25% at Euston but half or less at Wentworth. These are very large changes.

The Darling is the only significant tributary to enter the system after the Murrumbidgee so there is no inflow compensation for upstream extraction. The diversion from the Lower Darling represents 5% of total system diversion. Median monthly flows in the Lower Darling naturally showed very sharp peaks in September and March but now the peak is Dec-Jan with a very flat minima from March to October inclusive.

The degree of change to the flow regime at the border and at the barrages is similar to that at Euston and Wentworth ie all flows greatly reduced in all months and all years. There are no tributaries in this section and extraction represents 14% of the total system. Mean flow at the border is 44% of natural, there are now prolonged periods of low flow and flood frequency has been significantly reduced: floods of up to 30,000ML/d show a 51% reduction; floods to 60,000ML/d show a 73% reduction and floods to 100,000ML/d show an 81% reduction. Again, these figures represent very large changes. There is relatively more Darling flow in the system now than natural (because Murray flow is reduced) and this brings higher turbidity.

The Panel noted that groundwater is fresh in the middle River Murray but in the lower Murray it is often much more saline. As this was a surface water assessment, little mention was made of either groundwater or salinity, though the Panel did state that "*salinity is not considered to be a major ecological issue for the river"* – because it is largely natural*." However it may be an issue for the ecology of some inundated wetlands*".

The Panel noted "*Of particular concern were the changes that regulation has made to the variability of flow regimes with major reduction in variability at the daily, seasonal and inter-annual time scales*". This observation was the basis of principles 4 and 5 above. The Panel identified the following flow management practices as causing significant alterations to natural variability:

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1. constant flows for sustained periods
2. unseasonal flow
3. increased minimum flow
4. decreased frequency of flood periods
5. reduced duration of individual floods
6. rapid rates of rise and fall
7. constant weir pool heights.

It should be clearly understood that lack of water is not the issue upstream of Yarrawonga. When addressing flow related problems, the river and near-river environment should be assessed separately from the floodplain, or areas distant from the river. Issues 1, 2, 3, 6 and 7 above relate to in-river flows while issues 4 and 5 relate primarily to floodplain flows. For the in-river environment it is generally excess water which is the problem because the weirs raise water levels and the regulation of flow is at relatively high levels. Even in the Lower Murray many of the current in-river problems relate to the water stored in weirs because it is often in excess of what would naturally be there. In places where the annual or seasonal flow has been significantly reduced, the ecological problems may relate more to the floodplain than the river because this environment may be suffering from reduced flooding. The report did not clearly point out the differences.

The cause of these problems is often remote from the site of impact. For example a large headwater storage like Dartmouth Dam will impact on the flood regime over the full length of the river below it. Similarly because stored water in Hume Dam is used to fill extraction requirements nearly to the South Australian border, the impacts of regulation affect the full length of river between these points.

2.3 Ecological Changes

As noted above, changes occurring in the river need to be addressed separately from those occurring on the floodplain if effective solutions are to be identified. The Panel noted "*The effective floodplain (on a whole of river basis) is and will continue to be reduced in size and extent as there are areas where it is not possible to increase flooding frequency or restore flood peaks*." This is the core reason why comparisons with natural flood statistics are no longer relevant – the natural floodplain is no longer there to benefit from such floods. The Panel correctly noted that what floodplain is left is therefore all the more important; "*In general, the larger the reduction in functional floodplain, the greater the imperative to maintain the remainder <u>free of all pressures</u> which might impinge on its function as part of the floodplain river ecosystem*" (underline added). The underlined text highlights the importance of non-flow issues and the Panel specifically mentioned grazing and wood collection in this vein.

Alienation of the floodplain is noted as worst in the lower Mitta Mitta, as a result of flood mitigation by Dartmouth Dam, and in South Australia where the floodplain has largely been leveed, drained and filled. Levees also occur on many other parts of the system. While from a conservation perspective the reduced floodplain is a regrettable consequence of development, the current situation means that nothing like the natural volume of floodwaters is needed to sustain what is left. This is a very clear example of the difference between maintenance, which essentially means acceptance of a changed ecosystem, and restoration.

The report relates the current status of riverine flora and fauna primarily to changes in habitat which result from river management activities and land use. Some impacts relate directly to a particular action while most are the result of a combination of actions. With respect to fish the report notes impacts related to water temperature changes downstream from Dartmouth Dam and Hume Dam, barriers to passage represented by weirs and dams, loss of habitat (such as snags, macrophytes, or floodplain habitat) and water quality. "*Snag removal has been widespread throughout the river, leading to a major loss of fish habitats*", and "*Snags and woody debris are the most important structural habitat in lowland rivers*".

Indirect impacts are also noted, for example the report relates increased turbidity to erosion, tree clearing and land use practices. Turbidity may be a cause of reduced benthic algal growth and this in turn may explain the reduced number of invertebrate grazers in some places, such as South Australia. These flow on effects "*are potentially quite serious*". Turbidity was also noted as a cause of decreased macroinvertebrate abundance in the Lower Murray when Darling River water, which is more turbid, dominates. This is becoming more common because of reduced flow from the Murray.

With respect to impacts on macroinvertebrates in the middle reaches of the river, the report notes a number of impacting agents, such as blockages, disjunctions in the river continuum, construction and operational effects of storages, temperature alterations, alteration to flow regime, turbid water and changes to the availability of habitat. With respect to the latter the report states "*In this stretch of river the importance of logs, large woody debris and submerged and emergent macrophytes for the provision of refuge and a stable substrate for food cannot be over emphasised*." The Panel also notes "*it is difficult to precisely define a flow regime that will benefit their community. Any regime which promotes the extent of the macrophyte communities, the development of biofilms, and the reduction of sedimentation and erosion, and returns a seasonal pattern, will be a benefit*." These statements show two important observations. Firstly, impacts on the flora and fauna relate strongly to impacts on local habitat and secondly, while we may not be able to specify statistically what the "correct" flow regime may be, we do know what is generally beneficial and what is generally harmful. This is particularly important when tied to the premise of maintaining, before improving the existing ecology and the idea that beneficial actions relating to non-flow aspects of ecosystem health may be equally or even more valuable to the ecosystem as those relating to flow aspects. The Panel actually makes such conclusions in their assessment of individual river zones.

Some of the clearest changes to aquatic ecology in the system relate to the impacts on fish downstream of Dartmouth Dam as a result of alterations to the temperature regime. These are unequivocal and very significant and as the report notes, can be corrected without recourse to adjusting water use allocations. Another clear example is the loss of gastropod molluscs in the Lower Murray and the switch from one type of mussel, *Velosunio*, to another, *Alathyria*, in sections with significant weir pools. In weir pools of the Lower Murray there is a general change from native species adapted to disturbance (through natural variation in the flow regime) to species adapted to stable water levels.

The Panel suggested a major loss of aquatic plants in the middle Murray was probably linked to high turbidity, carp, and deep water during the late growing season. The Panel also noted significant changes in riparian species, particularly in the Lower Murray, including willows and *Lippia*.

2.4 Common Issues and Recommendations

With respect to land management the report notes "*Although outside the scope of this report, management of the floodplain land is a significant resource management issue with major impacts on floodplain and river ecology*"(underline added). The report notes key components of the floodplain to target for restoration include;

- anabranches and wetlands likely to be in contact with the river during high flows
- a riparian strip and islands and benches in the main stream
- currently forested areas including those used for passive recreation.

The report also notes that flooding of urban areas or areas of intense agriculture on the floodplain is not recommended because the ecological benefit accruing from flooding would probably be less than the problems of pollution which might result. This is an example where, even from a solely ecological perspective, returning to a more natural flood regime is not necessarily the best outcome. Interestingly the report does not mention the socio-economic impact, which would be very significant indeed.

The importance of these statements lies in the recognition that things have changed and they cannot be returned to natural; that "targeting" of areas to protect or restore is appropriate and that land management is a major cause of changes seen in the river and on the floodplain. A theme developed in this MIL review of the science is that it is legitimate and indeed reasonable to trade-off actions related to reducing the impacts of land use or physical infrastructure for less action related to the impacts of the volume of water extracted. This is not to say that volume is not important. What is critical, given the importance of volume to stakeholders such as MIL, is that other actions which can help maintain or improve the existing ecological conditions are prioritised where possible.

In Table 3.10 the Panel relates flow management actions to ecosystem health components (habitat, linkages, metabolic functioning) and notes the observed and predicted impacts. This is a thorough and well constructed table. Of the seven flow management actions, 3 relate directly to too much water (constant flow for sustained periods, increased minimum flow, weir pools), 2 relate to the timing of movement of water (unseasonal flow, rapid rates of rise and fall) and 2 relate to decreased volume (decreased frequency of flooding, reduced duration of individual floods). One could argue that if the irrigation was not occurring, there would not be the need for the elevated water levels or unseasonal flows but unless you stop extraction totally, those aspects will always be a problem to some extent. The core problem with these is how we move water about, that is, in-river transport, so the problems can be either fixed or ameliorated by addressing that issue without the need to significantly alter the volume extracted.

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Table 3.11 looks at non-flow management activities (either river or land management), again linked to the same ecosystem health components. It identifies 16 separate management actions. Putting the two tables together gives you 23 actions (22 if you count "weir pools" and "on-stream structures" as overlapping) of which seven relate to flow and only 2 of these relate to decreased volumes of water. This supports an earlier statement in this review that for the main channel and nearby areas the main flow related problem is one of too much water while for the floodplain it is one of too little. It also clearly shows the significant number of non-flow issues. How relatively important they are has not been addressed anywhere in the process that I am aware of and this is a very significant shortcoming.

The issues listed in Tables 3.10 and 3.11 were:

- constant flow for sustained periods
- unseasonal flow
- increased minimum flow
- decreased frequency of flood periods
- reduced duration of individual floods
- rapid rates of rise and fall (erosion and sedimentation)
- weir pools
- Grazing of riverbanks
- Clearing of riverbanks
- Promotion of exotic riparian vegetation
- Removal of snags
- Recreational boating
- Aggregate extraction (that is, sand and gravel)
- Floodplain development
- Various land use practices
- Culverts and regulators
- On-stream storage structures
- Increase in diffuse nutrient sources
- Diffuse toxicant sources
- Catchment-based erosion and sediment input
- Temperature of releases
- Hypolimnetic releases (water quality)

Some impacts noted as significant in other documents (eg Margules & Partners 1990) are not noted above, they include:

- Salinisation (though it is mentioned in "various land uses" as a barrier to fish movement.)
- Feral animals (eg rabbits and linked to grazing and erosion pressures)
- Logging
- Point source pollutants.

Similarly in Figure 4.1, only 1 of 12 major ecological issues (listed below) applied to all zones within the system. This makes the system approach of the later ERP report (Jones *et al* 2002) somewhat redundant because so few flow issues are equally significant throughout the system. The Panel noted that some issues were commonly encountered while others where more localised.

The common water resource development related issues were:

1. Changes to the flow regime
    - Constant flows
    - Sustained unseasonal in-channel flows
    - Reduced occurrence of floods
2. Linkages
    - Unseasonal high flows providing artificial linkages
    - Barriers to fish passage
3. Habitat
    - Conservation of the floodplain
    - Reduction of snags
4. Disruption of metabolic functioning
    - Unseasonally low water temperatures
    - Increased turbidity during summer
5. Effects of Weir Pools
    - Constant water levels
    - Effects on connected wetlands
    - Bank instability downstream of locks

In making recommendations with respect to Issue 1of the five common water resource development issues, "*the Panel aimed to return variability to the River Murray at the scales where it was seen to be affected to such a degree as to negatively impact on ecosystem health*". The key point here is that some degree of change is acceptable. With respect to flow issues the Panel used a benchmark of 50% of natural as the minimum value for any flow statistic, such as a flood event frequency, though there was no evidentiary basis for the selected percentage.

The Panels general recommendations were:
G1. Releases at a constant discharge should be avoided.

G2. To conserve flood events, abandon the current practice of pre-releases.

G3. Pass a percentage (10%) of inflows to storage as they occur.

G4. Review opportunities to increase the watering of targeted wetlands and identify river zones which would benefit most from this.

G5. Develop guidelines (ecological, hydrological, engineering) for the use of regulators (note this was a second priority option because regulators are basically small barriers, the preferred option was to reduce summer flows below the threshold likely to affect wetlands – this needed case-by-case assessment).

G6. Endorses the aims of the MDBC Fish Management Plan.

G7. Identification of floodplains or floodplain parts with high functional value for special protection. Development of ecological guidelines and priorities for land management policy instruments. No further alienation of floodplain. Land uses compatible with ecological functioning.

G8. Protection, conservation and restoration of snags and riparian zones.

G9. Installation of variable level offtakes for Dartmouth and Hume Dams.

G10. Manipulate South Australian weir heights over a range of 30cm in years when Darling water is predominant.

G11. Investigate triggers and sources of turbidity in the middle Murray.

G12. Introduce seasonal pulse flows to control cyanobacterial blooms.

G13. Introduce a summer base flow to the Darling River and Great Anabranch.

G14. Undertake an investigation of the effects of enhanced watering of Lower Murray wetlands, particularly with regards groundwater ("*as it is unlikely they (*the wetlands*) require further watering*").

G15. Draw down weir pools for 2 months in late winter early spring. Experiment with removing weir gates 6-8 weeks prior to a flood and reinstalling afterwards. Review function and utility of all Lower Murray and Lower Darling weirs with a view to complete removal of some.

G16. Fill weir pools gradually to avoid rapid water level decline downstream.

With respect to flooding targets, the Panel recommended floods should occur at no less than 50% of the natural frequency and those remaining floods should have durations as close to natural as possible. (In total, this would represent a greater than 50% reduction in flooding.) With respect to flood duration, they recommended no less than 50% and no more than double but this should be done in the correct season.

The recommendations with respect to floods, snags and riparian zones generally follow the priorities of Rutherfurd *et al* (2000), being:

1. Protect reaches that support endangered species or communities
2. Protect reaches in the best general condition
3. Stop streams from deteriorating
4. Improve the condition of damaged reaches, focussing on those that are easy to fix
5. Rehabilitate reaches that are already extremely degraded.

This again supports the basic "maintain and where possible improve" philosophy.

For a number of recommendations the Panel noted that hydrological modelling shows minimal impact on current water users, that is, environmental benefits can be targeted with little socio-economic cost related to a reduction in water allocations.

The Panel did however warn that upstream migration of extraction through water trading would only increase the length of river within which flows were reduced. The Panel suggested incentives to achieve downstream trading. This outcome is generally supported as long as the mechanism of getting the water downstream did not exacerbate current problems related to regulation.

In section 5.5.3 the report notes "*It appears likely that released pulses of water for environmental purposes (e.g. releasing part of the Barmah-Millewa Forest environmental water allocation in large volume pulses to extend natural flooding) from upstream storages could be recaptured in downstream storages (possibly previously lowered for the purpose). If the downstream storages were offstream, environmental costs would be less*." This idea supports my own philosophy that to create air space and therefore offer management flexibility in the river, an attractive theoretical option is to construct offstream storages. This would require detailed feasibility analysis. Similarly the report notes that the Barmah choke by-pass option is a means of getting water out of the system and adding management flexibility. The other key point recognised by the quote is that the same body of water can be put to multiple purposes.

2.5 Recommendations for individual river zones

Recommendations by the Panel for each individual river zone largely re-iterated the general recommendations, except where they were not relevant to that zone. In considering these recommendations it should be recalled that they were deliberately focused on improvements in river operations.

2.5.1 Zone 1. Mitta Mitta River – Dartmouth to Hume

Environmental condition:

Instream environment:

- Evidence of channel degradation and armouring in places
- Infilling of pools and extensive de-snagging

Riverbanks:

- Active bank erosion resulting from periods of sustained high flow
- "River improvement" by rock beaching, planting of willows and natives vegetation and snag removal

Riparian zone:

- virtually cleared via grazing
- replacement by willows in places
- bankside vegetation is depauperate

Floodplain:

- physical blockages reduce channel – floodplain linkages
- heavily grazed and with introduced plant species
- drained in places
- flood frequency and duration considerably reduced

Biota:

- native fish species largely replaced by cold water introduced species
- depauperate macroinvertebrate fauna

Water quality:

- thermal changes (cold water release)
- low level releases also affect oxygen, ammonia and orthophosphate.

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Recommendations:
Z1.1 *Surface water release from the dam*.

Z1.2 *Introduce variability into current patterns of sustained flow*.

Z1.3 *Abandon pre-release strategy*.

Z1.4 *Pass a percentage of inflows*.

Z1.5 *Re-establish flood runners*.

Z1.6 *Develop a stream restoration plan*.

Z1.7 *Develop riparian vegetation plan*.

Z1.8 *Determine the adequacy of current minimum environmental flows*.

Unseasonal temperature was recognised as the "*overriding issue*" in this zone.

2.5.2 Zone 2 – Hume Dam to Tocumwal (upstream of the Edward split)

Environmental condition

Overall environmental condition was thought to be "*highly variable*".

Instream environment:

- Channel degradation and armouring near Hume Dam, aggradation near Lake Mulwala
- Extensive de-snagging

Riverbanks:

- Very poor condition throughout. Active bank erosion resulting from periods of sustained high flow, boat wakes, stock.

Riparian zone:

- Mixed condition.
- Clearing and grazing, loss of understorey
- Reduced flooding

Floodplain:

- "*forested ribbon the width of the rivers meanders*" –re Red Gum below Yarrawonga
- Clearing of low lying areas upstream of Yarrawonga.
- Grazing where access is obtainable
- Floodplain size reduced downstream
- Some anabranches too wet, some too dry.
- De-snagging.

Biota:

- Excellent native fish populations downstream but upstream are affected by cold water and lack of snags
- Macroinvertebrates reflect in-stream habitat diversity

Water quality:

- thermal changes (cold water release) as far as Lake Mulwala
- low level releases and catchment effects on nutrients.

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Recommendations:
Note no recommendations were made regarding unseasonal high flows, despite this being recognised as the highest priority item. This was because the panel felt the lack of air space in the river, due to high irrigation demand, curtailed any management options, though they did note that any option which reduced demand or improved the capacity to deliver water by other routes, would be beneficial. The latter option has not been considered by other panels as far as I can see.

Z2.1 *The restoration of anabranches be recognised as a priority for funding for local groups.*
Interestingly, while recognising the importance of flood frequency and flow variability, the following land management practices were also identified as important:

- re-introduction of snags
- control of wood collection
- controls on stock access
- removal of blockages
- control of pest species, particularly willows.

The panel seemed to suggest that the fact that most of the area in question was privately owned may reduce the ability to implement these strategies "*It will be necessary to examine the rights and obligations of both management and landholders*…". Why? Why not first ask for joint involvement and assume an environmental ethic will produce the right outcome? In fact in this zone community cooperation has been excellent as Gippel (2003) reported with respect to the "Trial watering of wetlands on private land" project; "*The well-planned objectives, high level of community approval, agency support, and scientifically demonstrated success of the first trial were major factors that encouraged the expansion of the management policy in the following year*", and "*The project also demonstrated that the local community is willing to support and become actively involved in this form of management action*."

Z2.2 *Introduce variability into current patterns of sustained flow.*

Z2.3 *Abandon pre-release strategy*.

Z2.4 *Pass a percentage of inflows to Hume Dam*

Z2.5 *Surface water release from the dam*.

Z2.6 *Determine the adequacy of current minimum environmental flows.*

2.5.3 Zone 3 – Tocumwal to Torrumbarry, including the Barmah choke

Environmental condition
Overall environmental condition in this zone was considered to be variable, with some very poor aspects and other aspects displaying only minor signs of degradation.
Instream environment:

- Naturally low main channel habitat diversity (due to constricted channel and high flow velocity) but high diversity in the offtakes / anabranchs; "*The majority of these still contain abundant habitats*".

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- Dredging and de-snagging common, some erosion.

Riverbanks:

- Loss of bench habitat through active bank erosion and permanent inundation resulting from periods of sustained high flow.

Riparian zone:

- Includes Ramsar listed Barmah Millewa forests
- Reduced flooding in parts, but excess water near river causes tree death

Floodplain:

- Includes Ramsar wetlands – high conservation value
- Degrading because of persistent high flows and lack of wetting / drying cycles. This includes Edward River and a number of anabranches.
- High rates of sedimentation related to poor land management
- Floodplain size reduced by levee building in some places
- De-snagging.

Biota:

- Good native fish species complement but strong carp populations.
- Macroinvertebrates reflect in-stream habitat diversity – mainly on snags.

Water quality:

- No comment.

Recommendations:
As in Zone 2, "*the unseasonal flooding of wetlands is the most significant issue in this zone. This is because the river is used to transport water for irrigation during the summer months.*"

Z3.1 *During the period December 1 to the end of the irrigation season, run the Barmah Choke below channel capacity*.

The Panel recommended that in order to capture rain rejection flows, 20GL of "*channel capacity or storage space*", was required, though this would capture only 64% of events. In line with recommendations elsewhere in this review, I suggest offstream storage space is the better option. The panel also noted that decreasing allocations would effectively reduce summer flows.

Z3.2 *Develop guidelines for the use of regulators for excluding summer flows***.** (There are 28 regulators in this zone).

Z3.3 *Review opportunities for watering targeted wetlands*.

Z3.4 *Some variation in flow should be introduced* (noted limitations imposed by constant flow regime and risks associated with further summer flooding of wetlands).

Z3.5 *A study should be undertaken of the comparative ecological values of wetlands, anabranches (including the Edward River) and creeks and identify areas of high conservation value in order to nominate areas which might be used as zones of sacrifice*. This option assumes that whatever is done will only shift the problem elsewhere because of a basic problem of over-allocation. The language here is interesting, that is, referring to an area for which the beneficial use is other than environmental, as sacrificial.

The Panel suggested mechanisms to add system flexibility - policy instruments (charge for water not used); structural eg by-pass channel or on-route storages; on-farm efficiency gains given to the environment. Offstream storages were not specifically mentioned. The report also discussed the cost of reducing flows from Yarrawonga and this equated to millions of dollars in lost productivity.

2.5.4 Zone 4 – Torrumbarry Weir to Wentworth

Environmental condition

The description in this section apparently relies largely on the observations of the Panel during their site visit so it is difficult to know how reliable the description is for the overall zone. Generally it appears to be a mixture with some good riverine and riparian habitat features. Given the major reductions in flow recorded for this section the descriptions of environmental condition are surprisingly good when compared to general descriptions of the Murray in media or newsletter style publications.

Instream environment:

- Significant benches and anabranches.
- Complex assemblage of habitats around Wakool junction but evidence of erosion and bank slumping
- Generally good snag numbers and accumulations of debris and leaf litter.

Riparian zone:

- "*Structurally diverse*"

Floodplain:

- Between Torrumbarry and Euston is somewhat contained by levees but is in reasonably good condition with accumulations of woody debris and leaf litter.
- The issue of river connectivity is crucial
- **"***Floodplain vegetation consists of mature river red gum woodland with a diverse understorey of shrubs and grasses*."
- Near Wakool junction the floodplain "*appeared to be very healthy*".
- Below Euston the red gums were mainly young to mature regrowth with a simple understorey, "*presumedly a consequence, at least in part, of heavy grazing"*.

Biota:

- The section is "*expected to support a reasonable native fish population*" but strong carp populations.
- Macroinvertebrates are poor near Torrumbarry weir but improve significantly downstream, reflecting in-stream habitat diversity.

Water quality:

- Turbidity decreases downstream of Murrumbidgee confluence.
- Cyanobacterial threat significant.

Recommendations:

"The major threatening processes in this river zone are largely habitat related, though constant flows and bank and bench erosion are still significant problems."
Only one of the four identified priority issues relates to too little water:

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- Reduction of flood frequency
- Constant weir pool height
- Reduction in snags / increase in turbidity
- Barriers to fish passage.

The highest priorities were given to the last two.

Z4.1 *Identify opportunities for watering targeted wetlands*.

Z4.2 *Identify floodplains or parts of floodplains with high functional value for special protection***.**

*Develop guidelines for the use of regulators for excluding summer flows***.**

Do not further alienate the floodplain through incompatible land use.

Z4.3 *Protect and re-introduce snags and wood***.**

Protect and revegetate the riparian zone.

Z4.4 *Weir pools should be drawn down to the lowest level possible for two months in later winter-early spring*.

Z4.5 *Use flushing flows to prevent cyanobacterial blooms*.

Z4.6 *Review the function and utility of all weirs and regulatory structures. Provide fish passage at each barrier*.

Z4.7 *Introduce planning controls on the floodplain to prevent/remove blockages*.

2.5.5 Zone 5 – Wentworth to Wellington

Environmental condition

"*The entire lower River Murray is grossly modified by the presence of locks and weirs*." It is now a series of pools rather than a river. Again many of the descriptions in the SRP report appear based solely on the Panels site visit.

Instream environment:

- In-channel sand bars, benches and deep pools largely either permanently flooded or filled by erosion, both actions as a result of the weirs.
- Snag removal and dredging have been common

Riverbanks:

- "*The availability of riverbank habitat has been virtually eliminated in the lower River Murray***."**
- River training also common.
- High rates of erosion due to permanent wetting and rapid rates of rise and fall.

Riparian zone:

- "*Generally the riparian zone was in reasonable condition with river red gum and black box communities, although most areas have been heavily grazed*"

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- Effects of reduced flood frequency partly offset by raised groundwater as a result of the weir pondages
- Some evidence of saline groundwater causing tree death

Floodplain:

- Dredge spoil has commonly been used to fill the floodplain.
- Areas furthest from weirs suffer from decreased flooding and increased saline groundwater
- Areas nearest the weirs suffer from drowning
- Most of the floodplain is affected by grazing
- A considerable amount of woody debris has been removed
- There are a number of blockages preventing movement of water and fish.

Biota:

- "*Fish populations are significantly affected by the presence of barriers*."
- Significant lack of snags.
- Macroinvertebrates now reflect billabong communities and are less diverse when Darling River flows dominate.

Water quality:

- Fine sediment and high turbidity limits algal productivity.

Recommendations:
"*The Panel is more concerned about those wetlands suffering frequent or continuous inundation than those with a reduced flooding regime*". This is because the weirs raise the level of surrounding groundwater and the trees tap into this.

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Z5.1 *Develop guidelines for the use of regulators for excluding summer flows***.**

Z5.2 *Fringing riverine wetlands within the influence of weir pools should not be further watered.*

Weir pools should be drawn down to the lowest level possible for two months in later winter-early spring.

A weir be withdrawn for 6-8 weeks prior to a flood as an experiment with respect to the benefits of wetting and drying cycles.

Z5.3 *To conserve flood events, abandon the practice of pre-releases from Lake Victoria.*

Z5.4 *Additional water in Lake Victoria be used to augment floods that will water the floodplain rather than fringing river wetlands*.

Z5.5 *Identify floodplains or parts of floodplains with high functional value for special protection***.**

*Develop guidelines for the use of regulators for excluding summer flows***.**

Do not further alienate the floodplain through incompatible land use.

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Z5.6 *Review the function and utility of all weirs and regulatory structures. Provide fish passage at each barrier*.

Z5.7 *Introduce planning controls on the floodplain to prevent/remove blockages*.

Z5.8 *Fill weirs gradually to avoid rapid falls in water level downstream*.

Z5.9 *Protect snags in all environments.*

Reintroduce snags to key environments.

Protect and revegetate the riparian zone.

Z5.10 *Use flushing flows to prevent cyanobacterial blooms*.

Z5.11 *When Darling River water is dominant, manipulate weir pool heights over +/- 15cm in a month to increase the euphotic zone*.

2.5.6 Zone 6 – Lower Darling River and the Great Anabranch

Environmental condition

"*Whilst the general hydrological pattern down the Anabranch resembles the natural flow regime, the principal threats (actual and future) are associated with structures, such as culverts, weirs, retaining walls and bridges*." The Anabranch is the main area of floodplain while the river is a more incised channel. The river is the channel used to transport regulated water.

Instream environment:

- Habitat value of benches being eroded by high unseasonal flows.
- Lake habitat on Anabranch likely to be important (note there are 17 lakes and 12 of them are opportunistically cropped).
- Pools behind structures on the Anabranch offer near permanent habitat.

Riverbanks:

- Little habitat diversity due to constant high flows.
- Reduced flooding at upper levels

Riparian zone:

- Apparently reasonable?

Floodplain:

- Uncertain condition on the Darling but impacts from grazing, rabbits and potentially the reduction in flood frequency.
- Evidence of heavy grazing impact on the anabranch

Biota:

- Fish populations dominated by carp in the upper anabranch. The lower anabranch and the Darling support a diverse and abundant native population.
- Potential impact of barriers.
- Macroinvertebrates typical of lowland rivers.

Water quality:

- High load of fine suspended sediment and phosphorus.
- Cyanobacterial threat significant during low flows.

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Recommendations:
Z6.1 *Year round fish passage suitable for all native species be provided as a matter of urgency, possibly by removal of the weirs between Menindee Lakes and the River Murray*.

Z6.2 *Abandon the practice of pre-releases from Menindee Lakes*.

Z6.3 *Investigate the use of water from Menindee Lakes to enhance floodplain watering of selected wetlands.*

Z6.4 Pass a percentage of inflows into Menindee Lakes.

Avoid constant discharge.

.
Z6.5 Reiterates 6.4 (literally).

Z6.6 *A minimum baseflow be provided during summer for periods of greater than one week* (to control algal blooms).

Z6.7 *Investigate alternative means of supplying water to users along the Anabranch*. With respect to this recommendation the Panel noted that like the Lower Murray, "*the presence of weir pools has changed the local environment so much from the natural regime that a decision has to be made to either return it to a natural state or to leave it as it is*." Given the inefficient use of water, the Panel recommended a return to natural. This was not the recommendation for the Lower Murray.

2.6 Summary

The following points represent the key conclusions from a review of this report:

1. The in-stream structures and the in-river flow level they are required to maintain are possibly the most significant causes of ecological problems in the system.
2. An open-minded review of alternative and innovative means of water delivery is necessary.
3. Physical obstructions in anabranches, wetlands and on the floodplain are significant impediments to realising full ecological value from these environments.
4. In order for management to clearly address solutions, impacts need to be assessed separately for the river and near-river wetlands, and for the intermediate floodplain, while maintaining a holistic view.
5. In-river, the key impacts relate to habitat change resulting from too much water (in weirs or in transit), physical barriers to movement, snag removal, drowning or erosion of benches, erosion and sedimentation and lack of diversity of flow.
6. Increases in flow will not aid, or at least are not the best way to address, many of the recognised in-river problems.
7. Key floodplain impacts relate to physical alteration and alienation, reduced flood frequency and to a lesser extent, reduced flood duration.
8. Land use planning policies and best practice land use *per se* are essential to protection of remaining areas of functional floodplain.

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9. The report recommends identification (targeting) of key areas of high ecological significance and rehabilitation of the flood frequency regime, and to an extent the flood duration regime, in those areas as a priority.
10. The type of impact varies so significantly along the system that a regionally based approach to solutions, coupled with site-specific evaluations linked to point 9, is essential.

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3 Snapshot of the Murray-Darling Basin River Condition (Norris *et al*, September 2001)

The Snapshot represents a concise summary of Basin-specific data drawn from The Assessment of River Condition ("ARC", Norris *et al* 2001) plus some use of river-specific data for the River Murray drawn from several sources but mainly from Thoms *et al* (2001). The Snapshot summarises a vast amount of information, presents it in a readable manner and generally acknowledges its own limitations, and as such is a good piece of work. The limitations are substantial and relate mainly to lack of data, either with respect to particular aspects of the environment or in terms of spatial or temporal distribution of data points, the methods by which data has been modelled or condensed and the inability to place a relative weight on the various causes of impact. Unfortunately the caveats acknowledged in the report may be forgotten or under weighted when it comes to decision-making so in order to fully understand the utility of the Snapshot to decision-makers, the limitations must be clearly understood and for that, a review of the ARC is also necessary.

The Foreword to the report is by Roy Green, President of the MDBC. In that he points out that the Snapshot is a "*glimpse*", "*interim*" and in fact "*the first collation of river health information prepared specifically for the basin*". Given all the publicity and political emphasis on the Murray-Darling, the period over which environmental issues have been acknowledged and the period of existence of the MDBC and its predecessor organisation, the latter is astonishing. What is even more astonishing is that decisions will shortly be made which could significantly affect the lives of many people in the basin and make a significant impact on Australia's agricultural production, yet the best we can do with respect to environmental information, apparently the key driver of those decisions, is a "*glimpse*". The most significant outcome of the Snapshot should be recognition that our ecological databases are "woeful" (to quote from the SRP report) with respect to their ability to assist decision-making. The Foreword notes "*Decisions on future interventions can be both improved and facilitated by better information on river health*". This conclusion is obvious but what really needs to be decided is what level of decision needs to made now and how much risk is associated with it?

The Foreword assumes that substantial interventions are required to improve river health and that such interventions will have negative economic and social consequences. Why? The latter does not necessarily have to result from the former, even assuming the former is necessary. The assumption appears to be, and it is reiterated in the Overview by the Sustainable Rivers Audit Group, that a significant volume of water must be returned to the system. The overview actually states "*the current level of extraction in the Basin makes it inevitable that more water must be returned to the rivers to restore and maintain a balance commensurate with sustainable resource use*". This is not a conclusion made by the Snapshot. The Snapshot does not equate any level of impact to concepts of sustainability nor does it state that the way to correct hydrological problems is to restore volume. In fact it doesn't even mention the volume of extraction. The conclusion can only be the interpretation of the Sustainable Rivers Audit Group and it is difficult to support from data presented in the Snapshot. For example the Hydrological Disturbance Index is that which shows least change from natural when compared to the Catchment, Habitat or Nutrient and Suspended Sediment indexes (Table 2.1). This emphasis on volumetric adjustments at the very front of the document is inappropriate before readers even get to the data presented in the Snapshot.

The Snapshot was not forced by its Terms of Reference to concentrate solely on flow but "*evaluates the aggregate impacts of resource use on the rivers*". While with respect to the main stem of the Murray it concludes "*the main impacts (are) related to the operation of dams and weirs throughout the system*" the report warns "*Management that focuses on the main stems in the lower Basin is likely to be ineffective without consideration of problems that are generated upstream*". As noted earlier in this review, the presence and operation of dams and weirs causes impacts in its own right irrespective of the volume of extraction. The key causes of impacts to river condition in the basin which need to be addressed are:

- Nutrient and suspended sediment generation in the upper catchments
- Nutrient and sediment stores in the mid-slopes
- Damage to riparian zones in many areas through clearing and grazing
- The physical barrier effect of dams and weirs
- Loss of habitat associated with dams and weirs (consistent water levels), removal of snags and through conversion of floodplain to primarily agricultural areas
- The connectivity of the river to the floodplain, based on physical (levees) and hydrological attributes (water levels)
- Hydrological attributes.

The presence and operation of dams and weirs in the River Murray directly affects the last four points but as stated with respect to the SRP report, many of the impacting issues are probably best addressed by *how* we manage the movement and storage of water in the system and through specifically targeted volumetric adjustments which might lead to more or less water in particular environments at particular times.

The Snapshot is reviewed below under the chapter headings as presented in the document except that methods are presented before results.

~~1.2~~3.1 Introduction

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The introduction states that the "*primary purpose is to inform the Ministerial Council on the current condition of the rivers in the Basin, particularly the River Murray in the context of decisions to be made on the allocation and management of environmental flows*." Given the latter, it is extremely important that an estimate be made of the proportion of the aggregate impact which is attributable to flow. The report notes that "*when comparisons are made between variables, care must be exercised*". This is very true but given the importance of upcoming decisions acknowledged in the document, some comparisons are warranted and in places they have been undertaken but the document makes no conclusion about the relative importance of flow related or land use related impacts for example. In a statistical sense this could not be done because of the type of data available and our level of knowledge of causal relationships.

The approach used in the Snapshot, in which a hierarchical model of river function is used to generate three levels of indices for assessment, is well documented and supported. It is an unfortunate result of a lack of sufficient historic support for basic data collection that the data available from which indices could be produced for the three components of the assessment were extremely limited. This not only meant that the choice of indicators within each level was limited but the areal and temporal coverage offered by each indicator was inconsistent and often poor. Whether the indicators used in each category were the most appropriate or whether it was appropriate to have just one catchment index but three habitat indices, for example, is debateable but probably a moot point because this was not done by choice but by necessity. This problem does make it very difficult to weight any of the components against each other. Similarly the one biotic index may or may not be causally related to the catchment or habitat indices and this is not addressed in the Snapshot.

The available databases used in the assessments were by necessity often broad-scale and imprecise, which immediately limits the ability of the results to be used at finer scales of management.

The reference condition approach, in which the comparison of present conditions is with near-pristine or pre-European standards, means any targets derived from them relate to that standard and not to a lower standard which might represent a minimum sustainable level or be accepted under a healthy working river compromise. Similarly the distance-from-target or the amount of rehabilitation necessary to achieve the target, would be less in the latter. As a simple example, the only data used for the Biotic index is the AusRivAS model database. This model uses the near-pristine reference approach. Reference sites for the Murray would presumably describe the fauna of a flowing river. If however we accept that, in order to store water in the river, the macroinvertebrate community will change from one representative of a flowing river to one representative of a lacustrine (pool-like) environment, and this condition is acceptable under a community agreed healthy working river compromise, then the reference condition is no longer relevant. AusRivAS is not able to differentiate between these objectives, as it only has one reference condition.

Similarly if management chooses not to use a specific target state such as “natural” as its precise goal but uses maintenance of the current condition or an “improving trend” as the goal, then there are two reference conditions; the current condition being the most important and the assumed natural condition being a generalised long term comparator but not an ultimate goal.

The ARC notes that macroinvertebrates are strongly controlled by local conditions, meaning the extrapolation of a result from a site to a reach becomes more dubious as the length or complexity of the reach increases. The report also notes “*When examining data for macroinvertebrate communities within a reach, and their corresponding* AusRivAS *scores, we found considerable variation in both*”. This largely natural variability also affects the applicability of reference sites to different test sites. As AusRivAS provided the only biotic index, this variability is a significant component of decision-making risk.

The difficulty in describing near-pristine comparators when they were not measured until after change had occurred is noted in the report. With respect to the Murray, Table 1.1 notes that half of the reference conditions were described by professional judgement, a further quarter by modelled pre-1750 regimes, one by national water quality guidelines (which may not be totally relevant to the system or equally relevant throughout the system) and only one of eight was related to actual data (the AusRivAS system).

It cannot be overstated that data limitations have severely affected the utility of the Snapshot for specific management purposes. The outputs are however relevant as a general indication of the changes which have taken place in the catchment. As the Snapshot was produced after the ARC it relied on ARC data. Would the same set of data have been chosen if it was done before the ARC?

The reporting basis for the River Murray and Lower Darling is the main stem hydrological zones recognised by the MDBC and for which they are legally responsible. This restriction is inappropriate from a management perspective as it is not possible to ecologically separate the main stem from its tributaries. The report notes "*Management that focuses on the main stems in the lower Basin is likely to be ineffective without consideration of problems that are generated upstream*." When combined with the statement "*Management of single issues, such as environmental flows, is unlikely to be successful in improving river health if other issues are neglected*", it becomes clear that the restriction of assessment to just the main stem in effect biases the assessment toward only the impacts and causes manifested in that area. Crabb (1997) in an MDBC publication noted "*The role of the Murray-Darling Basin Commission is to promote integrated natural resource management across State borders and on a catchment wide basis to ensure sustainable use of the resources of the Murray-Darling Basin*". This seems in direct conflict to a restriction to consider just the main stem of the Murray. Crabb also noted that the 1902 Interstate Royal Commission on the Murray recommended "*the river and its tributaries must be looked on as one*." If it was obvious in 1902 surely it is more obvious now.

As noted with respect to the ERP report, if you only examine a section which is strongly impacted by dams and weirs, your management targets will almost automatically be directed toward flow management whereas if tributary issues are taken into account, the emphasis on flow is likely to be reduced and management targets regarding river health would be more likely to be appropriate and effective in the long term.

3.2 Methods

3.2.1 AusRivAS data

The macroinvertebrate data which form the sole basis of the Biota Index is interesting for a number of reasons. It is based on a reference approach, where reference sites are theoretically those in near pristine condition. Test sites are compared against the reference condition and unless they too are in near-pristine condition they will receive a score less than one. In the data presented in the Snapshot and the ARC for basins with AusRivAS data only, only test sites were included. The Reference sites, being the best sites in the Basin, were deliberately excluded from analysis and were not presented anywhere in the Snapshot. In the ARC the authors noted "*Their inclusion in a basin assessment would bias any estimate of basin condition towards the "reference" condition*". With respect to test sites they noted "*Many were chosen because a problem was known or suspected at a site. These test sites would bias a basin assessment towards a poorer condition*". As only test sites were included, the

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latter did occur so the results are poorer than reality and this is acknowledged in the ARC but it is not repeated in the Snapshot. The basis for this decision was the Precautionary Principle.

Further, "(test) *sites with OE ratios above reference were excluded from the basin assessment aggregation because the higher O/E scores would weight or create a bias toward the reference end*" (underline added). "*As test sites with O/E ratios above reference may be naturally taxa-rich communities or they may be suffering from mild organic enrichment*", they were excluded because of the risk that the score might hide the adverse impact. Unfortunately as noted they could also be naturally rich sites so their exclusion adds to the exclusion of reference sites and further biases the assessment toward poorer scores.

While there is some logic in the exclusion of reference sites and test sites with O/E scores higher than reference, there is no reason why their existence could not have been clearly mentioned in the text and recorded on a map. Such presentation would have allowed readers to see that in regions where the average score was that of an impaired system, there were still sites which were in good condition. As an example, the South Australian EPA web site provides a map which shows 16 AuRivAS sites between the border and Waikerie. Of these, 6 are Reference sites, 5 test sites are in Reference condition, 1 test site is in above-reference condition and 4 are Significantly impaired (there are no severely impaired sites). In the Snapshot and ARC report, only the 9 significantly impaired or reference condition test sites would have been included in the analysis whereas the 7 reference sites or sites which scored above reference condition would have been excluded. It should be noted though that the web site also shows three sites below Waikerie, two of which are severely impaired and one is significantly impaired.

Another valid reason for showing reference sites is that they form the basis of water quality objectives within NSW.

On page 147 of the ARC another bias toward poorer condition is noted "*Assessments are based on the FNARH sites alone, which may have introduced some bias towards poorer health*". The FNARH (First National Assessment of River Health) sites were not randomly selected.

The issue of what the reference sites really represent has been raised a number of times during the development of AusRivAS models. As it is extremely uncommon to find sites in truly pristine condition, the "near-pristine" compromise is accepted. If it is accepted that truly pristine sites would be in better condition than near-pristine sites then all test site scores are higher than would be the ideal case and impairment is therefore underestimated. However this assumes that whatever level of change may have occurred is sufficient to have noticeably lowered the condition of the currently near-pristine sites. This may or may not be the case. As will be discussed later in this review, if we set our management goal as an improving trend based on the current condition, the issue of trying to estimate the natural or pristine condition becomes redundant.

Where no AusRivAS data were available for reach analysis the ARC authors attempted to create modelled data. Sixty percent of the models attempted were rejected because "*the error in some predictions would have been too large to justify reporting at even the basin scale*". A primary reason for the failure of the models was "*O/E scores from an average* AusRivAS *model, explain only 30-40 percent of the variation in the biota*". Conversely, the models do not explain 60-70% of the variation. One would hope that decision-makers would prefer those figures to be the other way around.

The ARC also notes that the AusRivAS "O" score, which is a measured variable, is subject to natural variation and sampling error. This can lead to considerable consequences when the reach scores are produced because they are the average of all AusRivAS scores for the reach. The fewer data points available the less likely the modelled average will reflect the true average. The decision support rules for mapping AusRivAS (Bruce Gray, Environment Australia, 2001) also notes "*the most precautionary approach is seen as the most defensible and prudent*" and "*reporting the worst case recorded during the sampling period is simplest and most publically accountable*". What this means is that if there is any discrepancy between habitats sampled at the one time or the same habitat at different times, the worst score is given. In the ARC and Snapshot the averaging approach simply means that the scores from reaches with less data will be less reliable and if that data is from model components (season or habitat) which are less robust, it will be less reliable again.

A very good example of the real possibility of producing incorrect interpretations from limited AusRivAS data, or indeed any data, is shown by recent experiences in the Lower Balonne, a tributary of the Darling. Based on AusRivAS data available at the time, the Technical Advisory Panel to the Condamine Balonne WAMP (the TAP), classified some river sections as severely degraded. In the Snapshot they are shown in Figure 2.1 as the largest area of severely impaired biota on the map of the Murray Darling Basin. The data also affected the scores in Table 2 of the Snapshot. More recent data, both AusRivAS and otherwise, shows the area to be primarily in near-reference condition. This correction only came about after stakeholders refused to accept the interpretation of the expert scientists and commissioned their own data collection program. That data, and later data collected by Qld DNRM using AusRivAS protocols, was reviewed by Dr Richard Marchant as part of the Cullen review into the science underpinning the assessment of the Lower Balonne (Cullen *et al* 2003) and it was concluded "*the fauna at the majority of sites was indistinguishable from that expected at undisturbed (or reference) sites*". The original expert panel not only concluded that the fauna was severely degraded, they also concluded that the condition became worse downstream and further still, that it was as a result of water resource development. Dr Marchant independently rejected each conclusion. In other words the expert panel had got it as far wrong as it was possible to get it. Dr Marchant stated;

"*It is unfortunate that the Technical Advisory Panel made these preliminary conclusions with such limited data available to them in 1999*."

"*It also reinforces the need to base management decisions on more than one data set that is all that appeared to be available to the TAP preparing the June 2000 Draft WAMP*."

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"*NRM is advised to be more strategic in its collection of ecological data so that necessary information is available when needed for water resource planning*".

"*A more recent study is the Snapshot of River Condition in the MDB (Norris et al 2001). This assessment was done from the First National Assessment of River Health and used the macroinvertebrate data from Queensland which was used by the TAP, and has not been supported by subsequent studies. This means that the biological condition for the Culgoa in Table 2 is not correct in the light of more recent information*".

It would be hoped that no other reaches in the basin have the same problem, but then the question must be asked. The result certainly justifies the caveat under Figure 2.1 of the Snapshot, "*Data used are assumed to be correct as received from the data suppliers*".

With respect to the River Murray assessment the Snapshot notes "*Macroinvertebrate and fish condition in hydrological zones is generally poor below dams, showing some recovery downstream. This recovery is not reflected in the condition assessment, as an impacted zone is scored as impacted (precautionary approach)*". The precautionary principle should only be invoked once, and that should be when decision-makers come to weigh up the various components of their decision. It should certainly not be invoked every time a choice made in the process to produce each piece of data that goes into the decision matrix, as is currently the case. This effectively creates a very significant buffer prior to the ultimate decisions being made.

3.2.2 The naming of condition categories

In the specific River Murray assessment within the Snapshot, the fish condition scores are actually based on presumed associations between a form of impact and condition, rather than directly on condition; "*These descriptions of impact were turned into categories of condition as described below:*

1. *Good* — *not impacted*
2. *Poor* — *Affected by one major impact*
3. *Very poor* — *Affected by two major impact*
4. *Extremely poor* — *Affected by three or more major impacts*.

This approach describes an environmental feature, not a biotic index.

The naming of the categories within the Biota Index is also interesting. They are Reference, Significantly Impaired, Severely Impaired and Extremely Impaired. While these accord with the band names for AusRivAS outputs put forward by Environment Australia, they are not uniformly used. For example the Scope of the Sustainable Rivers Audit (Cullen *et al* 2000) uses the terms Reference, Below Reference, Well Below Reference and Impoverished. Each State also uses different terms, for example Queensland uses Good (Reference), Fair, Poor and Very Poor. The SIGNAL index, which is based on the same sample data which produces AusRivAS scores, uses categories of Excellent, Good, Fair, Poor and Very Poor.

The four categories in the ARC Environment Index are Largely Unmodified, Moderately Modified, Substantially Modified and Severely Modified. Similarly the presentation of the primary factors determining condition (section 2.1.8 of the Snapshot) uses Non-issue, Minor issue, Medium issue and Major issue. The adjectival descriptors for the Biota Index categories are thus more severe, particularly because the first category below undoubted acceptability is “significantly impaired”. When the results are used in media releases and comments by others on the system, the perception by stakeholders and the community of the term “Significantly Impaired”, is very different to the perception of the term “Fair”, “Minor issue” or even “Moderately modified”.

The same problem arises in the Snapshot assessment of the Murray. For example the States use categories of Good, Fair and Poor to describe nutrient concentrations and in-stream salinity but the Snapshot changed them to Good, Poor and Very Poor. Similarly the bank condition category names represent impact levels which may not be immediately obvious to many readers: Good = largely intact; Poor = minor modification; Very Poor = moderate change; Extremely Poor = moderate to major modification. The riparian vegetation condition categories, based on the percentage of red gum woodland in a zone which is degraded, are: Good < 5%; Poor 5-9%; Very Poor 9-14% and Extremely Poor >14%. In other words a zone can have 85% of its red gum woodland in perfect condition and it is scored as Extremely Poor. I doubt the common man would think the category titles equated well with the level of impact.

Why isn’t the Good category ever termed Excellent, even when it is meant to represent near-pristine or pre-European conditions? The ISC used in Victoria actually has categories of Excellent, Good, Marginal, Poor and Very Poor with the Poor category commencing at 50% of the possible maximum score.

3.2.3 Land use impact weightings

The land use component of the catchment disturbance index used weightings intended to reflect the different impacts on the aquatic biota from different land use categories. For the ARC, intensive and irrigated agriculture received the highest weighting of 0.7 while grazing received the lowest weighting (0.33) other than the Conservation category. Dryland cropping was weighted at 0.48. The Condamine Balonne Water Committee recently developed a catchment Water Quality Management Plan (CBWC 2001) using the Catchment Management Decision Support System developed by CSIRO. This also weighted land use categories according to their presumed level of impact. The authors of the report noted that the weighting for cotton (irrigated agriculture) did not reflect that most cotton in the region was grown entirely within bunded fields and all irrigation water was recycled on-farm, meaning there was no runoff from the farmed area to nearby waterways. Dryland cropping areas could contribute far more nutrient and sediment per hectare because they were not bunded, hence storm events could result in significant runoff reaching waterways. The report found by far the largest source of nutrient and sediment to the rivers was from grazing country. The heavy weighting in the ARC for any irrigated crop or area from which runoff is controlled is undoubtedly inappropriate.

Expert regional panels were assembled and used as a sanity check on ARC outputs and in the first four basins listed in Appendix 2 of the ARC it is noted that the expert panel felt water quality in the basins was near pristine whereas the ARC scored them very lowly. The error was believed to be based on inaccurate land use mapping.

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3.2.4 Geomorphic and Sediment related indices

The following text provides a discussion of the techniques and data used for the geomorphic and sediment-related indices of the "Snapshot" assessment. Particularly, it focuses on the bedload budget (incorporated into the Habitat Index) and the suspended sediment budget, incorporated into the Nutrient and Suspended Sediment Index. Both of these are part of the ARC_E (the overall environmental index) and are derived from the SedNet sediment budget model as used in the ARC.

At the outset it should be said that SedNet is a valuable tool for comparing broad-brush changes in geomorphic processes at a catchment scale. This is useful for identifying likely "hotspots" within a catchment such as the location of sediment slugs – a key purpose for which it is used. The model can be run for "pre-European" conditions and for current conditions, whereby the cumulative effects of changes since European settlement are averaged. The model uses a rainfall runoff model coupled with basic physical relations (such as the Universal Soil Loss Equation) applied at a fine resolution to catchment wide datasets. In practical terms, the model can be used to identify and prioritise likely problem areas, which can then be investigated further by on-the-ground inspections. Although a detailed assessment of the model is beyond the scope of this review, the following comments are provided based on experience with the use of SedNet results for river management studies. The strength of SedNet to highlight spatial differences in geomorphic processes at a catchment scale by definition, makes it less suitable for assessments of reaches at a smaller scale without follow-up field investigations. For example the bedload budget in the ARC which is used for identifying reaches subject to bed sedimentation and sand slugs is evaluated on a reach basis by comparing the bedload supply to the river's capacity to transport it. If supply is greater than capacity, then deposition occurs. However, if transport capacity exceeds sediment supply (e.g. in the reaches below weirs and dams), then no change is recorded (ie the model does not accommodate incision). Therefore, SedNet does not represent those reaches where slugs of sand may have passed through and incision is now occurring. Such a return to baselevel can occur, with Victorian examples provided in Rutherfurd (2001).

The model further assumes that a step increase in the supply of sediment to river systems occurred in 1900 and the rate of bedload supply has since remained constant. As such the steady state results do not recognise that improvements in land management in some reaches may have reduced the supply of sediment to the rivers in recent years which, in turn, would promote the erosion of historical channel deposits. Further, there is some discrepancy in the results of Thoms *et al* (2000, p26) which states that *"…the main sediment source is now the river channel rather than material supplied form the surrounding catchment surfaces"*, and SedNet output which typically reports that gully erosion as a major sediment source for MDBC Catchments (e.g. the Loddon River).

In fairness the ARC recognizes that sediment inputs are probably less now than historically and although the transient version of the bedload function can incorporate the residence time of sediment within a reach, the aim of the ARC was to:
"…*examine the <u>total</u> effect of historical erosion on the current sediment condition some 100 to 200 years since it commenced*." (underline added).
Therefore, the ARC results are only indicative of extent of bed sedimentation. The following comments are also made in the ARC:

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"…*the aim of the bedload sediment budget was to predict the extent of sand slugs derived from massive increases in supply of sand and gravel to rivers from gully erosion and accelerated bank erosion*."
[and with respect to the suspended sediment load budget]"…*This level of information is adequate for regional planning of land use change and catchment restoration and for identifying the spatial patterns of sediment sources, yield and potential impacts*."

Therefore the issue is that improvements in land management and a return to wetter climatic conditions in the future may promote a degree of bed habitat recovery that has not been incorporated in the snapshot assessment. Other assumptions used by SedNet worth noting include the following:

- With respect to the suspended sediment budget the argument that only deposition (not re-entrainment) of sediment occurs on floodplains. There is ample evidence to demonstrate that erosion or deposition upon near-river floodplain areas is heavily influenced by landuse practices, particularly near-river landuse, specifically tillage policy; and
- The model sets the proportion of total load contributing to suspended load at 50%. This proportion is known to vary considerably in reality.

Further uncertainty relates to the extent to which flow management can be used to improve the habitat and suspended sediment load indices. Assuming that Figure 9.2 of the ARC is correct, then adjustment of flow volumes and seasonality through management intervention will presumably merely re-distribute extended areas of bed sediments within the river network more rapidly towards their final destinations of reservoir impoundments, the river estuary or the floodplain. The fundamental ways to manage elevated sediment volumes within any river network are firstly to stop it getting there and secondly finding ways to get it out. Acknowledging that addressing the latter at an MDB catchment scale is virtually impossible over management timescales, then the main management options relate to reducing catchment erosion rates through improved catchment land management.

Despite the preceding discussions, SedNet remains a valuable tool for assessing the spatial variation of geomorphic processes at a catchment scale and in a relative sense. It has provided valuable preliminary data for the assessment of condition across the MDB. As previously discussed, key questions remain which relate to linking the existing outputs of SedNet, incorporated into the overall habitat index, to a meaningful condition rating without field verification.

Finally, it should be remembered that both the "Snapshot" suspended sediment index and bedload sediment assessments are entirely reliant on SedNet outputs (as opposed to field data), while the limitation of the bedload budget to include recovery through degradation means that the model represents the "total" or worst case conditions.

The Hydrological Disturbance Index is an amalgam of 4 metrics which essentially measure changes to overall flow volume and timing based on monthly, seasonal or annual flows. These 4 measures were derived from a combination of actual gauging station data, and output from the MSM-BIGMOD computer model. This model combines the MSM model (a monthly simulation model covering the geographic area from Dartmouth Dam to the South Australian Border including the Lower Darling and Menindee Lakes), and BIGMOD (a daily flow and salinity routing model for daily flood operation between Dartmouth and Yarrawonga). As BIGMOD did not incorporate some aspects of the water balance covered by MSM, it was necessary to combine the models. As BIGMOD and MSM operate on daily and monthly timesteps respectively, it is necessary to disaggregate monthly MSM results to daily values when the model is used with BIGMOD.

A review of the model is beyond the scope of this text although the techniques used for water balance, rainfall-runoff and flow routing models are well established and can be calibrated against existing data as has been the case here. However, the model uses inflow sequences rather than rainfall-runoff relations (like SedNet) and, as such, the effect of landuse change on runoff would appear not to be incorporated. For example, a proportion of the difference between "natural" and "regulated" scenarios would likely be due to changed runoff coefficients (in addition to the effect of regulation) due to, for example, the effect of farm dams, interception, "sealing" of sodic soils and the like. The relative importance of these effects is unknown, may be small but should be recognised.

Again, the link between broad-brush flow parameters and environmental condition is difficult to assess and more often than not related to threshold levels rather than flow volumes. For example, the flows that reach the overbank level, or flows that exceed the threshold for sediment transport are important for maintaining habitat. This kind of information is not normally provided by daily (or monthly) flow models and subsequent analyses would be required. Therefore, although the hydrological disturbance index is a valid broad assessment of hydrological change, further analysis would be required to establish the key flow requirements.

It should also be emphasised that a large part of the study area is either unmodified or not assessed (86% of the total river length in the basin, refer "Snapshot" p.9) with relation to the Hydrologic Disturbance Index (refer "Snapshot" Figure 2.3).

3.3 Results

3.3.1 What was assessed?

Readers should be very clear that when the report gives figures for percent of impacted rivers, it is referring to the "*percent of the river assessed*". In the case of Biota and Hydrological Disturbance the percent of river assessed is very low and does not automatically convert to a basin-wide figure. The Snapshot itself sometimes fails to clearly make the distinction, for example while the text referring to Table 2.1 is correct, the table itself is not because it refers to "*Percentage of river length in each category*". Unfortunately some key documents used to inform the public make the unwarranted extrapolation (The Living Murray – a discussion paper, July 2002; The Health of the Living Murray (FSLM002.102), February 2003). While the Snapshot states "*The ARC_B shows 38 percent of the river length assessed is impaired*", the other documents state "*vegetation and wildlife are significantly impaired along 40% of the total river length in the Basin*". It should also be clear that the ARC_B (the Biotic Index) as used in the Snapshot does not refer to either vegetation or wildlife but only to aquatic macroinvertebrates. This misrepresentation of the Snapshot in influential publicly released documents should not have occurred.

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One reason the distinction between "river length assessed" and "total river length" is important, is that what has been assessed may be biased simply because the sites which make it up were not randomly selected. For example the Hydrological Disturbance Index is based on just 14 per cent of the total river length in the basin and this length relates to the most regulated sections because they are the ones which are best gauged and modelled. The sections which are not modelled and therefore not included, are likely to be the less regulated and less hydrologically impacted, except for those areas where unregulated extraction is significant. Figure 2.3 indicates that the 14% comprises mainly main stem rivers whereas data for tributaries, even very major ones, is almost non-existent.

Similarly if one examines Figure 2.1 Biota Condition, the data are strongly concentrated on the Victorian and Southern NSW alps, with very little information on any inland waterways. These latter areas are the ones which Dr Marchant, as part of the Cullen review into the Lower Balonne, felt would not produce strong AusRivAS models for the bed habitat and for which the ARC team could not produce satisfactory E-ball models.

3.3.2 Basin Results

The results section of the Snapshot commences by noting that reaches in the Significantly Impaired category have lost 20% of the taxa which would be expected to occur there. The term "lost" is not necessarily correct for a number of reasons: AusRivAS scores are for sites, so un-sampled sections of reaches may contain the missing taxa; within a reach there may be reference sites or sites which scored above reference levels but these were excluded from analysis; as reach scores were an average of all site scores in the reach, this does not take account of which taxa produced the scores at different sites, so again all expected taxa may actually be present. The less samples available for a reach, the less likely the conclusion would be correct in any case. As one of the River Health Objectives of Ministerial Council is to "*prevent the extinction of native species from the riverine system*", the distinction between "lost" (extinct?) and "missing" for example, is important. As the AusRivAS O/E score is simply a measure of the number of taxa observed over the number expected, taxa may be missing from the data but this is not the same thing as taxonomic loss at all.

The report suggests that a bias in the data toward upland sites and a lack of data from mid-slope or western sites may be causing a better than expected result for the basin. Similarly the lack of truly pristine reference sites may bias the result to the better end. Whether this balances the biases in the opposite direction is unknown and the former does not operate at reach level.

The indexes which comprise the ARC_E (Environmental Condition) show (Table 2.1) the least modified attribute is hydrology while the most highly modified are nutrient and suspended sediment load and catchment disturbance. The report notes "*Disturbance to the catchment and changes to nutrient and suspended sediment loads are the greatest contributors to this change in (environmental) condition*". The report also notes with respect to an arc of substantially modified reaches down the eastern side of the basin, "*These changes are largely the result of poor habitat, nutrient and suspended sediment load conditions*".

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Increases in nutrient and suspended sediment loads are widespread across the basin and are noted as a result of catchment and river network disturbances. The loads are generated in the upper catchment but the effect is felt most in the lowland sections, particularly weir pools and reservoirs. With respect to the level of increase in total phosphorus loads in the Murray Darling and other rivers, the ARC states; "*it is likely that there have been substantial ecological changes as a result*". The ARC related these changes to grazing and tillage of cropped land.

With respect to hydrological disturbance the report notes that only 20% of the basin is regulated and only 14% could be assessed. The most severe modifications occur along relatively short sections immediately downstream of dams on upland streams. Those rivers with substantial modification related to an irrigation regime were the Murrumbidgee, Wimmera/Avon, Loddon and Darling. Impacts in unregulated rivers could not be assessed. The River Murray showed a moderate score in this category.

The Snapshot concluded; "*Catchment disturbances that have the potential to affect river condition, are widespread across the Murray-Darling basin*". Some of the most substantially modified reaches are in Victorian tributaries of the Murray so it is unfortunate that they were excluded from consideration in the Living Murray process.

Habitat condition showed extensive modification across the basin, primarily related to impacts to the riparian zone and increased sand and gravel bedload. The report noted that accelerated bank and gully erosion in upstream reaches was the primary cause of deposition in mid-slope reaches. Changes to the flow regime were noted as a secondary driver of bed sedimentation. "*Bed sediment condition is predicted to be poorer in the Murray-Darling Basin than any other region in Australia*". Connectivity issues were important in about 15% of the assessed stream reaches.

These basin scale conclusions would suggest management emphasis on land management issues in the upper catchment and mid-slopes would provide the greatest benefits to aquatic ecology. From a national perspective the ARC concluded; "*Reaches with the most serious sets of issues are located in parts of the Murray-Darling basin, the West Australian wheat belt, western Victoria and the South Australian wheat-growing areas. Reaches in these areas are generally affected by highly modified catchments, are subject to high nutrient and suspended sediment loads, have lost much of their riparian vegetation and the movement of biota and material in the river is affected by dams and levees. Should a strategy of rehabilitation be adopted then these reaches represent those in most urgent need of management and rehabilitation*". Clearly, volumetric adjustments to water extraction were <u>not</u> identified as a priority in the most severely impacted reaches.

The scores for individual valleys within the Basin are presented in Table 2.2. There are 23 river valleys in the basin and according to the table, the Lower Murray ranks 2nd for biotic condition, the Upper Murray 4th and the Murray Riverina 8th. The text reports that the majority of very poor reach scores are in the Lower Murray and this seems in conflict with the table. It is interesting that the Goulburn River, from which a significant volume of water is extracted and it appears to be as hydrologically disturbed, if not more, than the Murray according to Figure 2.3, and which shows substantially poorer environmental condition according to the ARC_E results in Table 2.2, shows substantially better results for the ARC_B.

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The report states "*the Paroo and many of the Victorian streams were in better condition than most of the other river valleys in the Basin".* The latter includes the Ovens, Upper Murray, Campaspe, Loddon and Goulburn, with the poorest of these showing 78% of assessed reaches in Reference condition. This is important for management because the lower ends of the tributaries may provide similar habitat to the main stem and be used by the same suite of species. Tributaries can serve as refuges for the main stem and can provide colonists. They can be the source of clean water, sediment and organic matter. Impacts on the main stem can however affect the tributaries, even though they are upstream. For example the physical barriers in the main stem can impact upon fish populations in the tributaries.

The better scores for the southern tributaries may be an artefact of the AusRivAS modelling because inland sites, particularly in the bed habitat, often have low natural species counts so that only a small variation in the capture efficiency or even natural variation can lead to relatively large changes in the O/E ratio. This was noted by Dr Marchant in the review of the Lower Balonne (Cullen *et al* 2003).

While some rivers in Table 2.2 show good relationships between their scores for ARC_B and ARC_E, there are a number of anomalies. The Murray main stem for instance ranks 5^{th} for ARC_E but last for ARC_B. The Loddon ranks 22^{nd} for ARC_E and 6^{th} for ARC_B. The Campaspe ranked 21^{st} for ARC_E and 5^{th} for ARC_B. The ARC_E for the basin generally shows a poorer result than the ARC_B. This may indicate a lag effect in that the biota has not yet responded to the environmental changes or it may mean the changes are of a type or degree which is within the range of tolerances of the fauna used in the biota index, in which case the two indices would not be expected to align. Given the time since impacts occurred and the fauna used in the Biota Index, the latter is more likely. This calls into question the merit of the indices in comparisons because, as we have not established quantitative relationships between ARC_E and ARC_B components, the result discussed here is equally likely to simply be an indication of inappropriate relative scoring of the indices.

In Section 2.18 the Snapshot addresses the primary factors determining condition. It does this firstly by not considering hydrological indices, because they were much more limited than the other indices, then by including them. The report states "*For effective management decisions it is important to know the suite of the problems, their interrelationships and their relative locations*". It is also very important to know their relative degree of impact but the scoring process cannot tell us this because the relationships between the various causes and the biotic response is largely unknown. Because relative weightings have not been assigned, the colour codes in Tables 2.3 and 2.4 are only applicable down each column, not across rows. That is, the relative importance of Riparian Measure as opposed to Hydrologic Seasonality cannot be determined. Because the relative importance could not be differentiated, the Snapshot assumed each issue has the same potential impact so a red in the Connectivity column is equally as serious as a red in the Riparian column. This is evidenced by the classification of groups according to the number of reds they have rather than by what the red refers to.

In Table 2.3 Riparian Measure and Connectivity are the indexes which recorded major issue status in the highest number of Reach Groups and while Nutrient and Suspended Load Index and Catchment Disturbance Index recorded no major issue results, they also recorded no non-issue results, meaning they effected all reach groups at intermediate levels. In Table 2.4 (including hydrological data), Catchment Disturbance was recorded as a major issue in all (6) Reach Groups and Nutrient and Suspended Load was a major issue in all but one Reach Group. Hydrologic Seasonality was recorded as a major issue in one Reach Group and was classified as a non-issue in all other groups. The different scores for the same measures in the two tables relate mainly to the different reaches which were assessed. Table 2.3 includes data from 2/3rds of the reaches in the basin whereas Table 2.4 includes only those with suitable hydrological data, being mainly the main stems of larger rivers (14% of reaches in the basin). It is not possible to say that one factor is actually more important than the other without establishment of causal quantitative relationships between that environmental factor and the biota index. Further, no weighting has been applied to the factors.

The impacts applicable to particular reaches varied considerably. Using Table 2.4 and Figure 2.8, Hydrologic Seasonality was a major issue in just one of six groups of reaches (28% of all reaches assessed) and the group included most of zones 2, 3 and 7 of the Murray (Dartmouth to Torrumbarry and Menindee to Darling junction). That group of reaches also had major issues with respect to Riparian measure, Nutrient and Suspended Sediment index and Catchment Disturbance index. Combined flow measure was also a major issue in one group of reaches (19% of all reaches assessed) and included substantial lengths of zones 5 and 6 of the Murray (Lock 11 to Wellington). This flow measure included volumetric attributes. This group of reaches was also impacted at major issue level by Nutrient and Suspended Sediment and Catchment Disturbance.

Zone 4 of the River Murray (Lock 26 to Lock 11) was mainly categorised in Group 4, being reaches having modified hydrology (combined flow measure) as well as degraded riparian vegetation and bedload condition. The Snapshot stated; "*multiple issues need to be considered in management and also highlights problems that accumulate from upper parts of the catchments into the main stem reaches*".

From a hydrological perspective the conclusions of the Snapshot mirror those of the SRP report, that is, in the mid-Murray the main problem is one of seasonality rather than volume but this reverses as one moves downstream.

Table 2.3 and Figure 2.7 show that reaches with only minor issues (other than catchment and water quality effects) included parts of the Upper Murray, the upper part of zone 3, zone 4 below the junction with the Murrumbidgee and much of zone 7. Reaches with medium issues included the lower part of zone 3, the upper part of zone 4 and much of zone 6. Reaches with one major issue (connectivity or riparian measure) included parts of the Edward Wakool system parts of Zone 4 and the Lower Murray. The Upper Murray and a small area within Zone 2 were classified as having two major issues - poor connectivity and riparian vegetation. The Snapshot concluded; "*attention to longitudinal connectivity (e.g. fish ladders) and riparian planting would be likely to have marked benefits*".

The conclusion from these assessments is "*The principle issues are land use effects, damaged riparian vegetation, poor water quality and bedload condition, and modified hydrological condition*". In Section 3, Implications for river management, the priority

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action areas are emphasised again "*Changes to bedload in the mid-slopes, water quality in the upper basin, and loss of riparian vegetation have each been highlighted in this report as major issues in need of attention, together with catchment and hydrological disturbance*".

3.3.3 River Murray results

Section 2.2 is more narrowly focussed on the River Murray main stem from Dartmouth to Wellington. The assessment uses ARC data for most assessment categories supplemented by actual trend data from AWT (1999) summaries of water quality and macroinvertebrate indicators. No more detailed analysis of the outputs of the ARC assessments or of the base data was apparently attempted, and certainly no more detailed maps showing conditions are presented. For example a breakdown of the index results by reach, such as in Table 2.1 for the Basin, is not attempted. Other than ARC data, the Snapshot relies heavily on the expert panel report of Thoms *et al* (2000) and the purpose of that report was "*to identify short term actions which would improve the environmental flow conditions of the river Murray*." As such, conclusions are almost obliged to be flow orientated. This is disappointing because this section adds little to what was in Thoms *et al* or the basin assessment within the Snapshot.

The Summary of Condition notes; "*changes to the operation of regulatory structures in conjunction with habitat restoration, could significantly improve habitat quality and thus the riverine biota*". The section also notes:

- Fish passage
- Stabilisation of banks using riparian revegetation
- Re-connection of river-floodplain linkages, and
- Water quality issues in the lower rivers are related to upstream actions.

It should be noted that these actions are not necessarily, and in most cases definitely not, related to flow volume.

In summaries of each of the biological data sets, the strengths of the underlying data are not discussed. For example with respect to macroinvertebrates it is stated that populations are poor in all zones and severely impaired in zones 3 and 5. This is difficult to understand because the condition data is the same as used for the basin and Figure 2.1, *Biota condition in the basin*, shows no macroinvertebrate data in Zone 3, except perhaps at Yarrawonga Weir, and none appear to be coloured red. There are very limited data in Zone 5 though that at the lower end shows as extremely impaired. There is also no ARC_B data in the lower half of Zone 4. The problem may simply be the scale of the maps presented but it is unfortunate that Figures 2.9 to 2.13 do not incorporate sampling site locations if they existed and the actual data if the data is sparse. The maps would also have been more use to stakeholders if the reference sites or sites which scored above reference were incorporated, including any on tributaries (there may of course be none, but this should have been stated for sake of completeness). While the NSW EPA web site does not show Reference sites or sites with above reference scores, Map 5.1 does show individual site ratings based on AusRivAS scores. This shows the test sites in the headwaters to be in generally Good (Reference) or Fair condition. There are 15 sites shown on the main stem below the headwaters and 2 are in Good condition, 5 Fair, 8 are Poor and none are in the Very Poor category. In the Edward – Wakool system there are 16 sites shown of which 7 are Good, 7 are Fair and 2 are Poor.

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To emphasise the importance of considering tributaries, the web site of the Victorian EPA provides AusRivAS data reports for the Campaspe, Loddon and Avoca rivers. Table 3 of the report shows 46 sampling sites. Of these, 7 are Reference sites, one is in Above Reference Condition, 16 are in Reference (Good) condition, 14 are Below Reference (Fair) and 4 are Well Below Reference (Poor). Interestingly the report went so far as to investigate the causes of the poorer scores and recommended remedial measures related to revegetation of riparian zones, restriction of stock access to watercourses and reduction of nutrient export from urban areas. With respect to flow related impacts the authors suggested the fauna directly below dams was probably impacted by sudden fluctuations in flow.

Unlike the Basin or national assessments, the biotic condition scores for the Murray in the Snapshot are usually worse than the environmental condition scores, partly because fish often score worse than macroinvertebrates and only the latter was included in ARC assessments. Also, as the alterations to this system are older than many others in Australia or the Basin, most biotic impacts would be expected to be fully evident by now so a lag effect is probably no longer relevant, except perhaps for long-lived trees.

The zone assessments allow a closer examination of possible cause and effect. The condition ratings for each feature in each zone are tabulated below along with any cause put forward in the text of the Snapshot. Causes put forward in italics are suggested by this review as none were specified in the Snapshot. Those interpretations are not quantitative and are based largely on the SRP report. In discussing its outputs the Snapshot states that variation in assessments by different reports may result from a different break up of zones or the use of different databases. As an example the Snapshot ranks the fish community as very poor in zone 3 but the SRP notes the section between Lake Mulwala and the Barmah choke as containing "*excellent native fish populations*" and the section from Tocumwal to Torrumbarry, while being dominated by carp "*there are significant populations of native species*". The protocol for scoring fish condition in the Snapshot actually scored the assumed significance of a number of impacts (nearby dams or weirs, lack of snags, presence of introduced species), not actual fish catch data.

Biotic or environmental feature	**Condition**	**Primary causes**
Zone 1. Dartmouth to Hume		
Macroinvertebrates	Poor - improving	Cold water release
Fish	Ext. poor	Physical blockage, cold water release
Riparian vegetation	Very poor	Heavy grazing, weeds
Hydrological condition	Poor	Decreased flood frequency and duration, constant summer high flows
Nutrient and sediment loads	Good	Catchment in good condition
Riverine habitat	Very poor	De-snagging, armouring, grazing, erosion, loss of pools
Bank condition	Very poor	Erosion, grazing, *water levels*
Catchment impacts	Poor	*Erosion*
Zone 2. Hume to Yarrawonga		
Macroinvertebrates	Poor	Cold and unseasonal releases, de-snagging, reduced flooding

Fish	Very poor	Physical blockage, cold water release
Riparian vegetation	Good - poor	Grazing and clearing
Hydrological condition	Poor	Flood frequency and some seasonality
Wetland inundation	Very poor	Reduced linkages
Nutrient and sediment loads	Poor	*Catchment clearing / agriculture*
Riverine habitat	Poor	Armouring, erosion, de-snagging
Bank condition	Poor	Erosion, *grazing, water levels*
Catchment impacts	Poor	*Erosion*
Zone 3.Yarrawonga to Torrumbarry		
Macroinvertebrates	Extremely poor - improving	Unseasonal high flows, loss of habitat via erosion
Fish	Very poor	Unseasonal flooding, loss of snags, flow regime alteration, blockages
Riparian vegetation	Poor	*Clearing, grazing*
Hydrological condition	Poor	Seasonality of flooding, increased frequency of low floods and decreased duration of floods
Wetland inundation	Very poor	Unseasonal high flows, sedimentation, levees
Riverine habitat	Poor	Erosion, flooding of habitat
Bank condition	Very poor	Erosion
Catchment impacts	Poor	*Erosion*
Zone 4. Torrumbarry to lock 11		
Macroinvertebrates	Poor – better downstream	Sedimentation and lack of habitat below Torrumbarry weir
Fish	Very poor – better downstream	Snags, blockages, habitat loss
Riparian vegetation	Good	Some floodplain overgrazing
Hydrological condition	Poor	Reduced flood frequency and duration
Wetland inundation	Very poor – floodplain good	Ephemeral wetlands permanently inundated by weir pools
Nutrient and sediment loads	Poor	*Catchment effects*
Riverine habitat	Poor	Sedimentation, reduced connectivity
Bank condition	Poor	Erosion – constant river heights
Catchment impacts	Poor	*Erosion*
Zone 5 & 6.Lock 11 to Wellington		
Macroinvertebrates	Poor - Very poor	Constant high water levels (billabongs rather than river). Darling turbidity
Fish	Extremely poor	Physical barriers, sedimentation, de-snagging, altered floodplain wetting
Riparian vegetation	Extremely poor	Heavy grazing, reducing flooding, rising saline groundwater
Hydrological condition	Poor	Reduced flooding frequency, duration. Levees. Prolonged low flow.
Wetland inundation	Very poor	Permanent inundation of weir pools, reduced linkages, grazing, removal of woody debris
Nutrient and sediment loads	Poor-very poor	*Catchment effects*
Riverine habitat	Poor	Flooded or eroded habitat, sedimentation
Bank condition	Very poor	Exacerbated by prolonged wetting in weir pools and water level fluctuation

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Catchment impacts	Poor	*Upstream and local*
Zone 7. Menindee to Darling Junction		
Macroinvertebrates	Poor - improving	*Loss of riverine habitat*
Fish	Poor - good	Blockages
Riparian vegetation	Poor	Clearing and grazing
Hydrological condition	Poor	Reduced flood frequency, duration, altered seasonality
Wetland inundation	Very poor	Flood reduction, grazing
Nutrient and sediment loads	Very poor	*Catchment effects*
Riverine habitat	Poor	Constant flow, permanent inundation
Bank condition	Poor	Erosion
Catchment impacts	Poor	*Upstream and local*

It is clear that the major flow-related threats in Zones 1 and 2 actually relate to increased flows (unseasonal and constant high flows). The major threats are cold water releases from Dartmouth Dam and habitat loss associated with de-snagging, riparian zone damage, loss of pools and armouring (related to constant high flows). These are also the major threats in Zone 3 though the potential for impacts associated with reduced flooding increases in this zone.

In these and all other zones, the impacts associated with the presence of the weirs themselves (permanent inundation of riverine habitat and associated wetlands, physical blockage effect on fish and sediment plus erosion and armouring associated with releases) are major threats to condition. These impacts are related to how water is transported and stored rather than to the volume extracted.

Clearing and grazing, particularly of the riparian zone, constitute major threats in most zones, as do catchment related influences on water quality and sedimentation. This is supported by the conclusion of Young *et al* (2001) who stated; "*The most significant and widespread historical change to either the flow or sediment regimes of upland rivers in the basin is an increase in sediment inputs. Land clearing in the upper catchments has resulted in greater run-off and increased erosion – often as gully incision. The introduction of rabbits and grazing animals has also increased erosion in many areas*".

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From Zone 4 down, while the common threats remain the same, including the permanent inundation of wetlands by weir pools, the impacts on the flow regime, particularly flood frequency and duration, increase, as do impacts related to salinity. The Snapshot notes that the weir pools exacerbate upstream catchment related issues by increasing sedimentation.

Despite any methodological considerations and caveats regarding errors in the estimation of condition, it is the conclusion of this review that it is highly unlikely that the main stem as discussed could be regarded as in an ecologically sustainable condition as a whole. Parts of the system are in better shape than others and parts of the tributaries and floodplain are certainly in quite reasonable condition, though they were not specifically assessed here. Condition tends to be worse downstream of Lock 11 and in the zone between Dartmouth and Hume dams. The causes of degradation vary along the system and water resource management issues (not solely flow) are undoubtedly one significant cause.

The Snapshot notes that changes to the flow regime "*will be exacerbated by erosion, riparian clearing and stored nutrients and bedload*". Erosion and subsequent movement and deposition of the sediment "*destroys habitat and alters stream function*". The very existence of instream regulating structures causes significant damage to the system through blockage, habitat loss, sedimentation and erosion and when coupled with the increased nutrient content derived from upstream, sets the scene for algal blooms. Loss of natural variation in flows and changes to seasonality are key threats associated with the flow regime.

The Snapshot recommends disconnecting land use effects from the riverine environment through implementation of on farm best practice and riparian management. The MIL review also suggests that greater disconnection of water transfer and storage effects from the in-river environment, by greater use of off-river mechanisms, would greatly assist riverine condition.

Snapshot conclusion 12 states "*This assessment has highlighted the extent and source of some problems throughout the basin, notably bedload accumulations, nutrient and suspended sediment loads and loss of riparian vegetation*". In the Murray itself, issues associated with the presence of dams and weirs, and a decreased flood regime in key areas, would be added to those highlighted causes of impact.

3.4 Implications for Management

With respect to potential options for management in the Basin, the Snapshot concludes that the priorities for rehabilitation suggested by Rutherfurd *et al* (2000) should be adopted, vis (in order from highest to lowest priority):

~~1.~~6. Protect reaches that support endangered species or communities
~~2.~~7. Protect reaches in the best general condition
~~3.~~8. Stop streams from deteriorating
~~4.~~9. Improve the condition of damaged reaches, focussing on those that are easy to fix
~~5.~~10. Rehabilitate reaches that are already extremely degraded.

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These are also relevant to the River Murray itself and can be extrapolated beyond reaches and streams to subcatchments or whole catchments. The thrust of the process is the protection of areas which are still worth protecting while not exhausting limited resources on areas which are already extremely degraded, that is, maintenance before improvement or restoration. Where do the various parts of the Murray fit into this scheme? The Snapshot clearly shows a mosaic of levels and causes of impact along the main stem and significant tributaries which form part of the Basin. The main stem is a hard working river surrounded by a very hard working catchment and in the lower end it is a very hard working river, suffering from both locally derived impacts and the cumulative impacts from upstream. The degree of impact associated with upstream causes makes protection or rehabilitation of downstream reaches difficult. From a flow perspective, corrections with respect to volume are most needed in downstream reaches but as little or no flow is generated locally, the water to do it can only come from upstream reaches.

With respect to priority 1, the Snapshot points out that we have little information to go on, but fish are probably best known. In the Murray, the Trout Cod is a well known example. Within this priority group or in group 2, I would also place areas of conservation significance. This includes Ramsar listed areas, National Parks and reserves of various types. These areas were usually protected for good reason, often represent the best examples of particular habitats or communities and also often have management plans in place or are sufficiently well known ecologically that key management actions can be identified and undertaken fairly rapidly. As areas identified under priority 1 or 2 are to be protected, this means actions under lower priorities will also be undertaken there. That is, in order to protect, you need to stop deterioration if it is occurring and you may need to improve or rehabilitate certain areas. The existing management plan for the Chowilla Floodplain is a good example of targeted management covering the spectrum of impacting attributes.

Under priority 2 the Snapshot lists the Australian Alps, Kiewa River and Ovens River as examples of reaches in the best general condition. These are tributaries of the Murray and the most critical areas to protect within them in terms of potentially affecting the health of the main stem are the reaches closest to the main stem. Other tributaries have also been noted as in a relatively healthy condition. The riparian zone in Zone 4 has been assessed as in good condition, as has the floodplain and the biotic condition of the Edward-Wakool system so this area should be afforded some protection. That protection may be also be achieved relatively cost effectively (priority 4) through adjustments to the operation of weirs to reduce the permanent inundation of ephemeral wetlands by the weir pools and to reduce their impact as physical barriers. In other words under this approach there would be little or no socio-economic cost associated with a reduction in water entitlements whereas there would be socio-economic benefits, and financial costs, associated with the engineering works needed to implement the changes.

Priority level 3 is "*stop streams from deteriorating*". The Snapshot notes the arc of reaches in the mid-slopes region from the Queensland border with New South Wales to Victoria and several hydrologic zones on the River Murray and Lower Darling as having been assessed as showing deteriorating trends. The basic concept here is that the first target should be that the current condition should be maintained rather than let get any worse. That is, maintenance should occur before rehabilitation and identifiable deterioration is targeted for cessation before stable areas, even if impacted, are targeted for rehabilitation. The only trends identified in the River Murray relate to nutrient and sediment loads (or concentrations) and salinity and the trends are not uniform within the zones. Further, the basic cause of deterioration in these parameters is not flow but land use. It could also be interpreted that streams or reaches are <u>at risk</u> of deteriorating if certain actions are not taken. While this is a longer bow to draw, it is not illogical with respect to the physical barrier effect on fish movement or the likelihood of blue green algal blooms in weir pools. Again these risks can largely be managed without recourse to reductions in allocations to water users.

The Snapshot notes riparian zone rehabilitation and the impacts of dams on a small number of reaches in upland areas as areas in which the condition of damaged reaches can be improved (Priority level 4). The riparian vegetation in the Murray is scored as extremely impacted in Zones 5 and 6 and some of the noted causes can be relatively easily addressed, such as overgrazing and clearing, while others such as flood frequency and saline groundwater either need detailed investigation to confirm the root cause or will require active manipulation such as adjustment of levees or regulators to ensure any actions such as fencing and replanting are not wasted. In several other zones similar impacts, other than salinity, are noted and can largely be overcome by well established approaches such as fencing, offstream watering and replanting. Riparian zone maintenance and repair is a key means of separating land use impacts from the river. A key feature of this priority level, though it is also relevant to others, is that the focus is on reaches and impacts that are easiest to fix. Easy to fix is a relative term and the environmental benefit gained should be weighed against any socio-economic cost incurred.

The lowest priority category is rehabilitation of extremely degraded reaches. The comments in the Snapshot suggest this is generally not worth the expense and management is better stopping at priority level 3, that is, preventing further degradation. According to the Snapshot one would have to wonder if parts of the lower Murray fell into this category. The SRP applied this philosophical question to the Great Anabranch and decided it was worth rehabilitating by removal of the structures but the same conclusion was not reached, or perhaps not specifically addressed, with respect to the Lower Murray.

The concluding remarks of the Snapshot suggest a more targeted, and likely beneficial, approach to management than can be conducted at the river or basin scale; "*Management responses at the local level should be based on more detailed local information. Local assessment should focus on identifying the assets that require protection and problems that are amenable to restoration. Restoration assessments need to identify the critical ecological drivers of degradation and identify where management can significantly modify those driving forces.*" The prioritisation process outlined above can be conducted at larger scales, but only once the local information noted here has been generated. Trade-offs between areas to be protected, and between areas or stakeholders who need to provide the means to protect them, then become possible.

3.5 Summary

1. At the basin level the Snapshot is based on the ARC, which was a major undertaking but was significantly limited in its ability to describe specific reach conditions because of a lack of suitable local scale data.
2. There is only one input to the biotic index – AusRivAS data, and the form and extent of this data has significant limitations.
3. The number of data points making up the biotic index scores is not specifically noted for any reach and a low number of data points is a strong limitation on our ability to confidently infer condition.
4. The links between the environmental features examined and the biotic index is at best correlative, that is, there are no quantitative cause and effect relationships.
5. Several features of the way the biotic base data or models were used direct the results toward poorer condition scores.

6. For the Murray, the majority of additional information is from an earlier expert panel report, except for some trend data on water quality and macroinvertebrates. The earlier report did not quantify condition, or causes of condition, in a relative or consistent manner.
7. The key causes of impacts to river health in the basin which need to be addressed are:

- Nutrient and suspended sediment generation in the upper catchments
- Nutrient and sediment stores in the mid-slopes
- Damage to riparian zones in many areas through clearing and grazing
- The physical barrier effect of dams and weirs
- Loss of habitat associated with dams and weirs (consistent water levels), removal of snags and through conversion of floodplain to primarily agricultural areas
- The connectivity of the river to the floodplain, based on physical (levees) and hydrological attributes (water levels)
- Hydrological attributes.

In the Murray, thermal impacts can be added to the list.

8. The Snapshot clearly recognises that non-flow related attributes can be significant factors affecting river condition and addressing them can provide significant benefits.

~~8.~~9. The Snapshot, while not recommending reductions in the volume of water extracted, does note that aspects of water resource development, including flow attributes, can be significant forms of impact in parts of the system.

~~9.~~10. A major outcome from the Snapshot is recognition of the poor quality of environmental data upon which any management decisions can be made.

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4 Independent Report of the Expert Reference Panel on Environmental flows and Water Quality. Requirements for the River Murray System. (Jones *et al* February 2002)

This is probably the most influential but least scientific report with respect to environmental flows in the River Murray. It is influential because it was submitted to the highest decision-making body, Ministerial Council, prior to being reviewed by either the public or peers. It is the one which relies most on expert opinion and hydrological models, models which do not cover the floodplain *per se*. It is apparently the only report to set volumetric flow targets supposedly to sustain a healthy river but it does so on the flimsiest of bases. It is essential that anyone basing decisions upon it fully understand its strengths and weaknesses, the validity of any assumptions made and the certainty of any conclusions drawn. With regard to such points, the more significant issues which need to be discussed relate to:

1. The use of a system-level approach to assessment.
2. The definition of a "healthy working river" and derivation of outcomes to achieve it.
3. The restriction of the report to only flow related impacts.
4. The basis of the 2/3 natural threshold.
5. The scoring process by which risk categories were assigned.
6. The relevance of some of the chosen indicators.

4.1 System-level approach

The ERP reported that they used a "system-level approach", meaning the score for any option was the amalgamation of the scores for the five hydrological zones within the river or the five Ramsar sites used for scoring purposes. The scores were amalgamated firstly for zones within each statistic, then across statistics in order to give the summary score for each option. Section 3.1 states "*In arriving at its final system level assessment for each Flow Option Package (section 4), the ERP considered the EFR's and indicators outlined in Table 3 in five managed hydrological zones* – " (underline added). These zones were all in the main stem of the river (except the Lower Darling). The fact that only part of the main stem of the river was assessed, and the catchment above Dartmouth Dam as well as all other tributaries were excluded, means that an emphasis, appropriate or not, was immediately imposed on the importance of flow in the main stem. This is not a system-level approach either with respect to geography or the range of impacts affecting the system.

The sum of the length of the tributaries is far greater than the length of the main stem and tributaries offer a diversity of habitat which is far greater than that offered in the main stem alone. The lower sections of the larger tributaries often offer very similar habitats to the main stem but in some cases are less hydrologically disturbed. The tributaries can serve as refuges from main stem impacts and a source of colonists for downstream reaches, including in the main stem. The Upper Murray, Kiewa, Ovens and even Goulburn catchments showed some of the best results in the Snapshot for both environment and biota indexes so if the "system" really was assessed, it would probably appear to be in better condition, and therefore in less drastic need of repair, than is suggested by the part of the system which was selected for presentation. It is understood that the main stem is the part for which the MDBC has legislated responsibility hence the ERP was restricted by its client but this restriction is ecological nonsense.

In a true system-level approach, consideration of trade-offs between tributaries and main stem would be contemplated, as would trade-offs with respect to which impact might be addressed, particularly if the recommendations of Rutherfurd (2000) or the Snapshot were followed with respect to setting priorities for maintenance or restoration. As it has currently been assessed, the only geographic trade-off options are between sections of the main stem and the only impact trade-off options are with respect to flow volumes. These are only a small proportion of the potentially beneficial management options available in the system.

With respect to the assessed scenarios, there is no inclusion of habitat influences, noted by both the Snapshot and the SRP as a key component of river management. Similarly there is no inclusion of catchment issues, either by way of land clearing and land use issues or via influences on water quality and sediment movement, both identified by the Snapshot as of very high importance to river management. Other than for one indicator (salinity) only volumetric aspects of flow are quantitatively assessed.

What the report actually assesses is a very limited number of flow attributes in a restricted part of the system. It is acknowledged that this was a limitation of the Terms of Reference rather than a choice by members of the ERP.

Using a system-level approach does not allow an assessment of what can specifically be achieved with the various volumes which have been put forward as reference points. There is a strong basis for believing that non-flow related constraints on the ecological well being of the system will dictate that any return of water can only achieve so much, or in some cases, nothing at all. Similarly, overcoming other causes of impact on parts of the system may, in fact will in some cases, be more beneficial than actions which target flow.

The declaration by Ministerial Council that the locks and barrages will not be removed and summer irrigation flow will remain a feature of the river between Hume Dam and Yarrawonga (p20-21 Living Murray discussion paper July 2002) is a prime example of the above. Given that these very substantial impacts will remain, the need to identify key remaining ecological attributes or sites and link specific actions to specific outcomes at those locations becomes paramount. The ERP in fact did this by using Getspells analysis at 5 specific Ramsar sites – this is distinctly not a system-level analysis, but it is more in line with some of the Ministerial Council objectives as presented in Table 1 of the report (Objectives 1,2 5 and 7) and is fully supported by this reviewer as a more practical and meaningful approach to assessment (if the topographic and hydrological data behind the assessment is sound).

Both the SRP report and the Snapshot presented results and recommendations (moreso the SRP report with respect to the latter) by zones within the river, clearly identifying that management actions needed to vary depending on location along the river. Pressey had been even more specific as early as 1986 and Margules & Partners had done similarly with respect to riparian zones in 1990. Numerous studies (Gehrke *et al* 1996, Keenan *et al* 1996) have noted the importance of key areas for protection of fish species, those areas being major nursery areas or areas which harbor genetically distinct populations. The type of system-level approach adopted by the ERP actually threatens this knowledge-based planning approach.

In essence what has happened, and why the ERP report seems out of step with the rest of the process, is that the other reports and many of the on-ground actions such as those agreed to by Ministerial Council with respect to changes in the operation of weirs and locks or with respect to local area management such as Barmah Millewa or Chowilla, represent a bottom-up approach whereas the ERP report is top-down. I suggest that in a highly modified and geographically diverse system it is too late for narrowly focussed top-down management because you have to work with what you've got, not what you think you had.

Section 3.2 of the Condamine Balonne TAP report, a report referenced by the ERP, notes "*Not all rivers are the same, in fact it may be more appropriate to say no two rivers are alike, and many flow characteristics are likely to be of greater importance to the ecology of some rivers than others*." While this is correct, it could easily be extended to say sections within rivers, particularly rivers as long as the Murray, should not be expected to be alike (longitudinal profiles, gradient changes, breakout points etc) and certain flow characteristics will be of more relevance to some aspects of riverine ecology in some locations than others. A flow characteristic which is important to Murray Cod may be of no relevance to macroinvertebrates or vice versa. What this means is that the system-level approach used to score flow statistics places limitations on the local applicability of the outcome.

In Section 2.5 of the ERP report it is stated; "*The current debate over an appropriate mix of environmental and other uses for the River Murray is essentially a debate to determine how much water can be taken from the system with a tolerable reduction in ecological integrity*." This is incredibly simplistic. The volume of water extracted from the system is only one component of the "*appropriate mix*" as it is not the only factor causing a reduction in ecological integrity. Further, it cannot be assumed that throughout the system, the volume of water extracted is the key component of impact and therefore the aspect management should be concentrating on.

A real danger of the system-wide approach as presented in the ERP report is that the results will be construed as over-arching management guidelines and local actions may then be constrained to remain within or satisfy those guidelines. Such regulation may be inappropriate and hence actually be a hindrance to management outcomes.

The conclusion from the above is that system-wide uniformity in management approaches, in other than the broadest sense, is not only likely to be impossible in a practical manner, it is probably detrimental to sensible river management.

4.2 Healthy working river

The definition of a healthy working river is fundamental to the setting of targets and the assessment of risk associated with not satisfying the definition. The report uses:

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"*A healthy working river is one that is managed to provide a sustainable compromise, agreed to by the community, between the condition of the river and the level of human use*." As a concept that's fine, but the difficulty arises when one attempts to define "healthy", with respect to the condition of a river. The ERP use the definition of ecological integrity and note that they see it as synonymous with river health. Their definition of ecological integrity includes the phrase "*having the full range of elements and processes expected in the natural habitat of a region*" (underline added). This definition is essentially that of a completely natural system. Can a system be healthy when it is not completely natural? While I believe the answer is yes, it is a moot point because completely natural or pristine is an impractical system-level target so something less than natural must be accepted.

In section 2.5 the report states that the definition of a healthy working river used was "*Whilst the river must 'give up' some water for human consumptive use, this volume must be less than that which significantly risks the health and long term functioning of the river system*". While noting that pristine is not the target, the report notes the aim is to determine a "*tolerable reduction in ecological integrity*". To whom should the reduction in integrity or naturalness be tolerable? Presumedly it is the community. As the ERP, rightly, cannot define the communities level of tolerance to change from natural, their assessments start with fully natural as the target. Trade-offs with respect to "healthy" compromises commence from the ERPs end point – the ERPs end point is therefore not the end of compromise but the beginning.

In section 2.5 the report notes that the measure of health relates to the ecological objectives first articulated by the Community Reference Panel (shown in Table 1 of the report) and "*a healthy working River Murray is where the level of work allows these ecological objectives to be sustained indefinitely*". This is the third definition of river health found in section 2.5. One would think that defining health should be a simple concept but it is not.

The objectives in Table 1 are often quite specific and suggest a much greater tolerance to change than would be interpreted from the ERP's definition of integrity. For example River Health Objective 1 refers to protection and restoration of "key" habitats, that is, not all habitats and not even the full range of habitats. Similarly the environment objective relates to high value floodplain and wetlands of national and international importance – again a selection of the best remaining. The species requirement relates to prevention of extinction, indicating acceptance of changes in abundance or distribution as long as species do not go extinct.

Interestingly, the outcome the ERP generated in relation to the species extinction objective was: "*Improved diversity, abundance and distribution of native riverine biota*". This goes well beyond the community's extinction related objective and is obviously more related to the ERPs much broader definition of ecological integrity.

The ERP developed a range of ecological outcomes purportedly linked to the community and Ministerial Council objectives. As noted, the River Health Objectives relate specifically to environments, habitats, species and oddly, barriers to migration of fish species. The first three reflect the approach of the Snapshot, which used indices for catchment, habitat and biota characteristics. The SRP report also placed particular emphasis on physical habitat, primarily physical habitat diversity. If one were to take these objectives or outcomes and develop targeted actions to achieve them, on what actions would the emphasis be placed if they were not limited to only flow related actions? Using the information from the Snapshot, SRP and other reports, the species objective would be best directed at fish because they are best known in this regard so Trout Cod, Catfish, Silver Perch and perhaps Murray Cod could be targeted. The ecology of these species could then be used to target satisfaction of other objectives. The habitat objective would likely target:

- snags (because "*snags are as important to fish as trees are to birds*" (Koehn 1997);
- riparian zones (through managing the impacts of clearing, grazing, weeds, wood removal and flow - mainly <u>lowering</u> water levels to prevent drowning);
- floodplain areas and wetlands (by addressing clearing and in-filling, isolation through physical barriers such as levees and regulators, inappropriate use as waste disposal areas or salt evaporation basins and reduced flood flow), and
- reduced flood flow in specific areas.

The barrier objective might best be addressed by attention to:

- physical in-river and wetland barriers such as dams, weirs, regulators and levees (of all sorts, including roads);
- thermal barriers in the Dartmouth to Hume reach, and
- flow related barriers in some parts of the system.

While the ERP acknowledged that earlier reports noted principal ecological threats which were not all flow related, "*Complying with its terms of reference, this report deals only with flow related threats to river health*". As a result there is no discussion in the document about the relative importance of the various principal threats and thus no weighting of the range of potential actions which might be undertaken. As shown above, when all possible actions are taken into account, satisfaction of the Community or Ministerial Council Objectives is often better achieved by addressing actions other than flow. Integrated Catchment Management in the Murray-Darling Basin 2001-2010 (MDBMC June 2001) notes "*we must protect our catchments if we are to protect our water. We will therefore need to set targets for other aspects of catchment health such as nutrients in rivers, water sharing, riverine ecosystem health and terrestrial biodiversity. These targets will need to be integrated with each other, and with our social and economic aspirations, to achieve the catchment health we seek*." The specific concentration on flow in the ERP report and the Living Murray process fails to achieve the level of integration necessary to make decisions about volumetric aspects of flow.

With respect to the outcomes of the ERP report the above discussion may be moot because it does not appear that the various objectives were formally taken into account in the assessment process in any case despite the statement "*They underpin and directed the assignment of EFR's* (Environmental Flow Requirements) *and assessment of the options packages*". There was no linkage established between the ERP outcomes and any of the flow statistics used to assess options. The options were assessed solely in terms of hydrological change.

Further support for the suggestion that the target health used by the ERP is nearer to natural than envisaged by the community or Ministerial Council can be found on page 15 of the report where it is stated "*The consensus of expert opinion is that the River Murray System can no longer be considered as healthy*". The Snapshot is used as the main supporting document. The Snapshot assessed health based on a comparison with near pristine or pre-European conditions. This definition of health is therefore that of an ecologist, not a member of the public looking for a sustainable compromise or a "*tolerable reduction*". Any such reduction in the level of acceptable health would commence from the minimum level advocated by the ERP. As an example, Roberts (in Young *et al* 2001) notes that red gums show a stouter growth form in less well watered environments. If stakeholders are willing to accept a higher proportion of this growth form in exchange for greater access to water for human use then this represents a tolerable reduction in naturalness, with no loss of species.

The ERP appears to have set criteria for a naturally healthy river, rather than a healthy working river. This is appropriate as long as the distinction is clear, though it is a narrow focus when the "work" the Murray does is not solely flow related while the outcomes of the ERP, are. As stated in the report, "*It was not the role of the ERP, or scientists in general, to decide upon the compromise between the competing values of production, ecosystem services and the natural environment*". What this distinction means is that if the community is willing to accept a less academically healthy river, then the probability of attaining that level of health will be greater, for the same level of flow, than predicted by the ERP. Consequently, the need to reduce current levels of water extraction would be less severe than suggested by the report.

The objectives set by the community and Ministerial Council were developed prior to any knowledge of the potential impacts of strategies developed to achieve the outcomes so whether they now represent the communities' limit of acceptable change, or level of impact upon them, is debatable. Finding the compromise will be an iterative process. The scientists need to be able to estimate the degree and type of impact relating to various levels and types of work and the community can then decide on the acceptability or otherwise of that degree of change. As the communities environmental health objectives were determined without such knowledge, they cannot be seen as the final point of sustainable compromise but just the first round of an iterative process. The ERP report is just one input to the sum of potential consequences so is one starting point for the second iteration. Specific studies on socio-economic impacts are another input.

ICM in the MDB 2001-2010 (MDBMC 2001) notes that riverine ecosystem health targets are to be set by 2006, based on work to determine appropriate targets. How can the flows be set, using a healthy river scenario, without knowing what the ecosystem health targets are? The ICM document does note that targets will be benchmarked against current natural resource condition and trends in condition. "Current natural" is an oxymoron and the word natural can be dropped from the sentence to produce clear agreement with the Council directive to "maintain or improve" – because for that you only need to be able to measure current conditions and trends, you do not need an estimate of natural. We do know enough now to be able to reasonably estimate if river condition is getting better or worse even though we do not know (or need to know) exactly what it was like in its natural state.

In section 2.7 the ERP summarises the current condition and produces Figure 2, which shows the ERP's perception of the evolution of change from reference condition indicator scores to a state of significant impairment. It should be remembered that in the language of the Snapshot, "*significantly impaired*" actually represents the nearest category of three to the reference condition, or in the language of State agencies it is usually regarded as "fair". Similarly the Snapshot does not discuss any relationship between the categories used to measure condition and any definition of ecosystem health.

Figure 2 is not based on any quantitative data so is purely subjective. It is also meant to be representative of the entire River Murray. The future scenario based on "*do nothing more*" as presented by the ERP in this figure, shows a continued severe decline before tapering to an equilibrium point which is as much worse than the current condition as that condition is relative to the minimum healthy state. Using what data is available for the entire system (the Snapshot), it would be very difficult to support that assessment. For instance in Figures 2.9 to 2.14 of the Snapshot, some trend data is presented, though most attributes do not have enough data to show a trend. For those that do, macroinvertebrates show an improving or stable trend in six of the seven river zones assessed. In-stream salinity (EC) shows an improving trend in 5 zones and a degrading trend in two. The ratio is slightly worse for salinity loads. Nutrient and sediment loads and concentrations, which are primarily land-use issues, show degrading trends at the majority of sites, though this is based on modelled data.

The theoretical basis for a lag effect is reasonable but just how much impact is yet to occur in the Murray is very debateable. Figure 4 of the ERP report shows that most biota would react within a few years of change occurring while long lived fauna or trees may take decades. Given the length of time since major water infrastructure changes commenced (192*0s* and 3*0s*), the imposition of the cap at 1994 levels and the level of impact probably related to land use change reported in the Snapshot (2001), it is debatable whether any further significant decline in in-stream biota based on changes to flow will be evidenced. Similarly the estuary was reduced in physical size by 89% when the barrages were constructed so any further decline can only relate to the remaining 11% and that decline will have been happening since the 194*0s*. The Fish Management Strategy suggests a 90% decline in the abundance of native fish has already occurred and predicts only a further 5% decline over the next 40-50 years. The replacement of native warm water breeding fish by introduced cold water species between Dartmouth and Hume dams is almost total. None of these changes support the do-nothing curve of the ERP.

Similarly while the national assessment in the ARC and the Basin assessment in the Snapshot show that environmental condition is generally worse than biotic condition, possibly lending support to the lag effect idea, in the Murray main stem this is not true and in fact the opposite is seen, lending support to the idea that very little if any lag is left in this system. The Snapshot also rightly notes that land management practices have been and continue to improve so while a "do-nothing-more" option may mean do nothing <u>specifically related to flow</u>, other improvements will certainly occur, decreasing the risk of further degradation.

Along these lines, Rutherfurd (2000) stated with respect to river morphology, "*It would be wrong to assume that the impact of humans will continue to be the same over time. Human impacts on erosion and deposition in stream channels is certainly declining in southeast Australia, with the probable exception of grazing. Stream channelisation, including de-snagging and cutoffs, is now uncommon, fewer dams are being built, the rate of land clearing in most of Australia is declining, and the*

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discharge of mining wastes directly into streams is rare. The rate of gully erosion triggered by humans is declining. In some cases, the condition of streams is even improving, with large amounts of money being spent on riparian revegetation programmes and a general trend to restoring "river health".

The depiction of the ongoing and rapid decline also assumes that all the relatively recent effort put into Landcare, Corridors of Green, Ribbons of Blue, all the funding through NHT and various other initiatives and all the development effort put into industry best practice standards, have had and will have very limited if any beneficial impact. Even if one considers just Environmental Water Allocations, Gippel (2003) lists eleven as currently active in the River Murray system and over half of them are less than five years old – they have not even had a chance to be effective as yet. For those allocations which had been monitored, beneficial environmental effects were either demonstrated or strongly indicated so for all these environments the health was improving, not declining. Similarly the recently announced $150M for structural and operational changes has not yet begun but is (Gippel 2003) "*expected to result in:*

- *Improved floodplain health*
- *Improved fish management*
- *Improved management of the Murray mouth, Coorong and Lower Lakes*."

The "do-nothing-more" line is difficult to support and may in fact be more realistically placed near the "intermediate actions" line.

The three future points noted on the figure relate to three levels of management action, The worst – "do nothing more", apparently relates to management as it is today and I suspect it is only considering flow, while the best – "major improvements in river management" relates to "*more environmental water, improved habitat condition, improved catchment and floodplain management and better water quality*". The latter acknowledges that <u>any</u> action which reduces risk to the river and floodplain system will lessen the predicted trend (except of course if one source of impact is so significant that it swamps all other beneficial actions). The "*intermediate actions*" line, which maintains the current condition, presumedly represents a mix of actions – but what mix? Maintaining the current condition, as opposed to allowing further deterioration or aiming initially for a restoration standard, accords with the processes and targets espoused in the SRP report, the Snapshot, Rutherfurd (2000) and indeed the Ministerial Council objectives, to a large extent. The mix of actions is what is critical, not a simplistic whole-of-system volumetric target. One assumes that the Murray Catchment Blueprint (DLWC 2003) will bring significant environmental benefits once it is enacted, as will those for other parts of the basin, and they will do so by addressing issues other than just flow. In reality, there is no such thing as the do-nothing-more option.

In summary, the definition of a healthy working river as used by the ERP actually represents that of a near pristine system and the continued severe decline in ecological condition predicted based on the *do nothing* option is difficult to support. The predicted improvements from management actions are of unknown accuracy.

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4.3 The risk assessment process – 2/3 natural

In this review I will reverse the order of the ERP report and address process issues first then move into the detail of specific indicators and scoring mechanisms.

The ERP refers to their assessment of the question "*If we do x, what is the likelihood or probability of obtaining a healthy working River Murray system*?" as a risk assessment. Perhaps it could be construed as such but the term Risk Assessment has formal connotations which imply a far more stringent approach than has been implemented here. There is a national standard for environmental risk management (HB 203:2000 (Standards Australia 2000), based on the earlier AS/NZS 4360:1999). This, or earlier drafts of the standard, does not appear to have been followed in any formal sense. A formal Risk Assessment would certainly be of great benefit to this process and would include identification of all hazards associated with river health (not just flow related hazards), appraisal of the risk of occurrence of each hazard and the degree of impact should it occur (covering issues such as geographic extent, severity of impact, duration etc). A major component of risk assessments is the review and assessment of potential mitigation strategies. In the ERP assessment only one option for structural modification and several related only to flow volume increase were assessed. In a full risk assessment it would also include snag provision, riparian zone rehabilitation and protection, landscape management, pesticide reduction, floodplain levee correction, sediment and nutrient management and so on. Mitigation measures can target either or both elements of risk – that is, by reducing the risk of an event occurring or reducing the severity of impact if the event was to occur. Determination of the residual risk would allow targeting of further management actions. This would be an appropriate means of determining the "mix" of actions noted in the previous section.

The Barron River Environmental Investigations Report (DNRM 2001), Table 9.1 *Issues and Mitigation Strategies*, separates possible mitigation strategies into "flow related" and "other", then discusses which is more appropriate in particular circumstances. This is a sensible approach and one which appear absolutely necessary in the Murray before any decisions about volumes of water to be returned to the system are made. That Barron report concluded "*For some issues, the only applicable strategies, or the preferred strategies, are not flow-related*".

The major reason the current assessment uses the term "risk" is that our understanding of the relationships between aspects of flow and ecology are so poor that it would be impossible to state with any certainty what would occur in any circumstance other than one of major change. Hence the <u>risk of change</u> is an appropriate term. The Fitzroy WAMP Technical Reports (referenced by the ERP) stated "*It is important to note that the benchmarks are only useful as a guide to the estimated level of risk to which a system might be placed as a result of a particular future development scenario or flow management strategy. It would be incorrect to use the benchmark levels as an absolute measure of predicted impact for any flow statistic*." This is particularly relevant to the discussion of the two-thirds natural scenario.

In section 4.1 the ERP discusses the very core of their assessment process – the two-thirds natural guidance value. Support for using this threshold is provided by the ERP in the form of a number of references and this author has individually reviewed each, two in detail on behalf of other clients. The ERP actually provides no discussion on the other key value – half of natural.

The ERP notes that "*support for this 'guidance value'*" (2/3 natural) comes from Sheldon *et al* (Sheldon, Thoms, Berry and Puckridge, 2000) with '*further support*' from the Condamine Balonne and Fitzroy Basin WAMPs in Queensland. The ERP uses Sheldon and the Condamine WAMP as independent references but they are not. Sheldon and Thoms developed the critical response curves while they were both Technical Advisory Panel members on the Condamine Balonne WAMP. The rivers used as benchmarks were the same in both reports. This means one cannot really give "further support" to the other, as the ERP contends.

How much emphasis should be placed on this guidance value? Given that it is a hydrological rather than an ecological indicator, it is already one step removed from reality because the ERP report correctly notes that hydrological indicators are at best only surrogates for desired ecological outcomes. Logically, they are also at best only surrogates of ecological condition, hence the risk assessment thresholds are often referred to as "*guidance values*" and any volumetric adjustments recommended as a result of using them can only be regarded as first order estimates or indications. They are also only relevant if one wants to restore a degraded system to a near pristine level, as discussed above.

Sheldon *et al* and the Condamine Balonne WAMP used a series of reference curves or ecosystem response curves which attempted to describe the relationship between changes in flow and ecology. The ERP note that "*These curves were developed using an extensive biological data set*". In fact Sheldon *et al* states, "*The degree of physical and biological changes for each catchment were assessed qualitatively, employing expert judgement informed by published papers and reports*". While the ERP may be referring to the number of published papers and reports, in reality the curves were not based on correlative data but were <u>purely hypothetical</u>. To be clear, Sheldon *et al* did not relate flow regime change at a site to an observed ecological impact at that site. Sheldon *et al* acknowledged numerous limitations and possible problems with the approach in general and listed a number of means to overcome them and concluded "*We satisfied these requirements as far as the information base for each river allowed*". Unfortunately readers are given no guidance as to what this means. Did the information base allow poor or excellent satisfaction of the requirements? The manuscript is based on expert opinion rather than correlative data and as for the ERP, they are basing their expert opinion on somebody elses. Also the relationships developed by Sheldon *et al* were at best correlative, not causal. It is a basic statistical premise that it is invalid to extrapolate a correlation from one dataset to another unless causality is established. In this instance, subjective correlations for a limited set of rivers were extrapolated by the ERP to another system. It is not possible to objectively assess the validity of this action.

Sheldon *et al* used the End of System (EOS) flow as a correlate to the overall health of the river upstream, rather than a site-specific correlate. This is of dubious use. Consider for example a case where the only impact to a system is in the estuary (EOS). Does this tell you that the "system" is in trouble or just the estuary?

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Sheldon *et al* recognised that the response curves would vary depending on the hydrological (flow) statistic in question and the response (ecological attribute) and noted that "*In reality the shape of the response curve is likely to vary, depending on the flow attribute in question and the response being examined*." The authors put forward four possible variants on the shape of the curve, again purely theoretically derived, and noted that "*a number of responses might be seen in the same river depending only on the organism in question*". Logically, the assumption of the ERP that each of the statistics is equally important, and is so throughout the catchment, cannot be correct. Further, if one assumes a socio-economic weighting will be placed on sustaining certain aspects of the environment in certain locations, then identification of the more realistic localised responses noted by Sheldon *et al* would be essential. The statistics of most relevance in a rocky gorge would obviously be different from those in a floodplain section.

The Technical Advisory Panel for the Barron River WRP (DNR&M 2001), which developed a benchmarking process based upon that in the Fitzroy, noted "*There is a need for the robustness of the benchmarking levels among different stream types and different stream sizes to be assessed. Different stream types (for example intermittent, perennial, sand-bed, gravel-bed) are likely to respond differently to flow regime changes. Responses are also likely to vary for different stream sizes*."

The Fitzroy TAP stated "*The benchmarks differ between different flow statistics according to the levels at which significant to severe impacts have been observed in other basins. For example, although a 30% change might represent a level at which severe impacts have been observed for one flow statistic, another flow statistic might be linked to severe impacts at quite different levels of change, say 50%*."

It is inappropriate to apply a catch-all statistical measure of change to the system as a whole because that statistic will not be the same throughout the catchment and it will not be equally relevant throughout the catchment, particularly when social and economic aspects are taken into account in different regions. As an example, Hydrologic Seasonality was shown in the Snapshot to be a non-issue in 5 of the 6 groups of reaches in the Basin but in the River Murray it was a major issue in 3 of the 7 zones.

As an example of the lack of definition or accuracy in these curves, the Condamine Balonne TAP stated: "*The first step taken towards the development of these assessment curves was to define any known points of reference. While there is exceedingly little quantitative data available on ecological responses to changes in the selected key flow statistics, at least two points on the curve or line describing this relationship are generally known*" (the start and end!).

They also stated "*There is no precise information available regarding other points on the line*".

And further, "*Another unknown feature of the relationship …… is the shape of the line between the known points*".

The Condamine Balonne TAP report also noted "*The estimation of these critical levels was the single most difficult task undertaken by the TAP*." The report also

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noted "*it is impossible to provide accurate and objective numeric scores on river condition in terms of all the ecological functions associated with the selected key statistics*". This is not surprising because each curve in that case was a composite of the effects of the particular flow parameter on fish, macroinvertebrates, vegetation, wetlands and fluvial geomorphology. It would not be expected that each aspect of the environment would react in a like manner with respect to any particular measured statistic, that is, for any given statistic, would the way a fish reacts be the same as a frog or a platypus?

In the Condamine Balonne report, the curves of ecological scores versus flow statistics in Figures 4-4, 4-7, and 4-9 to 4-12 showed a shaded area representing "*the uncertainty in scoring this statistic*". Similarly, the error or "*range of expected response*" was depicted by Sheldon *et al* as a grey area around the curve. These confidence limits are far from realistic. An indication of what the confidence limits are really like was obtained by reference to Table 4-11 of the TAP report. If we hypothesise that the Lachlan River at Forbes has an ecological score of 5, the curves for various individual flow statistics suggest it should have a score of from 1 (the worst possible), to 10 (the best possible). In other words, the confidence limits or uncertainty band would be very, very wide and as a result, the curves would be of no benefit to management. Underlying this must be very poor correlations between the flow statistics and ecological condition.

As can be seen from the above discussion, the process used to develop the curves was purely theoretical and if they are used as the foundation for any decision, that decision would be subject to a very high risk of being erroneous.

The curves produced by Sheldon *et al* and in the Condamine Balonne referenced whatever data was available and the EFL (Environmental Flow Limit) for the Mackenzie River site in the Fitzroy WAMP used actual conditions at the site. They did not use only sites which were solely effected by water resource development, or flow change. If those curves suggested 2/3 natural as some sort of threshold (though none of the references actually make this conclusion), then the ERP has used it incorrectly by "*Assuming suitable habitat and water quality*" (Figure 3) – because no such assumption was made in the previous, supposedly supporting work. As Sheldon *et al* noted "*Not all the observed ecological impacts can be attributed to hydrological change alone; each catchment has also undergone extensive agricultural development and vegetation clearance, both of which may disturb riverine ecology*". Sheldon *et al* also stated "*it would be fair to attribute a large proportion of the observed ecological changes to changes in aspects of hydrology*." This last assumption has not been supported by the preliminary results of the Aquatic Ecosystem Monitoring Pilot Project in the Condamine Balonne, conducted by Qld NRM (unpublished), which shows very poor correlations between any individual WAMP flow statistic and any ecological indicator and also shows similar proportions of variation in the measured ecological variables being explained by either flow or land use attributes.

The assumption behind the 2/3 natural flow threshold therefore overestimates the impact related to flow because the measured impact is actually the sum of all impacts or a level of impact of flow <u>in conjunction</u> with all other forms of impact. That assumption by the ERP led to the statement; "*The full benefits of environmental flow restoration will only be realised if river water quality, floodplain lands, and river* *habitat are also restored or protected*”. In fact what the “in conjunction” scenario means is that if we decrease the severity of some of the other forms of impact then there should be room to move below 2/3 of natural and still have a naturally healthy river. The data presented by the Fitzroy TAP and discussed shortly clearly showed that what the TAP termed significant impacts on river health had not been recorded in some systems till changes in flow were much greater than advocated by the ERP.

The left half of Figure 3 in the ERP report also attempts to link ecological condition to flow attributes using the healthy/unhealthy and 2/3 natural link. Moving from healthy to unhealthy is shown as occurring when flow attributes move below 2/3 natural. This is incorrect according to the right half of Figure 3 and the logic used in the supporting text. You can achieve a healthy working river at almost any level of departure from natural but the probability of doing so is less as the level of departure increases. The probability could be increased by improving any attribute which impacts on river health, including non-flow attributes, and in fact the process used by the ERP to create diagrams such as Figure 3 could equally well be used with respect to these non-flow attributes (though I would not recommend it).

While flow is undoubtedly a key driver of riverine ecology, it is not the only driver and it does not act in isolation. In a purely natural system flow is probably the key element more often than not. In a highly modified system it is less important simply because of the range of other influences which now impact upon the river. The changes in river function associated with other aspects of water resource development or with catchment land use, such as water quality and nutrient and pollutant loads, mean that flow in its own right is a less important feature than it would be naturally. Roberts (in Young *et al* 2002) stated with respect to floodplain trees; “*Since European settlement, land management has become as important as water management for successful regeneration*.” This needs to be taken into account when setting targets for rehabilitation or protection. It should also be noted that the correlations upon which the assessment of flow impacts on ecosystems is based are unable to completely de-couple the effects of flow from other human-induced changes to the catchment. Flow alteration is also done to achieve other human outcomes, and therefore, is always associated with other activities such as agriculture or residential development. The correlative approaches commonly used are unable to quantitatively attribute the amount of ecological change observed to the different stressors.

The ERP report also asserts that the ecological assessment curves “*provide supporting evidence for significant and unacceptable negative ecological impacts at as little as 30% deviation from the natural condition*”. The 30% figure in Sheldon *et al* actually referred to data from Cooper Creek (“*a relatively major pristine endorheic system*”) and showed natural ecological responses to natural seasonal and annual variation in hydrology. Natural fluctuations cannot be referred to as unacceptable negative impacts, nor were these fluctuations related to water resource development, as one could be excused for assuming given the ERP’s previous sentence – “*These curves….indicate marked ecological response to hydrological change associated with water resource development*”. The Cooper Ck data shows significant response to natural hydrological change. What is more important about the Cooper Ck data is that it shows how flexible our native fauna is and possibly, how natural climatic variation drives biodiversity. Cooper Creek is also a highly ephemeral system, in a separate biogeographic zone, and possibly not indicative of the responses of the rivers draining into the Murray from the southern Great Dividing Range.

The curves in question here are a form of benchmarking as used in the water resource planning process in Queensland. The CRC for Freshwater Ecology (Whittington, February 2000) noted that the following criticisms had been levelled against benchmarking:

- *"The difficulty of separating flow-related changes from non-flow related changes, such as land use or pollution*
- *The differences between rivers in their hydrology and biota, which reduce the validity of benchmarks from other basins*
- *The various types of flow regulation, which are likely to have different types of impact in different river valleys*
- *Longitudinal problems, upstream reaches may behave differently from downstream reaches*
- *The impacts of alien or introduced species on river health*
- *That a benchmark does not show how close the system is, in terms of a flow statistic, or a suite of statistics, to possible threshold levels for ecological change – assuming there is a threshold rather than a gradient; and*
- *That flow-related impacts may take decades to show up, and so the benchmark system may not be at dynamic equilibrium".*

The CRC review also specifically addressed the ecological assessment curves as used in the Condamine Balonne. The review concluded; "*The review does not support the use of ecological assessment curves for the presentation of benchmarking analysis because:*

- *They are confusing and complicated to interpret*
- *Assumptions in their development are not obvious*
- *They are susceptible to misuse or misinterpretation*
- *They appear to present qualitative data and professional opinion in an overly precise and quantitative way*
- *The ecological merit score does not add value to the raw flow statistic*
- *The shading around the ecological assessment curve has no formal basis, and this should be stated clearly. It is highly probable that the uncertainty associated with such a curve would be considerably greater than +/- 5%."*

Three members of the ERP attended the workshop where the discussions regarding these assessment curves took place. It is surprising that they managed to become the very foundation of the ERP's risk assessment process.

The other key piece of supporting information used by the ERP for the 2/3 natural guideline is the environmental flow limits (EFL's) from the Fitzroy and Condamine Balonne WAMPs, as presented in Table 4 of the ERP report. The ERP has simply misinterpreted and therefore presumably misunderstood, what the benchmarking statistics constitute in both of those documents. Page 12 of the Fitzroy WAMP notes that Line 1, which equates to the EFL for each statistic, relates to just 1 site on the Mackenzie River (a tributary of the Fitzroy) near Bingegang Weir, and not "*across several Australian river systems*" as stated by the ERP. The Mackenzie River site represented a site in reasonable though somewhat degraded condition. Only if the

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ERP wanted the entire length of the Murray to look like Bingegang Weir would this figure be relevant and of course that would assume that a figure of relevance to the Fitzroy system, bordering on the tropics, was relevant in the Murray.

Also in the Fitzroy, the TAP used the range within which significant to severe impacts had been noted in other rivers as their benchmark statistics. These were represented by Lines 2 and 3 on the traffic light diagrams, as opposed to Line 1. If the ERP wanted to use "several", then they should have used lines 2 and 3, which show much greater levels of change than does line 1. Line 1 in the Fitzroy was never below line 2, that is, it was a more conservative measure in all cases, meaning it predicts less change in flow would be needed to result in a significant response. The ERP figure is different from the Fitzroy TAP figure for Line 1, though it purports to quote the document and it was again more conservative in all but one case. The reductions from natural at which significant impacts had been noted (lines 1 and 2) for each flow indicator, compared to line 1 were (ERP numbers are in brackets):

Mean – 35-70%; line 1= 26% (25)
Median – 50-60%; line 1 = 50% (50)
Floodplain – 40-60% line 1 = 30% (27)
Bankfull flows – 30-55% line 1 = 15% (14)
Mid-channel flows – 25-40% line 1 = 25% (25)
Channel maintenance flows (2yr ARI) – 50-60% line 1 = 35% (33)
Key Biological triggers (FPWFE) – no comparison EFL 70% (72)

The ERP figure is often not exactly the same as the actual EFL, possibly indicating the ERP estimated the EFL's from the coarse but colourful traffic light diagrams whereas they should have read them directly from schedule 7, where they are tabulated (FPWFE is in schedule 6).

In the Condamine Balonne the EFLs were set simply as the mid-point on theoretically derived ("*conceptually developed*") ecological assessment curves, so that point does not represent field data and is of no particular ecological relevance. The EFLs are the same across all nodes (Table 1, Schedule 4 of the WAMP), so were not averaged across seventeen nodes as the ERP suggested. I suspect again that the ERP tried to interpolate the EFL's from the Traffic Light diagrams rather than get them from the schedule and this is why the ERP tables present a narrow range for each statistic rather than a single number (meaning their interpolation wasn't accurate).

The EFLs are simply planning targets for particular catchments and it is inappropriate to transfer them to other catchments, where different planning targets would apply. In fact even in the catchments where they were developed they were not applied to all reference nodes. In the Fitzroy for example seasonal baseflows were used at all 15 reference nodes, FPWFE at 14 nodes and the remaining 7 statistics at usually just 7 nodes.

The ERP does not provide any estimate of error or certainty in their use of 2/3 or half natural thresholds despite the considerable importance of such an estimate to decision-making. The closest the report comes is a note in Appendix 4 which states "*The sensitivity of some indicators is constrained by the use of the River Murray monthly simulation model*". This is undoubtedly true and a simple case in point is the earlier recommendation by the SRP to fluctuate weir heights over 2 week increments; a monthly model would not pick this procedure up. The sensitivity would also be constrained because many of the statistics used relate to floodplain inundation and gauging or modelling of such is notoriously difficult. Prof Russell Mein, former Chief Executive of the CRC for Catchment Hydrology, noted (Cullen *et al* 2003) that acceptable standards for models such as IQQM in such areas would be; for higher peak flows (30-40% error), event volumes (15-25% error), annual volumes (10-15% error) and between scenarios for the same period of record (5-10% error). The latter does not negate the gauging errors, whereby a good gauge may give flood volumes with an accuracy of +/- 10% and at a poor gauge it is more like +/- 25%. Expert ecology panels rarely discuss errors in the hydrological models, which is unfortunate because they can certainly be significant and add considerably to decision-making risk.

The volume of water which can be returned to the system should be that which is sufficient to protect or maintain remaining important ecosystems and these can be specified locally. That is, the environment may not benefit from the volumes specified in the ERP report because at a system-wide level, very little of the original environment exists. There is no ecological benefit to be gained by flooding what is currently valuable and productive agricultural or urban land. This was one of the core assumptions in the SRP report. The relationship of management targets to pre-development or natural flow levels is meaningless in this context. A more meaningful comparator would be the natural flow regime <u>*of that proportion of functional environment which remains*</u>. This immediately and significantly reduces the volumetric targets resulting from a 2/3 natural scenario because the comparison only applies to a much smaller volume to start with. This reviewer has not come across a recent figure for the proportion of ecologically functional floodplain remaining but available data suggests it is only a fraction of the original. It should be noted that there are benefits in flooding some agricultural land but they are not ecological benefits.

In summary:

- There is very little scientific evidence to support the 2/3 natural guideline.
- There is no practical benefit in equating required flows to the natural case because the environment to which those flows related no longer exists.
- The ERP has mistakenly interpreted the supposed supporting evidence (EFLs) from the key documents referenced.
- The thresholds drawn by the ERP are conservative relative to the EFLs provided by the supporting references.
- Changes noted in systems used in supporting references are <u>inclusive</u> of all impacts, rather than <u>exclusive</u> as suggested by the ERP hence the ERP's thresholds do not take account of non-flow actions which may reduce ecological risk.

4.4 Indicators and Scoring

The two thresholds for impact, ½ natural and 2/3 natural, create three possible scoring categories: low, medium and high. These categories include 50%, 17% and 33% respectively of the entire scoring range. When one looks at the statistics in Appendix 3, in many cases there is little difference between scenarios except when the much larger volumes of water are added. This may simply be because the assessment technique used is too coarse to detect finer levels of change, meaning a reasonable size increment in flow can cause a statistic to move from low, straight through the very narrow moderate band, and into high. You would need to investigate in detail how any particular volume would be used in order to refine the assessment, leaving aside for the moment our lack of knowledge regarding flow/ecology links.

The Development of Options Report (MDBC April 2002) noted that a range of options which were thought to be beneficial could not be modelled, including; fish management, management of rain rejection flows at Yarrawonga, lowering weir pools, pipelining water to the Great Darling Anabranch and using regulators to improve connectivity between the floodplain and river. To extrapolate, any potentially beneficial action which could not be incorporated within the existing hydrological model of the system, could not be assessed as a means of improving river health. As all the outputs of the scoring process used by the ERP relate to comparisons of targets within existing hydrological models, those features of Option A listed above were not included in the scoring of this option, or indeed any other option. Why wasn't some other scoring process incorporated?

The existing model does not include a floodplain component so the ERP, to their credit, used a different model, *GetSpells*, in order to investigate the benefits to specific floodplain wetlands. *GetSpells* was used to assess 7 of the 13 statistics (not counting water quality), clearly showing the limitations of the MSM BIGMOD model. MSM BIGMOD does not model floodplain flows and even *GetSpells*, as used here, was apparently based on monthly flows at the nearest riverine weir rather than on a daily flood model specific to the site of interest. Clearly, when a large number of the statistics used by the ERP relate to overbank flows, the lack of such a floodplain model is critical.

The statistics chosen as the basis for scoring take little or no account of potential benefits obtained from non-flow or non-volumetric approaches or from location specific strategies which do not relate to Ramsar wetlands. For example Option A was specifically developed to provide environmental benefits with minimal alteration to current usage levels and is therefore largely non-volumetric. Any scoring statistic which weights an increase in volume would automatically not score significant benefits from this option. Similarly as this option was not developed as a strategy for enhancing the watering of specific Ramsar wetlands, though it could have been, it will not show any benefits when assessment statistics relate specifically to the volume of water reaching those wetlands. It is unknown if the *GetSpells* analysis, which shows that the duration of significant flood events in Ramsar wetlands has been significantly reduced, accounts for the action of regulators in extending the apparent flood duration.

Many of the chosen statistics are volumetrically based. Of the 16 statistics used, all but two would be expected to show a trend of improvement based on volume alone. When one considers the SRP decided seven flow statistics were particularly important and only two of those would show a positive response to increases in volume, the turnabout one presumes must relate to the limitations imposed by the hydrological models. The ERP noted "*Deriving ecological indicators from hydrological models will always be difficult and constrained by the model outputs*". From an ecological management perspective, the reason for the apparent decrease, by the ERP relative to the SRP, in importance of the current excess of water actually in the river at most times, as opposed to on the floodplain, requires clarification. With respect to those problems, the addition of more water at the wrong time could be more detrimental than beneficial and only detailed assessment of the actual use of any extra volume will ensure the outcome is what was intended.

The selection of statistics in general therefore predisposed the scoring to favour any option which increased the volume of water flowing in the river. As an example the salinity statistic simply relies on dilution to produce a better statistic without any consideration of alternative means of control. Dilution does not address the cause of salinity so is a band-aid on the symptom and would not be the preferred management option. As a hypothetical alternative, is lowering the weir pools in South Australia and letting saline groundwater drain into the river, as it naturally did, a generally better option than using elevated flows to flush salt out of surface areas? A constraint on such an option is the drinking water quality required by Adelaide but this is another question.

A further strategy considered very beneficial to the environment, particularly fish, and raised a number of times in preceding documents, is the fitting of multi-level offtakes to Dartmouth and potentially Hume dams as a means of addressing the cold water release problem. While raised in the ERP report it was not assessed because it could not be modelled. According to the SRP, this is the over-riding issue in this part of the river.

Alternative means of achieving the same result were not considered for any identified threat. For example when the aim is to reduce summer flows this is achieved by a reduction in the cap, which in turn simply reduces how much water irrigators draw in their peak season. As high summer flows and reduced winter flows are basically an issue of seasonality rather than volume, alternatives which considered timing of delivery should have been considered. An obvious alternative raised by the SRP is the use of offstream storages. These could be filled with relatively high flows in late winter/spring and thereby potentially achieve the same shift in seasonality of flows but without the impact on volume.

Similarly, weir drown out is the statistic chosen to address the key threat of instream barriers to fish movement. Physical removal of the barriers or addition of effective fish transfer devices (ladders, lifts etc) are mentioned as a significant component of the solution in the SRP report, the Fish Management Strategy and the NSW Fisheries Weir Removal Program but only the volumetric solution, drown-out, is used as an indicator statistic by the ERP. These other strategies are likely to be more effective and they do not rely on a significant volume of additional water. Weir drown-outs also results in downstream erosion and potential bank slumping upstream when water levels recede so this strategy is not without its down side. At the assessed location, Lock 1, the structural adjustments package lifts the percentage of natural weir drown out from the low probability (high risk) category to the moderate category and only Option E (an additional 4000GL) takes it into the high probability (low risk) category. Obviously, only if that statistic were extremely important to achieve at this site would the addition of any water beyond the structural adjustment package be considered.

The scoring process assessed the performance of 16 flow statistics against the ½ or 2/3 natural benchmark in each of five river zones or Ramsar wetlands (Table 7). The scored categories (low, moderate or high probability) for each zone or wetland were amalgamated to produce the summary system level categories for the statistic (Table 7 also). These were similarly summarised for each system level attribute or flow attribute category (Table 6). Option summaries were produced by amalgamating the attribute summaries (Table 5).

It is apparent from the figures presented in Appendix 3 that some lee-way (5%) was allowed in the scoring, presumedly to compensate for errors in the hydrological modelling. If we accept the categories as presented for each scoring zone or site in Table 7, over a third of all cases with multiple scores show summary system-level scores which appear very conservative. That is, in cases where four scores are shown and two are high and two are moderate, the summary score is moderate. There are even four cases (all MDS statistic) where more than half of the scores are the higher probability category yet the summary score is in the lower category. As there was apparently no weighting applied to any statistic or location, this discrepancy is difficult to understand. It may be an example of use of the precautionary principle.

There also appear to be inconsistencies within the system-level summaries such as Flow Distribution, Option B shows 4 low scores, 4 medium and 1 high and receives a Low – Moderate score overall yet the exact opposite scores achieved by Option D (1 low, 4 moderate and 4 high), does not receive a summary score of Moderate – High (it received Moderate). If summaries scores were applied as discussed here, the ultimate summaries in Table 5 would vary as shown in Table 4.1.

Table 4.1 Revised Summary System Scores

	Table 5	**Revised score**
Do nothing	Low	Low – Moderate
Option A	Low	Low – Moderate
Option B	Low	Moderate
Option C	Low – Moderate	Moderate – High
Option D	Moderate	Moderate – High
Option E	High	High

Considering this scoring process is the ultimate output of the report, it is essential that the process is clearly explained. The community may be willing to accept a moderate, or even low, probability in some locations but would seek a high probability in others, such as icon sites, even disregarding what they may accept as “healthy” for a moment.

4.5 Structural and Operational Requirements

The ERP report notes that; “*Further improvements in river operations beyond those described in options package 57200 may lead to better ecological outcomes for the same volumes of new environmental flows*”. In section 5 the report makes eleven recommendations noting; “*The following structural and operational requirements must be addressed to ensure that the environmental flow option package benefits described in section 4 are realised*”. The last statement is not quite appropriate because many of the recommendations are almost independent of volumetric considerations. The recommendations in Section 5 are largely not related to volume and include:

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- Permanent and seasonal removal of weirs
- Partial seasonal draw down of weirs
- Provision of fishways to weirs
- Undertake proper ecological assessment of any weir raising proposals (weir raising was included in Option A despite it not being recommended by the SRP)
- Thermal mitigation works on Dartmouth and Hume dams
- Adjust day-to-day dam and weir releases
- Adjust barrage releases
- Improve the management of rain rejection events (which results in unseasonal flooding)
- Remove unnecessary structures on the Darling Anabranch and replace with piped water
- Consider installing regulators to artificially promote natural wetting and drying regimes on important wetlands
- Audit all floodplain levees with the aim of removing those influencing flow unnecessarily.

The critical aspect of these recommendations which was not assessed is the sum of environmental benefit achieved by these recommendations alone or in some mix, that is, assuming no additional volume (essentially undertaking them in addition to Option A), and also in conjunction with each individual volumetric option. This would require an assessment technique other than using only hydrological modelling. Alternatively, the ERP report does note the ecological benefits accruing from implementation of each recommendation. They are all beneficial as discrete actions in their own right. It can therefore be assumed that if the risk assessment and probability category process conducted by the ERP was applied as suggested here, irrespective of the lack of a hydrological modelling depiction, the risk associated with each option analysed would undoubtedly be less. As many of these recommendations reflect those of the SRP it is likely they will be highly beneficial in particular zones and could lead to substantial reductions in the level of ecological risk without using volume to do it.

4.6 Summary

The conclusion from this review is that the qualitative and at times almost arbitrary nature of the ERP process leads to very risky decision-making when those decisions can lead to very significant social and economic consequences. In fact the ERP report and process actually adds very little to assist management because the approach used has little foundation, the volumes discussed are largely irrelevant to the system as it exists today, management will by necessity be focussed on smaller geographic units than assessed here (other than the Ramsar wetlands) and management must include the tributaries in order to produce a balanced and meaningful outcome. The most useful section of the report is Section 5 because it is not restricted to purely volumetric aspects of environmental flow provision.

Key conclusions from this review of the ERP report are:

- The system-level approach as used by the ERP actually only relates to a specific part of the geographic system and to one form of impact – flow. This negates the opportunity for any comparison with other forms of impact and any consideration of trade-off opportunities with respect to non-assessed components of the system.

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- The system-level approach does not allow an assessment of what can specifically be achieved with the reference volumes.
- The definition of a healthy river equates to one of naturalness or full integrity and this may not align with what the community will accept as a compromise.
- The outcomes generated by the ERP do not align well with the Ministerial Objectives developed earlier.
- A series of iterations will be required before the community could determine their willingness to accept a particular level of compromise.
- The depiction of a continued steep decline in river condition prior to levelling out, based on the "do-nothing-more" scenario, is not supported by the existing data and assumes no benefit from recent environmental initiatives.
- "Natural" is not a suitable comparator because the natural environment no longer exists and never will again on a system-level basis. Comparisons with the volume of water required to flood the natural floodplain are irrelevant because a large part of it does not exist in an ecologically functional form. This results in a significantly overestimate of the volume required to satisfy the existing floodplain.
- The "2/3 natural" guideline has no quantitative ecological support and supporting references derived the ecosystem response curves purely theoretically.
- The ERP misunderstood the Environmental Flow Limits as reported in the two key supporting references and produced extremely conservative targets as a result.
- The ERP used the same statistical targets on a system-wide basis and for all ecological attributes yet the key supporting references clearly noted the targets would vary from place to place and between environmental attributes.
- The ERP did not report any estimate of error in the guideline values but reference to the original documents shows they would be very large indeed.
- The "*unacceptable negative ecological impacts with as little as 30% deviation from the natural condition*" reported by the ERP actually referred to natural variation in a system, Cooper Ck, which is unaffected by water resource development.
- The use of the curves in a key supporting reference was not endorsed by the CRC for Freshwater Ecology when they reviewed the process.
- The assumption that other mitigating actions must be in addition to flow related actions is incorrect because the supporting documents did not separate flow impacts from non-flow impacts.
- As a result of the above, it is legitimate to trade-off non-flow actions against flow actions (to an extent) and still achieve improvements in river health.
- The structural and operational requirements listed by the ERP would produce environmental benefits in their own right and can form part of the list of non-flow options which could be used to improve river health.
- Hydrological models are not capable of estimating ecological benefits from various non-flow options.
- The ERP provides no estimate of the gauging or modelling errors involved in generation of the indicator statistics and these can be significant on the floodplain.
- The selection of indicator statistics predisposed the scoring to favour any option which increased the volume flowing in the river.
- Volumetric solutions suggested to be beneficial by this approach may not be the best solution as no alternatives were considered.
- The various levels of summary scores for the system appear to have been very conservatively constructed and led to unnecessarily low probabilities of obtaining a healthy working river.

5 Overview – Hydrological change and existing ecological condition

This section summarises aspects of the physical and hydrological changes which have taken place in the River Murray and it's floodplain over the last century. It also uses the available literature to describe the existing ecological conditions for major components of the environment. The data sourced was primarily that referenced in the core documents reviewed above. It is not a comprehensive review but highlights key findings and is suitable to support a basic understanding of the system as well as providing the basis for management options developed in the following chapter.

Margules & Partners (1990) gives a potted history of human use of the area, noting the commencement of grazing in 1838. Most riverfront land was occupied by 1850. By 1865, 350,000 sheep per year were brought along the river, monopolising the feed. In the 1870s decline of saltbush as a result of sheep grazing was noted. By 1890 there were 13.7 million sheep in the western division of NSW. Drought around the turn of the century knocked this back to a stable number of around 7.5 million.

In 1899 the devastation of the western plains of NSW by rabbits and overgrazing was noted by politicians.

Logging, largely of red gum, was very heavy in 1860s to 90s for river boat fuel, sleepers and construction. Logging then declined as use of boats declined, railways had been built and the building market became depressed. Better forest and land management then evolved such that those areas designated as State Forests are today some of the best remaining stands.

Cadwallader and Lawrence (1990) noted that the Murray was closed to fish netting in 1897 because of an observed reduction in catches.

Ogden (1997) used cladoceran fossils collected from cores to estimate historical macrophyte coverage in 7 billabongs in the upper Murray and Lower Ovens rivers. He found a sharp decline in macrophyte coverage immediately after European settlement. Tree clearing and or farming were implicated as the causal agents. Ogden pointed out that as the decline was evident in the regions most pristine billabongs, the impact of land use would be underestimated unless a historical component was incorporated in assessments.

5.1 Hydrological Changes

The following information is sourced mainly from MDBC April 2002 (Environmental Flows for the River Murray), the Water Audit Monitoring Report for 1999/2000, Crabb (1997) and the MDBMC 1995 Audit of water use. Other sources are noted as appropriate. While some of this information may not be compatible because it is based on different dates of accuracy, the order of magnitude of the changes will be obvious to all readers and that is the purpose of the section. While noting the figures readers should be cognisant of the errors involved in both gauging and modelling of flows, as noted in the review of the ERP report.

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The Murray-Darling has a very small mean annual discharge relative to its length and catchment area when compared to similar rivers in the world. For example while the Murray-Darling mean discharge is 0.4ML/sec, the Ganges is 38 and the Danube is 7. It takes less than one day for the Amazon to discharge the same amount of water as the Murray does in an average year. Most of Australia is quite dry and the Murray-Darling is no exception. Most of the water resources are in the northern part of the continent but the population and agriculture is in the south. The need to manage our water resources in drier areas was a clear driver of our forefather's decision-making processes.

Margules & Partners (1990) noted that the River Murray Commission was established in 1915 to regulate the rivers for beneficial use. The commission designed 26 weirs with locks to allow permanent navigation (though the river boat trade was dying at the time) and irrigation water supply upstream of Echuca. Lock 1 at Blanchetown in South Australia began in 1922. Locks 1-11 were built between Blanchetown and Mildura but then only lock 15 at Euston and Lock 26 at Torrumbarry. All were completed by 1935. Weirs have individual pool lengths between 29km and 88km and storage capacities between 13GL and 64GL. Other weirs, without locks, were built at Yarrawonga and on the Edward River (Steven's Weir). From the Murray mouth to the top of Lock 11 the weir pools are continuous. Pools are kept at "normal pool level" which is within the original banks except for Lake Mulwala at Yarrawonga. The five mouth barrages were built in the 1940s and caused significant impacts both downstream and upstream. Downstream, the barrages reduced the area of estuary by 89% while in upstream areas readers "*need to recognise the extensive impact of level changes a the barrages on fish, aquatic biota, irrigators and rural communities, with the critical zone extending as far as Mannum and more limited effects up to Blanchetown*" (Jensen *et al* 2000). "*The primary change for the lower River Murray, since the construction of the barrages and the dramatic reduction in flows, has been the loss of the vast estuarine system and the consequent loss of biodiversity and ecological resilience*."

Thoms *et al* (2000) noted; "*The entire lower River Murray is grossly modified by the presence of locks and weirs*." They also noted that dredging was and is common in the Lower Murray with spoil historically used to fill the floodplain. River training was also common. "*The availability of riverbank habitat has been virtually eliminated in the lower River Murray*." Reclaimed swamps and billabongs were leveed for use as irrigated pasture for dairy cows. Snag removal was a continuous exercise from the 1850s to very recent times and the authors suggest almost 5 million snags have been removed.

Hume Dam was built in stages between 1919 and 1936 then enlarged in 1961 to 3038GL. Between Hume Dam and Wellington, 52% of the length of the Murray consists of weir pools. Dartmouth Dam was built between 1972-1979 and holds 4000GL. Lake Victoria (1928) holds 680GL and Menindee lakes (1968) on the Darling River holds 1794GL. Major expansion of irrigation areas occurred in the 1950s and 60s in NSW and Victoria.

These very significant physical changes to the system bring significant ecological consequences, irrespective of the volume of water extracted as a result. The imposition of these structures immediately impacted 100% of the impoundment zones. What was a river became a lake and existing habitat was drowned. Water quality changes eventuated because of the depth and stability of the pools and included increased risks of blue-green algal blooms. The impact of Dartmouth, and to an extent Hume Dam, on water temperature is well documented. In South Australia in dry years, sea water used to infiltrate 250km upstream from the mouth whereas now it is restricted to the relatively short section downstream of the barrages.

Thoms and Walker (1992) noted trap efficiency of impoundments "*may be as high as 73% indicating a marked reduction in sediment supply downstream. For these reasons it is likely that regulation has significantly affected the morphology of the river channel*." This referred to reducing the bed slope between weirs, by eroding and armouring at the top end below the weir and depositing at the head of the next pool downstream. The sediment now being trapped is also finer than the original (as a result of slower flow, higher trapping efficiency and the coarse material being captured in upstream areas).

The structures are not only a barrier to sediment but to invertebrate drift, organic material and fish, except at times of very high flow. While being an effective barrier, these structures are often not efficient water storages because of their shallow depth. Lake Mulwala averages only 2.8m in depth, Euston Weir 2.7m and Torrumbarry 4.8m.

Levees built along the side of the river or around infrastructure add significantly to the barriers. Significant lengths of levee were built between 1870 and 1900 and many remain in place today. Numerous regulators have been constructed to manage the movement or exclusion of water from anabranch channels or wetlands. There are 28 such regulators between Tocumwal and Torrumbarry alone.

Within Australia's 12 drainage divisions the Murray-Darling ranks 5th in terms of "divertible resource" (an engineering term related solely to the volume of resource) but 1st in terms of developed resource (how much is currently diverted) – it is obviously a very hard working river with respect to water resource development in all its forms. The table below is based on 1987 figures.

Table 5.1 Development of water resources within Australia's largest drainages

Drainage division	**Divertible resource (GL)**	**Developed resource (GL and % of divertible)**
North-east coast	22,900	3,540 (15.5%)
Timor sea	22,000	1,980 (9.0%)
South-east coast	15,100	4,280 (28.3%)
Gulf of Carpentaria	13,200	78 (0.6%)
Murray-Darling	**12,400**	**10,000 (80.6%)**

The bulk of the water in the basin comes from the Great Dividing Range. The Upper Murray catchment represents 1.4% of the basin by area but contributes 17.3% of the mean annual runoff. Eighty six percent of the basin contributes virtually no runoff except during floods.

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Over 93% of the resource generated by the three major contributing sub-catchments (Upper Murray, Murrumbidgee, Goulburn) is developed. Being developed does not necessarily mean the water is used in that part of the catchment e.g. Upper Murray resource goes into Hume Dam and is used to regulate flows to the South Australian border. The least developed rivers tend to be relatively small contributors to the total flow.

Table 5.2 Development of water resources in the tributaries of the Murray

River (east to west)	Divertible resource (GL)	Developed (GL)
Upper Murray	3,200	3,200
Kiewa	350	10
Ovens	500	100
Broken	180	100
Goulburn	1,930	1,780
Campaspe	115	110
Loddon	100	100
Avoca	30	5
Murray-Riverina	50	50
Murrumbidgee	2,500	2,140
Mallee	0	0
Wimmera-Avon	120	110

Australia has a higher runoff variability than any other continent and the Murray-Darling is no exception. In the period 1894 to 1993, annual discharges varied between 1,626GL and 54,168GL. The southern tributaries of the Murray are more reliable but minimum annual discharge is between 4% and 31% of the mean, while maximum annual discharges are between 187% and 442% of the mean. Annual flows in the Warrego, a tributary of the Darling, range between 0 and 900% of the mean. Our rivers are boom and bust and average years rarely occur. Extended periods of wet or dry conditions do occur, leading to long (decadal) periods of flood or drought dominance.

Mean annual natural outflow at the mouth is 12,900GL but basin runoff is 24,300GL meaning 50% is "lost" through natural processes before reaching the sea. "Lost" is the engineering term applied to water which evaporates, infiltrates, is taken up by plants or is otherwise no longer available as surface water. These losses are natural and are only "lost" with respect to potential human uses. Reduction of losses in altered systems can however represent a real volume of water which is available for use and may not impact on the natural environment. As an example, the Condamine Balonne Daft WAMP recognised a category of water referred to as "Type A". This water is "created" because levees around cropped areas no longer allow flood waters to be "lost" on that area, thereby increasing the flow downstream. The extraction of this water is allowed because the removal of it has no net impact on downstream flows. The volume of Type A water can be considerable. Transmission losses are generally estimated to account for 14% of gross water consumption in the Murray though ACIL Tasman recently noted that conveyancing losses accounted for 29% of the water diverted in the southern Murray Darling Basin.

Mean natural flow at the mouth is 12,900GL and the licensed diversion under the Cap totals 12,000GL/year, yet flow from the mouth still averages 5,200GL/year or 40% of natural. This is partly because the allocation is not all used, partly because a component of what was natural “losses” are now used as water and partly because of the inter-catchment transfer from the Snowy Mountains scheme (580GL into the Murray and 555GL to the Murrumbidgee average per annum). If all the allocation was used the mouth would close more frequently. Approximately 4300GL/yr is licensed for diversion from the Murray itself.

Median annual flow at the mouth is 27% of natural. The difference between the median and the mean (40%) partly relates to the infrequent very large floods which still pass through the system without losing significant volumes to storage.

Storage and extraction have greatest effect on small and medium floods. The mouth now experiences severe drought-like flows in 60% of years compared with 5% under natural conditions. Regulation has eliminated the extreme low flows in the entire Murray except the mouth. By “eliminated” this means they have generally been replaced by higher regulated flows and high standing water levels in weir pools.

The effects of flow modification vary greatly throughout the system. At Albury, median annual flow is actually greater than natural because of consistent irrigation releases from Hume and Dartmouth dams and because of the supplementary supply from the Snowy. However the seasonality of flow is almost completely the reverse of natural because floods which would have occurred naturally in late winter and spring are captured in Dartmouth and Hume dams then released over summer such that peak flows now occur in that season. Larger floods will still result in flooding in natural sequence but the capacity of the dams is such that small to moderate floods can generally be captured.

Seventy-two percent of system (Murray) extraction (3100GL) occurs in the Albury to Wakool Junction section, with only 9% from that point to the border. Major extraction points are the Mulwala Canal and Yarrawonga Canal, which can divert 13,400ML/d from Lake Mulwala, the pondage of Yarrawonga Weir. This extraction results in a major reduction in average annual volumes downstream. As releases from Hume Dam are used to service this downstream area, the volume in the river is kept unnaturally high during the irrigation season. The travel time from the dam to the point of extraction means that a long lead-time for ordering is required. If rain occurs in the interim and the crops do not require irrigation, “rainfall rejection” occurs and the volume which had been ordered is disposed of, at times in inappropriate locations or at least at unnatural times.

The altered seasonality decreases downstream of Yarrawonga because a significant proportion of the unseasonally elevated flows have been extracted. By the time the Edward River and Murrumbidgee have entered the system, seasonality has returned to normal but the overall volume is greatly reduced. Reduced volume translates to smaller and less frequent floods, other than for the very largest floods.

Weirs in the upper section raise the water level to allow irrigation channels to be gravity fed. In lower regions this is not the case and pumping is required, leading to a higher value being placed on the water and hence the crops which rely upon it. Weirs and locks in the lower Murray (primarily South Australia) are also maintained for navigation purposes.

The capture of floods in headwater storages and the constancy of irrigation releases during the growing season means the general effect is a decrease in flood flows in winter and spring and an increase in base or in-river flows in summer and early autumn. By the time that Euston is reached the decreased volume means flows at all times of year, for almost all flows, are less than natural. This result becomes more severe further downstream, with the eventual outcome being the statistics for the end-of-system noted above.

The conundrum here is that the flow-related problems in the main channel of the river relate largely to elevated water levels and unseasonal flows while on the floodplain they relate to decreased flood frequency and duration. In simple terms, there is too much water in the river too often and not enough on the floodplain. This is not true for the very outer limits of the floodplain which would naturally only be reached by the larger floods because those floods have generally not been significantly impacted, except perhaps by physical barriers on the floodplain.

Groundwater is also used throughout the catchment. The Water Audit Monitoring Report for 99/2000 showed an estimated sustainable groundwater yield from the surface water sub-catchments of 1115GL and use in the year was 353GL. Groundwater allocation was 951GL. The report noted that NSW parts of the Basin (Darling tributaries particularly) are generally grossly over-allocated and plans are in place to address this.

The report further notes that a 600ML reduction in stream flow results from each 1000ML of groundwater used, that is, swapping over saves 40% directly, and also lowers groundwater, which would be a benefit in areas where rising saline groundwater was an issue. If the unused portion of the sustainable yield in 99/00 had been used, instead of surface water, this would result in a net saving of approximately 304GL. In that particular year, high rainfall may have been the reason that the allocation was not used.

"*Groundwater is an important resource in which there is a considerable scope for future development within the current allocation*."

The above summary serves to show that major land use impacts happened largely between 1840 and 1900. Water resource development impacts in a physical sense commenced largely from the 1920s and were cumulative upon the land clearing / grazing impacts. Volumetric impacts of water resource development increased as the physical structures came on line and made regulation a more significant possibility. As we have little or no ecological data (apart from rainfall and modelled flow data) from prior to the commencement of water resource development, how do we set any targets for the environmental system we want to achieve? How does this relate to the "Reference" condition used in AusRivAS comparisons for example? In the next chapter I will discuss targets and monitoring and this history of change is an important point because we cannot turn back the clock now in order to collect pre-European data.

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5.2 Existing Ecology

5.2.1 Macroinvertebrates

Bennison (1989) conducted a five year program in the main stem and divided the river into three clear zones based on the fauna – upland, mid (riverine tract) and lower. He concluded; "*The invertebrate fauna is generally indicative of a healthy environment*". Longitudinal changes were in accordance with the river continuum concept except at weirs, which acted as discontinuities via their function as a blockage, capturing drift and organic matter and producing localised flow and water quality changes. In South Australia the fauna was of lower abundance and contained more crustaceans (shrimps and prawns). Bennison suggested this may be due to water quality effects related to flows from the Darling River, to strict regulation and to the action of weirs in drowning habitat.

Bennison and Suter (1990), using the same data, stated "*Although there are impacts on the River Murray which affect the invertebrate fauna, the overall diversity is high at all sites with the exception of those downstream of impoundments and the sites along the River in South Australia*."

Geddes (1990) noted that Yabby populations (*Cherax destructor*) showed no net evidence of adverse effects with deleterious impacts of habitat modification and over-fishing balanced by the fact that flow regulation and the habitats offered by dams and weirs actually favoured them. Decline in River Murray Crayfish (*Euastacus armatus*) was certainly related to over-fishing in parts and possibly to habitat modification. This species favours a riverine environment. A number of programs were noted as being in place to re-build populations.

Walker (1990) noted that the river mussel *Alathyria jacksoni*, now had less habitat available while the floodplain mussel *Velesunio ambiguus*, was expanding its range because it is more tolerant of the altered conditions in weir pools. As the larvae are parasitic on fish, anything which affects fish is not helpful to the mussels.

Walker *et al* (1991) "*argue that the river-edge boundary is a vital part of the Murray ecosystem and so deserves special protection in the planning for conservation and management*". There is a disturbance gradient between the weirs and flora and fauna communities follow the gradient. Examples given were the macrophytes *Typha / Myriophyllum* and the mussels *Alathyria / Velesunio*. There were formerly 15-20 species of snail in the Lower Murray and they have been virtually eliminated – possibly primarily because of water level changes. Turbidity may be a factor via inhibiting plant growth. Crayfish, prawns and shrimps are less affected because of their high mobility. The authors concluded that "*it may be possible to modify weir management practices in ways that would have beneficial effects for the river environment and that would not necessarily prejudice other kinds of water use*".

Sheldon (1996) noted that the Lower Murray was dominated by the shrimp *Paratya australiensis* whereas other western rivers in the Basin were insect dominated. Sheldon suggested this was because the Lower Murray is a series of impounded lakes rather than a lowland floodplain river.

Suter (1993 and 1996) investigated eight wetlands from the Lower River Murray and concluded they "*were generally well vegetated with eucalypt woodland over grasses* *and macrophytes and most are grazed by sheep. Large congregations of waterbirds occasionally occur on most wetlands, where they may contribute large nutrient loads to each waterbody through their faeces*." He also concluded; "*it is clear that the number of taxa* (macroinvertebrates) *collected from the River Murray flood plain in SA over the 1990-93 period was high, and that the eight wetlands sampled are among the most diverse in Australia*." The relative abundance of community groups was also consistent with other wetland studies elsewhere in Australia.

The South Australian EPA has 20 AusRivAS sites on the River Murray but only three below Waikerie. Their web site (accessed August 2003) reported six reference sites, one test site in above reference condition, five test sites in reference condition, five significantly impaired and three severely impaired. The severely impaired sites were at Morgan, Blanchetown and Disher Creek North Basin. The main river channel was noted as in poorer condition than the floodplain, which had a number of good sites. No site specific explanations of condition were offered except for Disher Creek, where salinity was suggested as the cause of the poor result.

While the NSW EPA web site (accessed August 2003) does not show Reference sites or sites with above reference scores, Map 5.1 does show individual site ratings based on AusRivAS scores. This shows the headwaters to be in generally Good or Fair condition. There are 15 sites shown on the main stem below the headwaters with 2 in Good condition, 5 Fair, 8 Poor and none are in the Very Poor category. In the Edward – Wakool system there are 16 sites shown of which 7 are Good, 7 are Fair and 2 are Poor. There are also a number of sites on tributaries between the Murray and Murrumbidgee systems of which approximately half are in Good and half in Fair condition.

The web site of the Victorian EPA (accessed August 2003) provides AusRivAS data reports for the Campaspe, Loddon and Avoca rivers. Of 46 sites, 7 are Reference sites, one test site is in Above Reference Condition, 16 are in Reference (Good) condition, 14 are Below Reference (Fair) and 4 are Well Below Reference (Poor). Interestingly the report investigated the causes of the poorer scores and recommended remedial measures related to revegetation of riparian zones, restriction of stock access to watercourses and reduction of nutrient export via sewage effluent from urban areas. With respect to flow related impacts they found the fauna directly below dams was probably impacted by sudden fluctuations in flow.

In the Ovens catchment the upland and intermediate altitude sites were generally in reference condition or above. The lowland region showed below or well below reference conditions at most sites. The rivers in this region were characterised as surrounded by dryland grazing, viticulture, broadacre cropping and some irrigated horticulture. The riparian zone was described as generally of poor quality. The causes of the poor results were attributed to land clearing, erosion, grazing and cropping, which led to impacts via nutrient enrichment, turbidity and poor habitat condition.

In the Goulburn-Broken catchment, the same three geographic zones were recognised: higher altitude, intermediate and lowland. The authors noted the difficulty of separating land use impacts from flow related impacts. Upland sites tended to be in Reference condition; intermediate sites were more variable but still close to reference, while lowland sites were mainly below or well below reference. Causes of these

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changes were attributed to nutrient enrichment (sewage, intensive agriculture such as fish farms and irrigation return drains), sediment (via erosion as a result of clearing, agricultural practices, high water levels for irrigation in lowlands). The report noted nutrient reduction as critical and erosion control, via riparian revegetation and protection, as important. With respect to flow, the report suggested returning seasonality as close to natural as possible. The report noted that these issues had been identified by the local CMA and actions to address them had commenced.

Young *et al* (2001) concluded; "*Overall the changes in macroinvertebrate communities in lowland rivers are due to habitat alteration rather than direct flow effects on the organisms. Reduced flow variability, reduced habitat diversity due to snag removal, bank slumping and loss of littoral vegetation, changes in substrate, changes in water temperature and the predominance of slow turbid flows in the lower river have all contributed to changes in macroinvertebrate diversity and abundance*." Shiel (1990) stated; "*there is no good evidence that the problems of water quality identified for human users in the Murray-Darling system (eg salinity, turbidity, algal blooms) are problems for the plankton fauna, which appears to be highly tolerant of natural environmental fluctuations*."

5.2.2 Fish

The NSW Rivers Survey (Harris and Gehrke 1997) appears to have been the most comprehensive survey of the fishes of the Murray-Darling catchment to date, and built upon and provided comparison with Llewellyn's earlier review (1983) of the distribution of fishes in NSW. However, while Llewellyn partially based his assessment of fish distributions on field sampling, but also relied heavily on museum records from before and after 1960, the Rivers Survey was based completely on field sampling. The report states that "*the NSW Rivers Survey aimed to improve our understanding, to show how rivers and their aquatic life are faring in the 1990s, using freshwater fish communities as indicators, and to provide knowledge needed for better management. The project sought high-quality science as the best means of producing that knowledge.*"

To achieve this aim, the Survey used a number of standardised sampling techniques and a rigorous sample site selection technique over four surveys at 80 sites throughout the State over two years. This required a very large effort to collect and collate the data, and analyse and report on the results.

However, when considering this survey, particularly as a basis for decision making for management of fish communities in the Murray River, it is important to understand the strengths and weaknesses of the approach. The Survey measured what was caught when they sampled, using the methods that were selected. The methods were not adapted to the local conditions, except that in shallow areas boat-mounted sampling gear was replaced by hand-deployable methods. Specifically, boat-mounted electrofishing was replaced by backpack electrofishing in shallow areas, which were typically in the montane areas.

The Survey did not directly measure other influences that may have affected the fish stocks in each area, and in particular, it did not try to account for the influence of fish stocking. It was purely a measure of what fish were there, not how they got to be there. As it was essentially a snapshot over a two-year period, it does not provide trend data. Some inferences were made by comparison with the distribution mapping of Llewellyn (1983), but that report was based partly on field surveys using a different set of methods, and partly on museum records, which will have been based at least in part on very targeted sampling, that was adapted to the local conditions and may have been targeted at a specific species or suite of species. The two surveys are not directly comparable, except in very general terms.

The Survey did demonstrate low relative abundance and diversity of fishes in the Murray Region. Only 4.4% by numbers of the total NSW River Survey native fish catch were caught from the Murray region, including the Lachlan and Murrumbidgee Rivers, from 25% of the total number of surveyed sites. In comparison, the Darling Region produced almost ten times as many fish from the same number of samples. While the densities of sampling sites were generally low, with only 80 sites across the State and equal proportions of sites in the montane, slopes, and regulated and unregulated lowland rivers, the per-site comparisons are informative at this broad-brush level.

The site density was a product of the need for a State-wide survey, and finite resources, but it resulted in low site densities in the lowland regions of the Murray-Darling system. Only two sites, one regulated and one unregulated, were included on the Murray River itself, and similarly two on the Murrumbidgee River, while one slopes site and one unregulated lowland site were included on the Lachlan River. This low site density in the lowland region means that the Survey is not able to be used for detailed investigation of differences between river reaches, and also partially explains why no Murray Cod were collected during the survey from the Murray region, despite acknowledgement that *"the species is still regularly caught by commercial and recreational fishermen in some areas of the Murray region*".

Therefore, while the Rivers Survey does provide a good basis for a broad assessment of the status of the freshwater fish communities of NSW, it cannot provide sufficient detail for use as a basis for reach-by-reach or even within-one-river management of fish communities.

Clearly though, the overall abundance of fishes in the Murray Region was relatively very low compared with river systems elsewhere in the State. The diversity of native fishes, as collected by the standardised methodology of the Survey, was also comparatively low in the Murray region. By comparison with the Darling Region, by river type within each region, the average number of native fish species collected per site was:

Table 5.3 Native fish species per site from the Murray and Darling rivers

Type	Murray	Darling
Montane	1.0	1.2
Slope	3.0	4.6
Regulated Lowland	3.0	6.0
Unregulated Lowland	3.2	6.6

This indicates considerable lower average native fish diversity in the Murray compared with the Darling, and that the difference was greater in the lowland reaches than in the more elevated reaches. Note that there is little difference between regulated and un-regulated lowland sites. This appears to also be true of the proportion of native fish in the total catch (27% in the unregulated versus 20% in the regulated in the Murray region). The only abundant species from the Murray and Darling regions that showed a significant effect of regulated versus unregulated rivers was the Bony Herring, *Nematalosa erebi*, which was in lower abundance or absent from regulated reaches. No reason for this could be determined from the Survey results. Of the non-native species, there was a strong positive relationship with regulation for Carp, *Cyprinus carpio*, in the Murray region, but not for the Darling region. The relationship between Carp numbers and regulation was correlated with height of the dam wall, which is not necessarily a flow-related feature. Carp appear to benefit from the ponding caused by dams, which results in an increase in available breeding habitats.

The NSW Rivers Survey provides a valuable snapshot of the status of fish populations across the State, but does not provide the fine detail needed to determine causes of changes, nor for assessing appropriate management responses at less than the regional (i.e. river basin) scale. While the results did indicate some impacts were related to regulation, this was in the general sense that patterns were found between rivers with regulation infrastructure in place and those without such infrastructure. The Survey was not designed to, and was therefore not able to ascribe the fundamental causes to those patterns, and many factors are altered by regulation of a river, including land use changes, physical habitat alterations and fish passage barriers, in addition to alteration of flow patterns.

The impacts of relevance to fish noted in overview reports such as Thoms *et al* (2000) include:

- Physical barrier effect of main channel structures
- Physical barrier effect of levees, regulators and other wetland or floodplain blockages
- Thermal barriers downstream of Dartmouth Dam and to some extent Hume Dam
- Habitat alteration, particularly loss of snags, change from a flowing river to weir pool environments and loss of wetland / floodplain habitat through land use change, change in macrophytes and water quality changes.
- Flow regime change acting as a barrier to access to the floodplain or altering triggers for migration or spawning.
- Over-fishing.
- Introduced species.

A number of experimental studies on fish in the mid-nineties provided some important information for management. For example Mallen-Cooper (1997) reported non-spawning upstream migration of several species through the Torrumbarry fishway in response to small changes in flow. The fishway was completed in February 1991. Large numbers of carp also moved. Movement was mainly mid-autumn and spring and confined to the river channel. Ageing studies showed breeding had occurred when flows were confined to the river channel and possibly not on flood flows, or, those which bred on floods had not been able to return to Torrumbarry because of other barriers.

McKinnon (1997) also concluded with respect to the importance of flow "*a large flood may not be as important for migration and spawning as a small rise in water level at the appropriate time of year*". Only for yellowbelly, and on only one occasion, was abundance statistically related to flood stage in a five-year study of the use of the Barmah Millewa Forest wetland by fish. A large flood does provide other benefits such as increased area and variety of habitat so should enhance recruitment. The author also suggested that local floods only assist local populations whereas floods which drown out weirs allow longer migrations. While the second phrase would be true the first is not a necessary corollary if functional fishways are in place.

Koehn *et al* (1997) monitored tagged Murray Cod over a 3-year period and found that upstream movement started in late winter and peaked in October. This occurred in both flood and non-flood years. Individual fish usually went to the same spawning area then rapidly returned downstream, to the same snag, in December – January. The distance covered was up to 120km but most moved much smaller distances. Murray Cod strongly preferred large wood debris piles and sheltered in them or under banks in high flows. They moved to anabranches and smaller channels as soon as they were available but did not use the floodplain. They survived well in Lake Mulwala (Yarrawonga) and moved upstream to breed – in both the Murray and the Ovens rivers. Whether or not they spawned in the lake was uncertain.

Trout cod also strongly preferred woody debris, but only moved in a major flood in 1993. They did not use the floodplain. With respect to snags the authors stated; "*it is now clear that this is the most important element of instream habitat for cod in lowland rivers. In fact, snags are as vital to cod as trees are to birds*". Other aspects of management suggested as important by the authors included; protection of anabranches and bankside vegetation; adequate fish passage; reintroduction of some elements of the natural flow regime, particularly flooding. However, Kearney and Kildea (2001) report that Cod spawn in response to water temperature increase, not flooding.

Saddlier *et al* (1997) also investigated Trout Cod and found spawning was linked to a rise in water temperature and not in response to flow. They also showed high site fidelity with large woody debris being the prime determinant of trout cod presence.

Meredith *et al* (2002) concluded; "*in both upland and lowland systems, spawning of many native species occurs at similar times of year independent of temporal changes in flow. This refutes the commonly held notion that a flood pulse is necessary to stimulate spawning and recruitment of native fishes. A new model, the temporal trophic cascade, is suggested as a more appropriate model for the management of native fish populations*." This is a prime example of knowledge increasing with real field data but unfortunately it takes time for new knowledge to be incorporated within decision-making. Gippel and Blackham (2002), in reviewing the impacts of flow regulation on the River Murray, were not aware of this new information and noted "*Flow regulation is implicated in the declines of native fish species because floods are vital for reproduction in most species*,".

Gehrke *et al* (1997) noted "*Variability is an integral characteristic of natural systems*" and discrete fish communities in the Basin reflect different environments hence "*These differences point to the value of adopting regional priorities in* *developing and implementing habitat and fisheries management strategies. The findings also provide support for restoration of pre-regulation hydrological regimes in key habitats*".

In a conclusive study on the impacts of Dartmouth Dam, Koehn (1997) re-used pre-dam impact assessment sites and techniques to assess the fauna 13 years after dam completion. Murray Cod, Trout Cod and Macquarie Perch were no longer present below the dam, whereas they had been relatively common beforehand. Brown Trout abundance had increased significantly and now made up 71% of fish numbers. Native fish only comprised 7% of the fauna in the river below the dam. The highly probable cause of these changes was decreased water temperature associated with deep water releases from the dam.

Macroinvertebrates had similarly not recovered since construction impacts were first felt. Blame in this case was put to high levels of sediment during construction, an almost totally changed flow regime (loss of floods, replacement of low summer flows with constant high irrigation releases), thermal effects, reduced instream habitat (especially pools as a result of infilling) and river management works. These factors also impact upon the fish.

The authors noted that recovery was unlikely if the thermal regime was not corrected.

The Murray-Darling Basin Ministerial Council released a draft Native Fish Strategy for the Murray-Darling Basin in June 2002. The document purports to provide strategies for management of native fish species and stocks for the period 2002-2012, with the stated goal "*to rehabilitate native fish communities in the Basin back to 60 per cent of their estimated pre-European settlement levels after 50 years of implementation.*" The intent is for revisions of the strategy to be released every decade, which will review past performance and revise the management strategy for the next decade.

The document makes no reference to the source data, nor explains the scientific foundation of the conclusions drawn at any point, with one exception of a figure for which the source of the data is specified. This makes it very difficult to establish the validity of the statements of current condition or the likely response to the suggested management options. Certainly some of the figures quoted appear to have been lifted directly from the NSW Rivers Survey report, but there is no citation to verify that.

Critically, statements such as "*Experts believe that if only one strategic intervention were to occur, such as allocation of environmental flows, this may help to recover native fish populations to about 25 per cent of estimated pre-European settlement levels.*" are left without support, as there is no indication of who these experts were, what information they based that finding on, nor how they were able to make such a projection on the basis of, as far as this review has been able to ascertain, no established causal relationship models between environmental flows and the responses of populations of any individual fish species, l*et al*one the entire native fish community. The projections of the results of actions, or no intervention, on native fish communities over the next 40 years upon which the main thrust of the Strategy is based are given in Figure 2. This figure shows a number of curves that indicate that no intervention would result in a decline from an initial stock of 10 % of pre-

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European settlement levels to less than 5 % over 40 years. Intervention via habitat restoration alone would result in a peak of about 25 % at 35 years, but for no apparent reason a reduction over the five years after that. Environmental flows allocation alone is projected to provide a peak improvement to approximately 34%, which is in contradiction to the quote above, while a combination of habitat restoration and environmental flows would result in a peak of about 48%. These responses are shown as lines with a data point every 4 years, but this is misleading, as there is no indication of the uncertainty of the estimates. As the projections must at best be based on semi-quantitative or empirical models, the uncertainty after a projection of 40 years from the present must be large indeed, and it is highly unlikely that there would be any significant statistical difference between the projections for the different options. Even ignoring the uncertainty of the projections, Figure 2 assumes that all actions will commence simultaneously at year zero, and it is only by this manner that the target of 60 % of pre-European levels can be achieved. This is an unlikely scenario, and an optimistic projection that all strategies have to work and work simultaneously to achieve the desired outcome. There is no allowance here for any action to fail to meet the projected benefit.

The Strategy includes 13 objectives that will need to be met to achieve the overall vision. This is a sensible approach to break down a complex problem into manageable units, but the objectives seem to be regularly confused and combined, probably because the issues remain complex and inter-linked. While this inter-linkage of issues associated with objectives is formalised to some extent in the figure on page 16 of the six Driving Actions, the discussion of driving action 1 – Rehabilitation of fish habitat – for example deals briefly with rehabilitation of physical habitat, then moves onto longer discussions of improvement of water quality, which is not a habitat but an environmental characteristic, and environmental flows allocations. While these issues are undoubtedly interlinked as flows are required to allow fish to move between habitats and to occupy them at various water levels, and fish will not occupy habitats in poor water quality, the focus on rehabilitation of habitats is diluted by a greater emphasis in the text on linked-variables rather than the fundamental issue. From the discussions of all the Driving Actions, one is left with an impression that there has been an overall emphasis placed on environmental flows, as this issue is returned to repeatedly, which may or may not be justified but the underlying evidence, models and assumptions are never identified.

Overall, the strategy appears to risk becoming a paper tiger, as it has no expressed structure or supportive legislation to enforce compliance or maintain funding despite the very long timelines, and indicative figures provided that suggest potentially very high costs to rehabilitate small reaches. An example is inadvertently given of how difficult it may be to ensure sufficient real support is developed for the Strategy under Driving Action 6 – Managing Fish Translocation and Stocking. The report states "*Appropriate guidelines and codes of practice to minimise this risk* [to native fish populations from translocation of other species] *are required. However, while some States do have guidelines in place, it is very difficult to verify whether these guidelines are being followed*." If the council cannot determine whether its member States are currently complying with their own codes of practice now, how will it ensure that they comply with the Strategy for the next 50 years?

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Despite the limitations noted above, the strategy should be commended for attempting to predict the benefit which might be obtained from a suite of management options acting individually or synergistically.

5.2.3 Wetlands

Pressey (1986) remains the major work on wetlands in the Murray. This initial review has served as the cornerstone to the various state and MDBC wetlands programs since it was released. Pressey recorded over 7000 wetlands on the Murray of which 83% were smaller than 10ha. There were 27 wetlands larger than 500ha. Floodplain wetlands were mainly in NSW in the Edward Wakool system. The largest wetlands are the Lower Lakes and Coorong in South Australia.

The survey was originally undertaken to assess hydrological changes though other impacts were noted such as effects of land use on water quality, grazing, logging, introduced plants and animals and recreation. Pigs, carp, nutrients, sediments and pesticides are also mentioned.

Pressey identified four categories of wetland based on hydrology.

- Category 1. These filled at minimum regulated flow (or pool level in sections with weirs) and hence were low lying and permanently connected to the river. They were mainly in the Lower Murray below Mildura. They constituted 35% of the total area of wetlands. "*This represents an enormous change to the wetland environments of the Murray Valley because all of these areas previously dried and filled periodically*".

- Category 2. These wetlands filled above minimum, but at or below maximum, regulated flow. They were mainly filled every year by high regulated flows. They made up 23% of the total wetland area and were mainly above Barmah because regulated flows are higher in this region.

- Category 3. These wetlands required flows above the maximum regulated flow hence are filled by floods or rain rejection flows. They constituted 31% of the total wetland area but 69% of the number of wetlands. The frequency of filling depends on floodplain elevation with higher wetlands filling less often.

- Category 4. These are again higher wetlands but receive supplementary watering in the form of effluent from irrigation, sewage or other development. Eleven percent of the total area of wetlands was in this category.

Pressey suggested management options appropriate to each category, noted the potential constraints, and specifically addressed some key sites.

Category 1 wetlands needed to have the wetting / drying cycle restored. Pressey suggested this could be done by manipulating weir pool levels or installing regulators on the inlet channel to raise the wetland to a higher hydrological category. This type of manipulation was not appropriate to all sites and Pressey warned of the need to watch the salinity of groundwater when altering water levels.

Category 2 wetlands vary greatly in the degree of change from natural and needed individual assessment because some needed more water and some needed less. Category 2 wetlands were noted as having few constraints to management.

Category 3 wetlands at low elevations were impacted by reduced frequency of minor floods whereas the frequency of filling of more elevated wetlands appeared not to have been significantly changed. Management recommendations related to getting water into the lower ones more often, and holding it there for a longer period, though the frequency and duration depended upon the specific management goals for the wetland.

Category 4 wetlands showed both beneficial and adverse impacts depending on the specific circumstances.

If we assume for sake of argument that half of the category 2 wetlands are too wet and half are too dry, then the wetlands which are too wet represent 46% of the total wetland area. Wetlands which are too dry account for approximately 42% by area.

During the field assessments Pressey also recorded 117 colonial waterbird nesting sites in the area, most of which were still used.

Pressey made a number of recommendations about gathering more data and developing individual site management plans. He concluded; "*Many are still thriving natural areas, even if many are hydrologically and ecologically different from what they once were*." Interestingly, this conclusion is quite relevant today to the definition of a healthy working river because it shows that a healthy system need not be the natural system.

Harriss (1997) reported the work of the NSW Murray Wetlands Working Group in trying to implement the recommendations made by Pressey (1986). The group developed planning, management and rehabilitation guidelines for 13 wetlands from Hume Dam to Wentworth. The report noted "*Unseasonal inundation by regulated flows over summer has had the most severe impacts on wetlands between Hume Dam and Echuca*." The author suggested that if you re-introduced a wetting/drying cycle you could in fact save water by reducing "losses" (this has in fact eventuated in Moira Lake). Remedial works commenced in 1995-96, 10 years after Pressey originally made the recommendations. Some wetlands were dried for the first time in 15-20 years.

Jensen (1997) noted with respect to a framework developed by the Lower Murray Flow Management Working Group for managing environmental flows, that a key component was the re-introduction of a wetting/drying cycle into currently permanently inundated wetlands and a stepped approach to flood levels which saw mid-level flooding increased.

Boon *et al* (1990) stated with respect to billabongs that each is independent and highly variable in all time frames therefore very different from each other and from itself at different times. They represent "*A heterogenous mosaic of habitats*" and are much more diverse than reservoirs because they have more niches. The authors noted the importance of hydrological variation and wetting and drying cycles in billabongs close to the river for productivity and the role of billabongs as "*pots of food*".

Sainty and Jacobs (1990) related the impacts on macrophytes in the Murray to ponding, increased nutrients, increased salinity, increased turbidity, increased sediment load and siltation, reduced variation in flows and timing of flows, feeding habits of carp, lowered water temperature and dissolved oxygen downstream of impoundments and weeds.

Rekcnagel *et al* (1997) conducted carp exclusion experiments in an ephemeral wetland in the Lower Murray. The author suggested carp affected wetlands by:

- significant reduction in macrophyte abundance
- signficant reduction in crustacea and insect abundance
- exclusion of molluscs
- reduction of native fish abundance
- significant deterioration of water quality
- significant reduction of primary productivity.

5.2.4 Riparian and Floodplain

The report by Margules & Partners (1990), based on data collected in 1987 and 1988, is still referenced as the main work on riparian zones along the Murray, though they had no sites above Albury. Unfortunately the report did not cover all of the floodplain, such as the vast area of the Edward –Wakool region.

The report noted that one third of all plant species on the floodplain were introduced and up to 63% of communities in floodplain plots were weeds; "*It is undoubtedly the most widespread form of vegetation deterioration along the river*."

The report classified vegetation as severely degraded based initially on air photo interpretation of crown death and field verification that the area was suffering severe long term degradation. As such, issues such as clearing, weeds or replacement by exotics were not incorporated within the definition. The riparian zone between Mannum and Lake Alexandrina has largely been replaced by willow but because the willow was healthy the riparian zone was not classified as severely degraded. Using their definition, just 1.4% of the riparian zone was assessed as severely degraded. The most impacted areas were downstream of the Wakool Junction.

The authors attributed the causes of impact as follows:
Salt – 49%
Drowning or drowned – 35% (too much water)
Water stress – 8% (too little water)
Clearing – 6%
Grazing – 2%

The report stated; "*it should be noted that grazing problems are far more widespread than depicted by this table*" and similarly with respect to impacts of recreation "*some river bends and floodplain areas are a maze of tracks and constitute degraded sites*."

Clearing was also a more significant impact than noted above because large parts of the farmed floodplain were not mapped. For example in section 8, below Mannum, the river was originally flanked by wetlands which were since drained and protected from flooding by levees and the riparian zone now consists of willows which were introduced to stabilise banks.

The report clearly noted that weirs cause marked changes in vegetation both upstream and downstream primarily as a result of altered water levels.

Eucalypt regeneration and health were worst in sections 7 and 8 (from near Loxton to Lake Alexandrina). Impacts to regeneration overall were mainly attributed to:

- Raised water levels
- Grazing – sheep, rabbits and kangaroos
- Weir flooding and lack of flow variability – particularly in South Australia
- Weeds.

Overall, "*soil salinisation* (is) *probably the issue of most concern for the long-term health of the riparian vegetation*". With respect to rehabilitation of salt affected areas the report noted; "*The scope of the works needed can be reduced through the use of salt-tolerant provenances or desired species or through acceptance of a modified community of other, hardier species*". The latter phrase is again equivalent to the social component of the healthy working river concept, that is, society may accept a change from natural.

The authors also pointed out that red gum is the most widely distributed eucalypt in Australia and significant forests still persist on the Murray. The report identified 196,900ha of red gum on the Murray and 35,200ha on anabranches. Of this, 121,900ha was in State Forest or protected areas.

The report noted that construction of Lake Alexandrina and Lock 6 (Chowilla) caused local water tables to rise and bring salt up, causing the death of large areas of red gum. Evaporation basins using former lagoons, creeks and anabranches, also caused salinisation and death of nearby trees. Use of these mechanisms declined with off-floodplain disposal systems. The authors noted that the leaching effect of flooding, particularly near the river where it is more frequent, was beneficial.

With respect to the utility of local management actions the report noted; "*The results from such localised efforts can provide long-term solutions to these problems*."

Bren (1990) conducted a vast amount of work in the Barmah forest and lists impacts to red gum forests as grazing, logging, recreation, insect attack, changes to flooding and fire regimes, salinity and rabbits. The author noted; "*Their health ranges from fair to excellent with the major forests generally being in good shape and well-managed*." Also, while pointing out impacts related to water stress, Bren concluded "*the problems appear quite amenable to solution*." Those solutions related to re-establishment of connections and flow paths mainly via levee adjustment and the use of regulators.

Jensen (1997) reported that the causes of low red gum regeneration in South Australia were thought to be a lack of flooding, saline groundwater (linked to a lack of flushing) and grazing (by rabbits, kangaroos and stock). Planted seedlings with well-established roots survived well in some trial plots when they were protected from grazing.

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Removal of physical blockages in flow paths was another recommendation of the report. Areas used as saline disposal basins showed very limited regeneration.

MDBC (2003b) reported a rapid visual assessment of red gum areas in South Australia in response to media comment about declining health. The report confirmed very high stress levels in places, particularly those higher on the floodplain. Based on literature, the report suggested decreased flood frequency and soil salinity were joint causes, including failure of flooding to flush salt from the soil. A WAVES model was set up which showed "predicted leaf vigour" increased following floods and decreased during dry times. Figures for WAVES output, local rainfall and river flow confirmed the current drought as very severe. In two previous major droughts (60s-early 70s and late 80s) death or die-back also occurred and in fact the presented figure suggests the vegetation is in better condition now than in the 70s drought and in similar condition to that of the 80s. The basic answer was that the vegetation needs a flood, natural or otherwise.

Unfortunately the report, classified as a technical report, used very unscientific language at times and romanticised the red gum eg "*The River Red Gum is one of the most loved, best recognised, and widely used tree species of inland Australia. Red Gums along the river Murray have shaped Australia's inland landscape for generations, and have captured the imaginations and memories of millions of Australians. This iconic species is largely responsible for the River's distinctive character and identity and holds a prominent place in Australia's heritage. They are testimony to the passage of time, wearing the scars of bark canoes and carrying dishes of Indigenous people, displaying the survey markers and carvings of early explorers, and providing shade and shelter to all who have walked or camped under the massive branches*". This non-technical text detracts from the reports technical outputs and is better suited to other types of publication.

The Murray is not the only river in the Basin to harbour significant red gum forests. Briggs and Thornton (1997) discussed a section of red gum forest on the Murrumbidgee between Wagga and Hay. Of 174,700ha of floodplain, 45,075ha was red gum wetland and only 1% was affected by local hydrological control. Red gum is continuous along this stretch with significant regrowth noted in previously cleared, ringbarked or thinned areas.

5.2.5 Other fauna

Scott (2001a) noted with respect to the aerial surveys of waterbirds conducted since 1983; "*suggest a decline in abundance of some species. However, because of the large fluctuations in numbers from year to year caused by floods and droughts, the data are not conclusive*". While birds which rely on a wetting and drying regime of near-river wetlands may have seen a reduction in breeding, other which prefer permanently flooded or saline areas may have seen an increase. Other impacts noted on waterbirds were clearing of vegetation along rivers and in wetlands, spread of weeds and grazing of wetland vegetation, changes to water quality, pesticides, hunting and predation from introduced animals (foxes and cats). Briggs and Thornton (1997) noted that late winter-spring was the best time to flood red gum for waterbird breeding.

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Scott (2001b) also noted that while there are a number of potential impacts of flow on platypus, "*there is no evidence of changes in platypus numbers below the major water storages*". Similarly with respect to impacts of flow regulation on native water rats the authors concluded "*few serious impacts are likely*". For frogs and tortoises while habitat had been lost by physical and flow alteration to the floodplain "*rural development has however created new habitat in some regions by the construction of permanent water storages and farm dams. These can provide suitable habitat providing that fringing vegetation is also present*". For tortoises, "*as many as 95% of tortoise eggs* (are) *being taken by foxes before they hatch*".

5.3 Summary

Before commencing the summary it is relevant to point out that the above section does not represent an exhaustive literature review and it should be read in conjunction with discussion of key documents above, principally the Snapshot and SRP reports. As this review was by necessity literature based, any recent information which is not yet published or referenced in documents which were available, was not available to the review.

One strong impression gained from the review is that while hydrological data has been collected for over a century and detailed hydrological monitoring and modelling programs are in place today, ecological data collection and monitoring programs have been relatively recent, rarely system-wide and rapidly evolving. The series of basic data collection programs commenced in the 1980s (wetlands, riparian zones, macroinvertebrates, water quality and so on) were either superseded by others (AusRivAS for macroinvertebrates for example) or gave way to management planning processes and therefore ceased (wetlands for example) and only water quality appears to have continued. The Sustainable Rivers Audit process is an attempt to recommence basic, consistent and repeated data collection and is strongly supported by this review.

It is very surprising that there appears to have been no systematic monitoring of fish throughout the river despite all the media interest the topic generates. Information paper No.4 from the Living Murray Initiative attempts to clarify the status and trend of native fish in the system but could not refer to a monitoring program.

It is also surprising, given that the impacts of reduced flood flows relate most obviously to Pressey's category 3 wetlands, that we did not come across any references to studies which monitored a range of such wetlands over time in order to determine just what the impacts were. Apparently there are monitoring programs associated with rehabilitated wetlands but long term monitoring associated with relatively untouched wetlands would be very informative.

It is clear that the impacts associated with the physical infrastructure have been particularly significant in the Lower Murray and the section between Dartmouth and Hume dams. In the intervening section the impacts are less severe, possibly because the gaps between items of infrastructure, and often the size of the pieces of infrastructure, are much less, leaving longer stretches of river between the weirs. The observation that macroinvertebrate communities are most impacted immediately downstream of structures but improve with distance from the structure, suggests that those sources of impact which are not directly associated with the physical infrastructure are less problematic for them. This is turn supports the idea that macroinvertebrates respond mainly to local influences, depending of course on the severity of other issues.

Despite the noted impacts in the Lower Murray there are remaining features of high environmental value, particularly on the floodplain. The work of Suter (1993), the State EPA AusRivAS results and the data behind the Chowilla Floodplain Management Plan and Biosphere Project all point to areas of conservation significance and considerable resilience. There are undoubtedly very large areas of significant conservation value in the Riverine Tract and the upper Mallee region, as evidenced by the existence of a number of Ramsar sites, large areas of remnant forest of apparent high quality, large areas of apparently high quality floodplain in the Edward-Wakool area and very good fish fauna in this region, including the most significant population of Trout Cod. Why is this section in apparently better condition than either upstream or downstream extremities? It is probably a result of a combination of factors, including:

- Decreased impact on seasonality of flow compared to upstream
- Less impact on flow volume compared to downstream, though still a substantial change
- Relatively few items of infrastructure and most fitted with fish transfer devices
- Relatively good quality riparian zone and areas of nearby floodplain habitat
- Relatively good in-river habitat in parts, partly related to the previous point.

The impacts of too much water actually in and near the river (as weir pools or evident as regulated flow) as opposed to the impacts of too little water on the intermediate floodplain are quite different and require different management solutions. Most research appears to have been directed to either the in-river problems or the nearby floodplain with few studies tying them together and little work at all on the intermediate floodplain. The in-river impacts largely relate again to the physical infrastructure itself and to the practice of regulation. Many of the authors quoted above noted the potential to address identified issues of concern and to do so through adjustment of the physical infrastructure or locally specific adjustments to wetting and drying regimes. Very few of the recommendations involved a significant volume of water being returned to the environment. Re-introduction of a degree of natural flood flows has been raised as being of benefit in the river and how this might be done is a key issue for management.

Other than the recent summary by Gippel (2003) there appears to be little discussion of how, where, or even specifically why, water should be returned to the intermediate level wetlands. As this is probably the key ecological issue related to the perceived need for increases in flow and potential decreases in allocations, it is an area apparently in need of urgent attention.

6 Options for aquatic environmental management

The three major impacting factors on the Murray are:

- Land clearing and land use
- Physical infrastructure in and near the river
- Changes to the flow regime, particularly regulation.

Other possibly equally important factors include alien species and de-snagging. In their own right each of these represents substantial change. They also act synergistically and to an extent cumulatively, so their impacts cannot be completely uncoupled or treated independently.

The impacts of these changes, and the socio-economic benefits obtained as a result, are not uniform throughout the system and the two are not necessarily correlated with a location; the societal benefits of Dartmouth and Hume dams are directly felt almost the length of the river and in fact indirectly felt beyond the region, but many of their physical impacts are far more localised.

The remaining areas of conservation significance, and they are significant in number, area and variety, are also not uniformly distributed through the system and the threats to them vary from location to location.

6.1 Localised Management Targets

The changes noted above are significant and because they will not be reversed to any substantial level because of social and economic impacts, "natural" is not a logical or practical target for system-wide management. The degree to which "natural" is a sensible target or comparator will vary with the existing ecological status of the area in question and the willingness of society to protect or restore the area. Existing urban or productive agricultural areas may well have ecological targets but they will logically not include "return to the natural state" of that area. A sensible management approach would be to identify areas of conservation significance and develop specific management plans for them, similar to what has been done for Chowilla and Barmah Millewa or by the Wetland Management Groups. This was recommended by the Scientific Reference Panel as reported in Thoms *et al* (2000).

As the threats to any particular location or the means to address certain threats cannot be managed entirely locally, a system-wide commitment to contribute to such management is necessary. It is foreseeable for instance that if water is required for a particular wetland or floodplain management plan, that water may be best sourced from Dartmouth, or Eildon or some other tributary dam. If as a river basin community we have agreed that the management plan should be undertaken, then the community as a whole should cover the cost, irrespective of the location which might "lose" as a result of implementing the plan. The same logic can extend to the Australian community as a whole because we all benefit from the productivity, and the ecological health, of the basin. A mix of user- and indirect beneficiary- pays.

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The process described in the previous paragraph is where system-wide aspects of management are appropriate. It certainly cannot be used to set targets by comparison with the presumed natural condition. The management targets for each individual area of identified high conservation value will by necessity be set specifically in relation to the needs of that area. For some of these, such as those currently in very good condition and not threatened by significant sources of impact which are essentially irreversible (in a practical sense), then “natural” may be an appropriate target. For the many more areas which have environmental value, though they are not and will never be natural again, a lesser target is appropriate. These systems can be sustained as healthy though not entirely natural. Instead of setting targets as a percentage of natural as measured by some index, such as AusRivAS, the target could more specifically align with what appears to be the overall philosophy of natural resource management in the Basin, that is, maintenance and possible improvement.

Maintenance refers to a situation of no deterioration in the current condition, it need not relate to maintenance of presumed natural ecological integrity. If the current condition is acceptable to society as a “healthy” system, then maintenance is all that is required. For some locations the identified ecological value of significance could be a single species. An appropriate measure of health in such a location need only be the maintenance of that species and need not cover all the other components of ecological integrity. Science can inform management of the key needs of that species and this will broaden the list of environmental attributes of concern. This type of situation relates more to plants, or perhaps a specific local habitat, than to aquatic animals. Fish for example can only be partly managed on a locational basis and management requires some system-wide commitment in relation to issues such as physical barriers to movement.

This regionalised, bottom up approach is not new. Sharley (1993) pointed out the various strategies being developed by the MDBC as part of the Natural Resource Management Strategy – algae, floodplain wetlands, fish, salinity and drainage, irrigation and so on. He espoused the idea of developing river management plans based on sections of rivers. An integrated river management plan would develop an optimal flow management strategy in each section in relation to the needs of all stakeholders, including the environment. “*Importantly, the process of developing integrated management plans for sections of rivers enables communities and governments to focus on issues specific to those areas*”. I am suggesting even more refined targeting, essentially following the process of Rutherfurd (2001).

The Integrated Catchment Management Plan for the Murray Catchment 2002 – Murray Catchment Blueprint (DLWC 2003) very much follows the above philosophy. “*One of the key benefits in developing a whole of catchment blueprint is that it identifies areas where actions are most effective and where the resources should be focused to achieve the greatest environmental gains or contributions to achieving the targets*.” I believe this plan, though non-regulatory, has a strong probability of achieving considerable success because it is community focused, it specifically targets the causes of ecological degradation, ‘maintenance’ is correctly targeted by using a 2-year baseline to establish the current condition (not an estimate of natural), and targets are specific, measurable, achievable and relevant.

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The above discussion outlines an approach which largely conforms with the work conducted to date and does not require the system-wide target setting for a volume of water to be returned to the environment such as was undertaken by the ERP as reported in Jones *et al* (2002). We already knew that a significant proportion of the total flow in the system was used to benefit society so by using a system-wide approach and setting a target as return to natural, the answer was always going to be that a large volume of water would need to be returned to the environment. The same answer would result if a similar approach were taken to address the other main causes of change, physical infrastructure or land use. Boulton and Brock (1999) noted that much of the degradation in Australia's rivers results from land use practices in surrounding catchments. Would there be any benefit in using an ERP style of analysis and showing that rather obvious result? I don't think so, other than to return some balance to the debate.

6.2 Risk Assessment Process

Natural Resource Management (NRM) must be undertaken in a holistic manner and it is clear that the MDBC is tackling the many issues which NRM, with particular emphasis on aquatic systems, encompasses, however what appears to be missing is a Risk Assessment process which results in a prioritisation of actions related to the risk of environmental harm. The Snapshot gave a brief overview but did not attempt to rank or prioritise actions, primarily because of a lack of data and such conclusions were outside its scope. Similarly the SRP report listed numerous threats but did not rank them and again in accordance with its Terms of Reference it concentrated on providing advice related to river operations. It is acknowledged that the various MDBC programs are not targeting flow management as the only means of addressing river health issues but the various media releases related to the Living Murray and the ERP document very quickly took us to an inevitable answer of giving back water to the environment without addressing all the alternatives in an integrated manner.

In order to appropriately allocate management resources it is important to attempt to assess the relative impact or threat related to individual hazards. Which flow management actions are appropriate, in which parts of the catchment and when they should be prioritised for implementation, can only be assessed by comparison with the potential results from non-flow related management actions which target similar outcomes and in this case the outcome is maintenance or improvement of river health. In determining where the planning effort with respect to river health should be expended, managers should undertake the following steps:

1. assess the relative risk to the aquatic environment from water resource development *per se* (ie, water resource development relative to land use or urbanisation or industrialisation),
2. if water resource development is the major risk factor then assess the relative risk to the aquatic environment from various aspects of it (non-flow related aspects: dams and their impacting attributes, levees, regulators; flow-related aspects: extraction, regulation, discharge from particular activities)
3. if flow related aspects are seen as the most significant component of risk, then assess the relative risk to the aquatic environment from aspects of the flow regime (non-volumetric aspects: seasonality, variability, constancy; volumetric aspects: reduced flooding frequency and duration).

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4. Those ecologically significant components of the aquatic environment at most risk from those flow regime changes (mid-level floodplain, fringing aquatic vegetation, riparian zone, fish, birds etc).

If the answer at step 1 in the above process had been that land use was the primary source of risk then steps after that phase would have been land use orientated. Each significant source of impact identified at step 1 should be followed through so that a three dimensional matrix can eventually be constructed. The ERP report made conclusions with respect to step 3 above without having passed through steps 1 and 2. It did however conclude, without offering any supporting data or logic, that fixing the flow aspects alone will not solve the problems; "*The full benefits of environmental flow restoration will only be realised if river water quality, floodplain lands, and river habitat are also restored or protected*". What this does not say is how much benefit is gained from doing <u>only</u> these non-flow related actions? As noted above, the ERP failed to note that the data used in the references which support their use of the 2/3 natural threshold actually used ecological impact which was <u>the sum of all impacts</u>, not just those related to flow. Point xvii of the Executive Summary of the ERP report notes that it is important "*Further improvements in river operations beyond those described in options package 57200 may lead to better ecological outcomes for the same volumes of new environmental flows*" In other words, there is ecological benefit to be gained by <u>how</u> water is managed rather than just by <u>how much</u> and also by management of non-flow related sources of impact.

This stepwise risk assessment process allows targeting and prioritisation of management actions and can be undertaken at any scale. For example for a specific area of conservation significance the primary risks to sustainability may be associated with the function of weirs and regulators which alter the natural flow paths, or in another circumstance perhaps with an invasive pest species. The most significant outcome of this review should be recognition of the need to incorporate steps 1 and 2 above in the environmental flows process and to recognise prioritisation across the full range of potential actions as an appropriate approach to holistic management of river health.

It is acknowledged that the quantification of risk associated with any single source of impact, or with a suite of impacts acting in synergy, would be very difficult given our current state of knowledge. It would certainly be possible though to list the main impacts affecting a particular site or a river zone (as was done by the SRP), rank them in order of probable relative importance (also partly done by the SRP) or identify which are the likely primary constraints (that is, which ones do you need to fix first so the effort on the others is not wasted?) and possibly even quantify the impact or risk associated with some of them. This process is not dissimilar to what is being done already when specific sites are considered for management action or rehabilitation eg Chowilla Floodplain. The process would undoubtedly be an improvement on the "isolation of flow" process which is the current thrust of the Living Murray.

6.3 Addressing the cause rather than the symptom

If one reviews the objectives of Ministerial Council as noted in Table 1 of the ERP report, it is clear that a number are better addressed by non-flow related actions and in several cases the use of flow management is secondary to the primary management action. The clearest examples relate to water quality objectives. The cause of water quality problems is not usually in the river, though this is often where the symptoms are seen. Flow manipulation can be used to dilute or flush a water quality problem but this is only addressing the symptom. Various pollutants, nutrients and salinity are all better addressed at source. River Health Objective 4, overcome barriers to the migration of native species, will be solved more by addressing physical barriers and thermal pollution than by addressing flow, though lack of flow can be a barrier.

As noted, a clear risk is that the management approach will address the symptom (e.g. changes to the flow regime), rather than the cause (e.g. physical barriers in the rivers such as "*ageing, out-of-date barrage structures*" (Jensen *et al* 2000)). The Gurra Gurra Lakes Wetland Complex showed the symptoms of a lack of water but the cause was blocked flow paths across the floodplain (Jensen 2002). Provision of appropriately placed and sized culverts was the sensible action to target the cause while provision of greater volumes of water would only have addressed the symptom. This is not a new understanding; Cullen (2000) noted with respect to our current means of addressing river health problems "*Once again we seemed unable to address the cause of a problem and spent a lot of time and money trying to live with the symptoms*". The same logic can be applied here; the approximately $150M already approved by Ministerial Council to undertake some adjustments to the current weirs is a drop in the bucket (pardon the pun) relative to the value of the associated agricultural product. Recent funding decisions by COAG appear to be recognising that the cost of restoration will indeed be high. This recognition simply makes it all the more important to target the expenditure and ensure that the best outcomes are attained. Using the funding to simply buy back allocation in order to reduce volumetric use is unlikely to be the best use of the funding.

The physical presence of the dams and weirs is the cause of increased flooding of riverine habitat and near river billabongs, of stratification leading to potential and real blue green algal blooms, of temperature differences, of physical barrier effects with respects to movement of fish and other aquatic fauna, of erosion downstream and of changing a riverine environment to that of a lake or billabong. Even if the larger of the reference volumes were returned to the river, these impacts would not disappear. Options such as lowering weir heights and providing pumps, or removing some weirs, or even providing alternative transfer mechanisms such as discussed in section 6.10 below, may seem expensive now, but in the long term they may well prove not only feasible but the only way to ensure sustainability.

6.4 Prioritisation of actions: non-flow / non – volume / volume

A frustrating outcome of this review is the clear recognition in the literature of the significance of non-flow and non-volumetric sources of impact yet the almost single-minded push for volumetric adjustments to flow. A South Australian ministerial submission to Ministerial Council in May 2003 recognised numerous serious sources of impact; "*the River Murray is more degraded than ever, suffering from projected increases in salinity, bank erosion, siltation, toxic algal blooms, reduced and altered patterns of flow, invasions of weeds and feral animals and fish, and degraded and dying floodplain forests and wetlands*" yet in the next paragraph concluded only "*Governments must agree as soon as possible a target for reduced use by all states*".

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What happened to all the other problems? This sort of attachment to the simplistic figures touted in the ERP report was always a very significant risk associated with their production.

The basis for suggesting a prioritisation of actions which sees volumetric actions take a lower priority than others is that volume is the essential basis of agricultural production and capacity for population growth. Changes to the volume available to agriculture through reduced allocations are highly likely to have a greater socio-economic impact than changes which address other aspects of river health. If other options are available and will improve river health, then there would be little reason for not implementing them first. That changes to volume may be required should be recognised and stakeholders should take steps to prepare themselves for the eventuality. Such preparations may include attempting to improve water use efficiency and these actions take time – another reason to implement other actions first and give stakeholders the opportunity to make adjustments which will decrease the impact of any eventual volumetric adjustments.

The difficulty of separating those impacts resulting from individual aspects of flow regime change from those relating to other aspects of water resource development, or from non-flow hazards, has been stated many times. There is currently insufficient data to allow a clear empirical determination. What is clear is that the key impacting or threatening processes will vary between catchments and parts of catchments. In the Murray the impacts of cold water releases and altered seasonality of flow relate almost exclusively to the section above Yarrawonga while the impact of converting a river to a continuous series of stepped lakes relates only to the South Australian section.

The recognition of this need is not new. The TAP report for the Condamine Balonne WAMP stated "*Some of the major ecological issues affecting the ecological health of the Condamine-Balonne river system that lie beyond the limits of what can be addressed within the WAMP framework include:*

- *Removal of instream vegetation and woody debris*
- *Levee bank construction and consequent loss of floodplain inundation*
- *Excessive clearing of riparian "buffer zones"*
- *Overfishing of recreational fish species*
- *Diffuse and point-source influx of water contaminants*
- *Effects of irrigated farming upon groundwater levels and salinity*
- *Influx of agricultural chemicals into the riverine environment*
- *Destruction of floodplain wetlands for the storage of water.*

In some cases, a combination of these factors may have far greater ecological impacts upon the riverine environment than changes to the natural flow regime through water resource development."

All of these factors are relevant to the Murray, in varying degrees. The ERP recognised a number of principle ecological threats noted by earlier expert panels:

- Altered hydrology
- Reduced in-channel and floodplain connectivity
- Degradation and loss of physical habitat
- Poor catchment and floodplain management

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- Degraded water quality
- Exotic and invasive plants and animals.

While flow is the primary driver of the first threat, it is secondary with respect to the second and third threats when compared to the impacts of in-river physical infrastructure and associated pondages, levees, regulators and floodplain blockages such as roads, de-snagging, dredging, wetland filling and farming. Flow regime change is of little or no relevance to the causes of the remaining three. This is not to say that flow is not important, but it needs to be put into perspective with respect to other forms of impact.

The book "Rivers as ecological systems: The Murray Darling Basin" (Young *et al* 2001), is a product of the Environmental Flows Decision Support Program and summarises the known and suspected linkages between riverine ecology and river flow regimes. With respect to the included Murray case study and non-flow impacts the document states; "*While these non-flow aspects are not the focus of this case study, they are certainly significant*". How can the process keep noting the significance of non-flow aspects but not specifically address how taking action in regard to them may decrease the need to adjust volumetric aspects of flow, and thereby decrease the potential socio-economic impact?

Similarly Gippel and Blackham (2002) noted that it is difficult to isolate changes due to flow regulation from others such as catchment land use, fishing pressure, introduced species, riparian vegetation cover, large woody debris distribution, and natural variation in the flow regime; "*The difficulty arises from the fact that changes to these factors can produce <u>similar ecological responses</u> and changes in most of these factors have been overlapping or simultaneous with flow regulation*" (underline added). The core logic behind the management approach recommended in this current review is that because many of the "other factors" produce similar ecological responses, addressing them can produce similar ecological benefits.

Gippel and Blackham (2002) also noted "*Environmental flow studies normally consider only hydrological aspects of river management, while the hydraulic environment falls within the domain of river rehabilitation (e.g. meander re-instatement, riffle construction or snag re-introduction), but this may be an unhelpful separation. Implementation of environmental flows is only one of the tools that can be used to rehabilitate rivers. River rehabilitation can involve flow issues, as well as floodplain issues, riparian issues, catchment management and in-channel works. It would be rare for rehabilitation of a degraded river to require consideration of flow issues only. Ideally, clearly defined rehabilitation objectives should guide the direction of the environmental flow evaluation*." The objectives of Ministerial Council and all the bottom-up work to date had the process going in the right direction but the Living Murray process, which separated flow aspects from non-flow, and the top-down approach of the ERP, turned this logic on its head. It is not only "unhelpful" to separate these issues, it is illogical and very risky with respect to decision-making which will lead to socio-economic impact.

Significant reports such as the Scientific Reference Panel and the Snapshot, noted the importance of maintaining quality habitat. It is clear that much of the faunal diversity is in small areas of specialised habitat, such as macrophytes, snags, tree roots, river benches and patches of algae. The area of such habitats has apparently been significantly reduced through the impacts of catchment-wide land clearing, particularly within the riparian zone, filling of wetlands, through grazing and its accompanying erosion and sedimentation issues, through snag removal, dredging, river improvement works and a number of other sources recognised in earlier works. Management action directed at specific habitat degrading impacts would appear to offer significant potential to maintain quality habitat and thereby, faunal diversity. The ERP report seemed to be overly concerned with the gross volume of water, and thereby the volume of habitat, rather than the quality of habitat.

The Scientific Reference Panel actually listed 15 non-flow related causes of impact and these can be seen as sub-sets of the points above:

- Grazing of riverbanks
- Clearing of riverbanks
- Promotion of exotic riparian vegetation
- Removal of snags
- Recreational boating
- Aggregate extraction
- Floodplain development
- Various land use practices
- Culverts and regulators
- On-stream storage structures (including):
    - Physical barrier effect
    - Erosion and sedimentation
    - Habitat reduction / simplification
    - Drowning of connected wetlands
    - Increased threat of algal blooms
- Increase in diffuse nutrient sources
- Diffuse toxicant sources
- Catchment-based erosion and sediment input
- Temperature of releases
- Hypolimnetic releases (water quality)

The on-stream storage structures category above has been expanded to show that it is multi-faceted; many of the other items also include a multitude of impacts. Some impacts noted as significant in other documents (eg Margules & Partners 1990) are not noted above. They include:

- Salinisation (though it is mentioned in “various land uses” as a barrier to fish movement.)
- Feral animals (eg rabbits and linked to grazing and erosion pressures)
- Weeds
- Logging
- Point source pollutants.

In reviewing this list it is obvious that action to address any item would likely provide benefits to river health but would not affect water entitlements. Some are more important than others but the precise order of priority for action is unknown and will vary between locations.

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Similarly there are a number of aspects of flow management which do not necessarily require a cut in allocated volume to address them or they actually relate to an excess of water. These include:

- Alteration of seasonality between Dartmouth Dam and the Edward-Wakool junction
- Unseasonal high flows, particularly in summer
- Elevated water levels in weir pools (the need for a drying phase)
- Rain rejection flows.

Seasonality of flow is obviously more an issue of timing than it is volume. Instead of trying to solve this problem by altering when the water went down the river, the ERP simply reduced the volume going down at what is recognised as the wrong time. Similarly while the SRP recognised unseasonal high flows as the highest priority item in the section between Hume Dam and Tocumwal, and suggested options of either reducing demand or delivering water by means other than the river, the ERP process took no account of the second option.

Hydrological models cannot assess all of these attributes; in fact they cannot even assess all the flow attributes. What is required is a means of weighting impacts from different sources and with different associations. This is where risk assessment really does come in.

Integrated Catchment Management in the Murray Darling Basin 2001-2010 (MDBMC 2001) notes that a well-developed action plan:

- *"Integrates a range of issues (single issue plans must clearly show effects of or impacts on other issues and take account of best management practices for those issues). (*Concentration on flows, and volumetric aspects of flows, does not do this*).*
- *Technically assesses biophysical processes and identifies the most appropriate responses*
- *Evaluates a range of possible options for action, including a 'no-plan' scenario, in order to optimise the benefits and minimise the costs*
- *Identifies priority actions and locations to achieve agreed targets and outcomes".*

The document also notes with respect to mechanisms for implementation; "*we will:*

- *Choose the mix of mechanisms and scale for applying them according to the effect they will have in helping achieve targets*
- *Involve our partners in determining mechanisms to be used*".

The Living Murray process to date, particularly as reported by Jones *et al*, is almost the antithesis of that espoused in the quoted document because it appears to be searching for a magic volume and largely ignoring the integration and targeting components.

6.5 Knowledge-based management

We seem to be prepared to make the most significant changes to those components about which we have the least knowledge. We have good confidence levels in our understanding of the importance of riparian zones, of the impacts of erosion and sedimentation, of the barrier effects of dams and weirs, of the drowning of habitat caused by these barriers, of the armouring of substrate caused by releases from these structures, of the importance of snags and macrophytes. We have very low confidence levels in our ability to predict biotic responses to particular components of the flow regime. We can certainly understand the general importance of high or low flows. We should be targeting those aspects which we know will have a beneficial result but also have the least socio-economic impact before targeting aspects about which we are less confident but know they will have significant socio-economic consequences. Volumetric aspects of flow largely belong in the latter category. Young *et al* (2001) noted a range of sources of impacts on native fish (general habitat degradation, altered streamflows, introduced fish and diseases, interrupted migration pathways, reduced water quality and pollution, overfishing and changed energy fluxes) and concluded "*the relative significance of these factors is unknown*". Given that, why not try to fix the ones which have the least socio-economic impact first?

A key aspect to consider with respect to the future information base for decisions was noted in the 1999/00 Water Audit, "*some of the technology based support systems (eg improved river modelling) are proving to be more involved, time consuming and labour intensive than originally anticipated*". While this was probably somewhat naïve, it will only get worse as stakeholders catch up and demand more accurate data and more certainty of predictions. Ecological predictive and monitoring systems are well behind hydrological systems and will require very considerable time and resources in order to catch up and be able to provide the level of information that stakeholders will demand.

Stakeholders need access to the key documents and they need knowledge-based interpretations of those documents in order to have informed input to debate. This review commissioned by MIL is a clear example of the recognition of the need and the increased desire of stakeholders to be intimately involved in decisions which affect their enterprises and livelihood. Both stakeholders and management agencies need better ecological data, both in the form of consistent and repeated monitoring results and directed research established to fill critical gaps in our understanding of relationships between environmental variables and ecological attributes. The Sustainable Rivers Audit will greatly assist the former and the current granting system can be targeted to satisfy the latter. Private stakeholders need to become more involved in the information gathering process and become significant owners of quality data upon which low-risk decisions can be made.

COAG recently linked declining river health in the Murray to over-allocation of water resources in the Basin. I strongly suggest that a significant portion of the $500M allocated by member jurisdictions be spent on attainment of knowledge which would assist the risk assessment process outlined above and on conduct of the process.

Documents which superficially appear knowledge-based, but make invalid interpretations, need to be identified as of limited use. The Living Murray discussion paper (MDBMC July 2002) is one such document. The document states; "*Some <u>major</u> issues of river health – like salinity, turbidity and the decline in native fish – are due to other factors besides altered flow patterns in the river*". This is probably true yet in the section "State of our Rivers; threats to the values we prize", it states that changes in flow have led to the following changes in river health:

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1. widespread increases in nutrients and sediment in water
2. river flow rated poor in all zones of the River Murray
3. vegetation and wildlife significantly impaired along 40% of the total river length in the basin
4. 16 of the Basin's 35 native fish species listed as threatened
5. salinity in the Lower Murray is projected to rise by 50% and more than 100% in many smaller rivers in the coming 50 years.

The document itself had earlier stated that points 4 and 5 were not due to flow (though point 4 certainly has some flow component). The reference for most of these conclusions is the Snapshot but as noted previously, point 3 is simply incorrect, exaggerated and therefore a misleading interpretation of what the Snapshot concluded. Similarly the Snapshot clearly concluded that increased nutrients and sediment are a land management issue (though water storages can effect these also). Point 2 simply says that flow change has led to flow change and as noted in the ERP report, hydrological measures are not actually direct measures of river health. The section also notes; "*Salinity, turbidity, nutrients, algal blooms and water temperature changes are signs of declining water quality, and all are effected to some extent by the amount of flow in the river*". While the statement is true the "*some extent*" must be quantified and "Amount" is volumetric. As such the text misleads readers to understanding that volume is the driver of water quality changes whereas it most certainly is <u>not</u> with respect to the bulk of the changes noted. For the statement to be of real use to the debate it needed to be supported by an estimate of the proportion of the water quality decline which was due to volumetric aspects of flow as opposed to non-volumetric aspects, or to non-flow aspects of water resource developments (the presence of dams etc). The last statement in this section is more correct; "*Improved catchment management is needed to address the causes of water quality decline. Improving the flow pattern will also help and is one part of this strategy*".

It should also be clearly noted that a <u>projected</u> (future) increase in salinity could not possibly have <u>led</u> (present or past tense) to impacts on river health. If the statement is relating those projected increases to changes in flow, then the link needs to be firmly established, separated from dryland salinity impacts and the changes separated into those related to raising water levels (weirs etc), use of the water (irrigation etc) or some direct impact of in-river flow on salinity.

6.6 Focussed flow management

Just as the eventual outcomes of the Living Murray planning process will largely be site based actions targeted at protecting particular areas or attributes, so the management of the flow regime needs to be more focussed to be effective. As an example of why the simplistic approach of the ERP did not aid realistic target setting, consider a red gum woodland in the intermediate floodplain, the area most impacted by reductions in mid-range flooding. The volume of water which actually fills that area of woodland and which is of real benefit to the trees is only a very small proportion of the total flood volume. Most of the volume simply lifts the necessary small amount out of the river and pushes it to the area of floodplain. The 80 / 20 rule may actually not be too far wrong with respect to environmental management of volumes of water – if we are innovative and target outcomes appropriately, we may be able to get 80% of the outcome for that area of woodland for 20% of the natural overall flood volume. This example does not ignore connectivity issues. It has simply made the assumption that the primary target at this particular site may be the vegetation, with connectivity issues at this site being a secondary issue. If they were deemed an essential component then a means to include them in the local flow management plan would be necessary.

6.7 Multiple use

Water is an extremely valuable commodity in Australia, even if it is still not properly recognised as such in a financial sense. Multiple use is a necessity. How can multiple use be built into innovative new water management systems of the future? For example, while it is clear that water in the river on its way from a dam to an offtake point is performing environmentally valuable work, how much such work do we ask that water to do once it enters the irrigation system *per se*? Should we use our irrigation delivery system to water mid-level floodplain wetlands as described above, rather than manufacture a flood to do it? This approach is in fact used in parts of the system today. Both volumes of water and systems of infrastructure can be multi-purpose.

How we account for multiple use is an important question. Gippel (2003) defined Environmental Water Allocations as volumes of water set aside specifically for environmental benefit. This specificity may be detrimental to efficient management. Simple water balances look at inputs, outputs and losses and these are not sophisticated enough to handle the concept considered here, possibly best termed “effective use”. As a simple example, if a volume of water is extracted from the river as urban water supply and the wastewater is then used to flood a wetland while en-route to a final effluent irrigation disposal site, then there have been four periods of effective use from the point of generation to the point of final use. The one volume of water has done ecological work in the river prior to extraction; it has performed work to benefit society following extraction, the wastewater, or residual following human use, has performed further ecological work in the wetland and finally any remaining flow which eventually produces pasture is performing further economically beneficial work. The sum of the volumes in each phase of effective use would be greater than the initial volume in the river. It is for this reason that the concept of “over-allocation” is an interesting one. The concept of multiple use negates the use of “divertible resource” or the like as a basis for stating that a system is over-allocated.

Similarly if a chain of wetlands has a volume of 100ML but it takes a flood of 1000ML to get that volume into the wetlands, then an alternative method of delivery which only needed to extract the fill volume itself would essentially be doing the equivalent work of a 1000ML under natural conditions (less any other work the 1000ML did on the way to the wetlands). Equivalent use is another concept which needs development.

A number of recent examples point to the potential benefits of multiple use and innovative thinking. Gippel (2003) reports that the restoration of Moira Lake in southern NSW produced environmental benefits in conjunction with an annual water saving of 2027ML. This is an example of incorporating a drying cycle into what was a permanently flooded wetland and this type of action was rated as a very high priority by the SRP throughout much of the system so similar savings could be expected in many areas. Conversely the "trial watering of wetlands on private land" in the Murray Irrigation area provided significant environmental benefits by flooding 572ha of wetlands which had been dry for up to 30 years. That project used just 3975ML. Putting the two types of projects together such that the water saved through wetland drying is put toward the flooding of dry wetlands, will clearly be able to produce significant environmental benefits for essentially no change in the volume of water licensed for extraction.

In Victoria, temporary trading of the Environmental Water Allocation, once all environmental requirements had been met, has generated $1.2M which was subsequently used to pay service delivery costs and cover some on-ground works (Gippel 2003).

The concepts of multiple use, effective use and equivalent use are examples of why simple comparisons of current flow with natural flow at a point in the river, or summing the flooding requirements of a number of sites, are essentially useless for determining what volume of water is actually required in order to perform targeted ecological tasks.

It is also important to realise that appropriate management of flow regimes in order to sustain aquatic ecosystems does not only refer to 'allocations' within heavily utilised parts of systems. Appropriate management probably already occurs through passive means (<u>not</u> stimulating water resource related development) in the upper catchment of most if not all tributaries and for significant lengths of tributaries such as the Kiewa and Ovens rivers.

6.8 Jurisdictional impediments to environmental management

One of the frustrating things which is obvious from a review of the relatively recent history of scientific research and management in the Murray is the clear recognition of a number of problems and an apparent very slow response by management in terms of actually doing anything about it. For example Margules & Partners specifically addressed dying red gums and limited eucalypt regeneration in South Australia in 1987-88 and referred to the need to address weir operation. Jensen (1997) stated "*Significant progress has been made in defining opportunities for changed river operations in the lower Murray below Wentworth to benefit floodplain wetlands, utilising the existing weirs and Lake Victoria*". A South Australian ministerial submission to Ministerial Council in May 2003 noted "*We <u>are developing</u> an environmental flows strategy for the South Australian section of the River Murray, and this <u>will incorporate</u> flow and water level variations in the otherwise static pools behind the locks and weirs. <u>It will</u> also contain operating rules to build upon and maximise the ecological value of floods*" (underline added). As the underline shows, it still hasn't happened.

Gippel (2003) concluded "*evidence from elsewhere suggests that implementation and monitoring of environmental flows is best reduced to local or regional scale problems that involve relative simple interventions, few jurisdictional issues and potential to build a strong sense of community ownership*."

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Cullen (2002) summed up the historical problem "*For much of the last 100 years our energies have gone into squabbling over dividing up bits of the pie rather than managing the resource in a holistic and sustainable way*." While stated as a comment on jurisdictional impediments to management, the statement is equally true with respect to separating discussion of impacts on river health related to flow from those related to non-flow aspects or to exclusion of most tributaries from the discussion.

6.9 Innovation

Management also needs to be innovative. Integrated Catchment Management in the Murray Darling Basin 2001-2010 (MDBMC 2001) specifically notes "*we will actively seek to use innovative mechanisms to achieve targets*". This review has not as yet come across any significant innovative thinking at any scale. For example is there a way that the conflicting impacts of too much water in the river and too little on the floodplain can be managed to result in no net change in volume extracted but achieve significant environmental improvement? Are we prepared to seriously consider major regional offstream storages in order to add flexibility to the system? Are we prepared to invest in some pumps to address the problem of high unseasonal flows? How can we reduce the conveyancing losses which currently account for 29% of water diverted in the southern MDB? (ACIL Tasman for MDBC, March 2003) While some of these are not innovative as such, they would certainly result in significant environmental benefits, at significant direct cost but for no change in volumetric use and therefore no impact on potential agricultural production.

Innovation need not be restricted to the scale of action which might apply to a site, such as pumps at offtakes, or reducing losses from channel systems. Innovation may be addressing what a sustainable irrigation system at the scale of the River Murray may look like in 50 or 100 years time. Are there ways to capture, store, transfer, use and dispose of water used for irrigation which would result in less environmental impact yet have minimal impact on production? Are we tinkering with the symptoms without addressing the causes? It is clear that in order to reduce the level of environmental impact we need to reduce the changes brought about by in-river physical infrastructure and the use of the river channel as the means of transporting irrigation water. This needs thinking beyond the level of tinkering with the operating heights of current weirs.

Cullen (2002) stated "*I would like to propose a Basin that in 25 years:*

- *Has doubled GDP generated in the basin*
- *Supports double the population we now support*
- *Provides a river where we can drink the water and catch Murray Cod in the Lower reaches*."

These goals will not be achieved without innovative thinking or without substantial ongoing use of the water resource. Achieving the balance will be much more complicated than guessing at 'one-size-fits-all' proportions of natural flow and the economic and social achievements would in all likelihood be impossible to achieve based on use of just 1/3rd of the resource.

Like Cullen, the Murray Catchment Blueprint (DLWC 2003) targets a win-win situation; "*The implementation of this Murray Catchment Blueprint will bring about*

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significant environmental, economic and social benefits to the NSW Murray Catchment community.” The Blueprint puts forward a range of non-flow intervention activities in order to maintain the existing environment and in some cases bring about improvement.

6.10 An alternative option

For the purpose of stimulating thought, and ignoring feasibility or cost for a moment, a discussion is presented about the ecological benefits of an irrigation system which uses more offstream storage and transfer options than the current system. If we assume a number of significant sized offstream storages (several hundred gigalitres for example) can be built at strategic regional locations in the system, how can they be managed and what would be gained? The storages should be as deep as possible (8m?) in order to minimise surface area and they should be multi-celled in order to allow amalgamation of remaining water and thereby reduce evaporative losses. This creates an advantage over the current single cell in-river storages (other than Dartmouth and Hume) because Lake Mulwala for example averages only 2.8m depth. The water level in the river can be reduced for a number of months following the peak irrigation period in order to achieve drying of the near river wetlands. A significant flow can then be used in early spring to re-fill the system, including the offstream storages. This could coincide with any pre-release for flood mitigation purposes and could be timed to closely mimic the natural flow sequence. Once the offstream storages are full, the river can be allowed to slowly lower to a base flow which is lower than is currently experienced under regulated conditions. The offstream and in-river storages can then be managed in conjunction to create the air space and short-term in-river flow variability which was targeted by the SRP. Given the total volume of use in the Yarrawonga to Torrumbarry section, it is likely that a more than one major flow in the irrigation season may be needed to top up the system. These floods should be managed to coincide with the natural period of flooding as far as possible and even if it resulted in out-of-season small summer floods, this is likely to be less deleterious than the consistent high non-flood flows as is currently the case.

This system would result in pulsed flows rather than the relatively static regulated flows which currently dominate and the reversal of seasonality below Dartmouth could be significantly addressed – without resorting to reductions in allocations.

In downstream areas with less use, one good-sized offstream storage could hold enough water to almost negate the use of the instream structure. Removal or lowering of the instream structures may be possible. The offstream structures would need to be well sealed in order to prevent accessions to groundwater. The offstream structure may also be more amenable to physical or chemical manipulations to enhance its water storage efficiency because they would not be a component of the natural system, as instream structures are.

The offstream transfer system for water within irrigation schemes could be extended so that they included a function for watering floodplain areas en-route. In other words water could be passed to or from the offstream storage through a valuable wetland or forest area and recaptured for further irrigation use downstream. Alternatively or coincidentally, part of the flow could be directed back to the river or an anabranch to achieve a level of connectivity. This is analogous to the SRPs recommendation with respect to Lake Victoria, which is currently used basically as an offstream storage; "*Additional water in Lake Victoria be used to augment floods that will water the floodplain rather than fringing river wetlands"*. As noted earlier, the volume needed to flood these areas does not necessarily have to come on the back of a flood in the river. The volumetric losses in such uses would be partially compensated by the decreased evaporative losses achieved through use of the deeper storage while the environmental benefit would allow the volume to be incorporated in the calculation of environmental flow volumes.

As the offstream storages would be closer to the point of use than the current headwater storages, the potential for rain-rejection events would be significantly reduced. The storages may be able to capture these events were they to occur. The Wanganella Swamp watering trial noted one difficulty as the long travel time between the wetland the point of river regulation – an offstream storage could alleviate this problem.

One of the main issues raised against the option of offstream storages is the availability of land. However it should be remembered that there is a lot more land on the landscape than there is river.

6.11 The Decision process and possible trade-offs

While targeting of sites or areas to protect, conducting risk assessments in order to set management priorities, and following the protocols outlined by Rutherfurd (2001) in decision-making, has been recommended in this report, there are a number of impacts to the river which are more widespread and for which generalised solutions can be sought. The SRP report identified a number of such common impacts. In prioritising means to address these impacts MIL may wish to consider the following.

Adjustments to water volume cause the greatest social and economic impacts in irrigation areas because volume is the key driver of productive capacity. As such, if beneficial outcomes for the environment are sought and can be achieved by other means, such as non-flow options and non-volumetric components of flow management, then these should be prioritised for implementation. Each circumstance will require specific analysis and innovative means to provide the water necessary, if that need were shown to be the case, must be investigated.

Results of implementation should be monitored but if community-agreed goals have not been satisfied by these initial actions alone, further action may be necessary and it may include volumetric considerations and these in turn may require a reduction of allocations if the volume cannot be achieved through efficiency gains. The community-agreed goals referred to here are those developed at the commencement of a wetland rehabilitation program for example. Bigger picture community goals, such as catchment or basin level goals, can only be confirmed when the impacts of whatever actions are necessary to achieve those goals can be identified.

If a reduction in allocation becomes necessary then a process which determines how and which allocations should be reduced will be necessary. Simple proportional reductions in all allocations are unlikely to be the most cost effective means and whatever the process, prioritisation which protects currently utilised productive allocation should be preferred, except in cases where it is clear that significant environmental damage is resulting from that specific usage.

In a big-picture sense, the impacts of water extraction on the environment of the Murray are likely to be significant as the level of use is very high. Even after targeting and prioritisation of actions it is likely that some present allocation will need to be re-allocated to environmental purposes. Where that water is sourced, as mentioned above, will depend on where it is specifically needed and it may be that all constituents pay part of the cost, in dollar terms, if one area suffers more volumetric loss as a result. Whatever the case though it is likely that MIL will have the option of transferring part of its allocation to the environment and this brings with it a range of trade-off opportunities. In fact it may be best if MIL and like-organizations were given the option of how they achieved any necessary volumetric reductions in their area. If MIL chose to look for efficiency gains from re-designing or upgrading their infrastructure or investing in alternative technologies then that would be their choice. Simplistic across the board cuts would negate any incentive to be involved in such innovative solution-driven activities.

The really big picture is a national level – why do we want to prioritise saving the Murray? The ARC showed that most rivers and most reaches in Australia are actually in reasonable condition and Rutherfurd and others point out that it is more costly to rehabilitate damaged systems than to avoid impact in the first place. Queensland parts of the Darling, eg the Paroo, Bulloo, Nebine and Warrego, have been protected from significant extraction through Water Resource Plans. The trade-off is that the Condamine and Border rivers are classified more as working rivers and greater extraction is allowed. The Murray is probably the hardest working river in Australia and there are good social and economic reasons why it should stay that way.

If we cut back on productive output of the Murray through decreasing extraction, is this just going to put pressure on systems which are not currently hard working or stressed? Trade offs thus begin at a national and a Basin scale.

Another trade – off consideration at this level is a time-based one. If we cut back on water use now, is this just going to create a major problem in the future when we think we need to use more? Our need for agricultural production and other beneficial uses of water is unlikely to decrease so while the potential environmental benefits of reduced allocations now may be significant, will they still be the “winner” in the balancing act in 25 or 50 years time when we have a much larger population and far more greater need for agricultural production?

Trade offs with respect to river health management can relate to:

- trade off flow adjustments against land use adjustments ie fix land use first.
- trade off non-volumetric adjustments against volumetric
- fix those parts which have a problem related to too much water first, as this does not hurt volumetric allocations but you must ensure that any water transferred to another location is used for environmental purposes
- use any new environmental water so as to get the best environmental bang for the volumetric buck (that is, prioritise those areas which gain proportionally more environmental benefit from smaller volumes of water)

- maximise water use efficiency through recycling, deep multi-cell offstream storages, polymer layers on dam surfaces, sealed transfer systems etc
- pipelining the water supply is an option but whatever water is sent this way cannot do any ecological work while its in the pipe
- water should be multi-purpose
- address parts of the system which show declining trends in particular attributes first – eg water quality in Zone 4.
- increase the use of groundwater in areas where it is currently under-utilised. This must be for net environmental benefit, that is, take the place of surface water use, rather than for increasing overall use and it must not affect salinisation.
- trade off social cost for environmental benefit eg give back water from irrigators and simply wear the cost.
- trade off one region for another eg it may be considered that the Lower Murray or the Dartmouth to Hume section is too degraded or too expensive to fix therefore protect somewhere else. The idea of sacrificing some parts of the river where it is just not worth trying to fix it accords with the principles of Rutherfurd (2001). The temperature regime of the latter can be fixed but very high flows will always be needed for transferring water and the section is essentially isolated because there is a major blockage at both ends (Hume and Dartmouth) so gains are limited. Having said that though, in this day and age multi-level offtakes in deep storages should be compulsory
- trade off regions based on agricultural economic sustainability. Put environmental funds into regions where agriculture is not likely to be sustainable. The concept of ecological zones of sacrifice may equally apply to agricultural zones
- reduce security of supply to a level where efficiency gains should be able to compensate
- sacrifice sleepers and dozers first ie those who haven’t used it, have lost it
- permanent trade of allocation to downstream areas eg from higher usage upstream areas or tributaries to South Australia. This gets water flowing down the system but it should only occur if it does not lead to environmentally negative consequences eg increasing the period of elevated baseflows or decreasing the ability to vary the depth of weir pondages or exacerbate salinity in downstream areas
- allocation of water to the lower end, if transferred from the upper, should be via pulsed flow at the natural seasonal timing and so do some environmental work on the way eg a small flood all the way down. Once it gets there, if its not planned to go to sea and is out of season for irrigation, it should go to offstream storage. This can be a wetland which needs water temporarily so holds it till the irrigation season (or slow releases it back into the weirs for later use)
- provide alternative means of accessing water for those on anabranches which are wetter than usual and need to be dried occasionally (groundwater? Small offstream storages? Different pump locations?)
- government or private bodies could buy water as part of an environmental bank.

6.12 Stakeholder involvement

As more and more power is devolved to regional bodies and stakeholder groups gradually amalgamate to form significant management bodies, their roles will change from being simple sectoral lobby groups or the implementers of government programs to being managers in their own right with all the corporate responsibilities that go with it. Murray Irrigation Ltd is still in the throws of that change.

Given the emphasis in this report on impacts associated with in-river infrastructure and the use of the river for transport of water, I would recommend that MIL assess what an efficient and sustainable irrigation scheme will look like in 50 years time and, while not locking in to any particular design, attempt to ensure that whatever actions you take now do not conflict with a long term design and ideally should be part of it (eg moving to regional offstream storage and transfer).

I suggest that stakeholders generally need to become more involved in regional environmental management and seek to include such as a core component of their responsibility (triple bottom line reporting). Coordination of responsibilities with respect to irrigation and environmental components will lead to better balance and integration of actions, a greater degree of ownership and less potential conflict. In doing so, stakeholders will become more responsible for setting targets, implementing strategies and monitoring performance. I suggest in doing so that the risk assessment process outlined here is a good starting point, followed by prioritisation of targets according to the protocols of Rutherfurd (2001). I strongly suggest that if MIL or any stakeholder develops an environmental monitoring program that it use the "maintenance / improvement" target as your basis. This will allow the use of the current condition as the baseline for assessment without reliance on comparisons with an assumed natural state. Whatever planning and actions you wish to undertake should be cognisant of and link to other regional planning activities as far as possible, as I know you currently do with respect to the NSW Murray Wetlands Working Group. The Murray Catchment Blueprint is a good example of potential management synergies in your specific area.

Endeavouring to assume more responsibility as suggested will also give you more options with respect to trade-offs. I appreciate that you are not the responsible authority for much of the system as discussed in this report but it would be of undoubted benefit if yourself and other similar stakeholders took each opportunity to gain a better understanding of the issues, have informed input to debate and assisted with the evaluation of options.

Your geographic region shows some environmental attributes apparently in very good condition but also large areas of possibly good environments about which we know little. There are also areas of known poor or questionable quality. An inventory and categorisation, on a suitable GIS base, would be appropriate as a first step toward knowing what your local options are. I note that such baseline establishment is a key component of the Murray Catchment Blueprint.

The science behind the Living Murray.

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8 Appendix A: Peer Review

The following is the complete review of a draft of this report as received from Dr Bruce Chessman. Dr Chessman's comments were taken into account, along with those of others, in production of this final version of the report. If however I did not completely agree with Dr Chessman, changes or lack thereof may not completely reflect his comment. Dr Chessman undertook the review in his own time, unconnected to his employer. Dr Chessman's comments are greatly appreciated and he is thanked for his time.

Comments on draft report 'The science behind the Living Murray' by EM (Ecology Management) Pty Ltd.

Bruce Chessman, October 2003.

<u>The following comments represent my personal opinions as an aquatic ecologist.</u>

I found this report to be an extremely thorough, detailed and incisive analysis of key documents and other scientific information relating to the Living Murray initiative. It builds a strong and well documented case for the importance of non-hydrological factors to the ecological condition of the Murray River and its floodplain. It exposes major limitations in recent evaluations of alternative environmental flow scenarios. I particularly liked the section on options for aquatic environmental management. I felt this contained many original and creative ideas and raised many key issues such as the importance of focussing on practical and high-priority management targets, informed by specific knowledge.

I could find very few technical errors in the report. In a few places I felt that the role of flow had been somewhat understated. Also, in-channel hydrological change is repeatedly described as 'too much water'. While from a perspective of natural ecology this is true of summer irrigation flows, there may be benefits to natural ecology from increased in-channel winter-spring flows (though to my knowledge not yet much addressed in scientific research on the Murray). Specific comments follow on components of the review.

Introduction

I suspect that an additional reason for the popularity of expert or scientific panels is their perceived role as a neutral umpire, independent of commercial interests and government, and the public acceptance that this engenders. Like EM, I am concerned that 'scientific panels' often seem to feel immune from the normal scientific requirement to support statements with evidence, and may omit or gloss over limitations and assumptions. Possibly this results from the pressure these panels feel to produce definitive answers.

In the reference on p.3 of the EM report to 'vagary in the outputs', I think 'vagueness' may be intended.

The science behind the Living Murray.

Report on the Murray River Scientific Panel

In the last line of the first paragraph (p. 6) I think 'ambit' is intended rather than 'gambit'.

At the end of the 2nd paragraph on p. 6 it is implied that the panel recommendations addressed only improvement in ecological condition and not maintenance, contrary to their brief. Although I agree that most recommendations are about change, maintenance does sometimes seem to me to be advocated (e.g. the last part of Z4.2 and first part of Z4.3).

On p. 9 reference is made to 'summer flows now 7-fold greater and late winter spring flows nearly that much less'. Clearly, they cannot be 7 times less. Perhaps one seventh as great?

In the 5th paragraph on p. 10, it is not clear to me how salinity can be 'an issue for the ecology of some inundated wetlands - because it is largely natural' (assuming natural conditions are considered desirable).

Snapshot of the Murray-Darling Basin

The review notes that the ARC analysis suggests hydrological change is less than some other forms of environmental change. I think caution is needed here because the methods used to calculate the various indices may mean that they are not entirely comparable, even though all scaled from zero to one.

A bigger problem is the use of AUSRIVAS. Although AUSRIVAS reference sites are routinely described in the Snapshot and other documents as 'near pristine' and 'minimally disturbed', in my experience this is often untrue. In fact, NSW reference sites are often subject to quite substantial disturbance from river regulation, flow extraction, altered catchment land use, alien species and other factors. These types of disturbances are simply unavoidable for huge areas of the Murray Darling Basin. Hence AUSRIVAS scores tend to underestimate European impact. I believe this is the main cause of non-concordance between the biological and environmental components of ARC, rather than the postulated role of lags or macroinvertebrate insensitivity. I have performed alternative analyses not based on AUSRIVAS reference sites that suggest that macroinvertebrates are actually quite sensitive to most of the environmental factors incorporated in the ARC (manuscript in review).

p. 35 refers to the final destination of river sediments as reservoirs and the estuary. I think floodplains are likely to be a major sink as well.

Independent report of the Expert Reference Panel

System-wide approach

The ERP generally uses the term 'system level' rather than 'system wide'. Although I agree with EM that the regulated-floodplain system considered by the ERP represents only part of the total river system, I don't think this limitation is problematic for the ERP's principal terms of reference of assessing alternative scenarios, since these scenarios apply only to the regulated system. However, I agree that the ERP report includes much commentary on the condition of the system that appears to apply mainly or solely to the regulated system, without making this restriction clear. Referring to the regulated system under MDBC jurisdiction as ‘a very restricted part of the system’ (EM report p. 50), is perhaps going a bit far, particularly if stream size is considered rather than just stream length.

Although the scenarios provided to the ERP for its assessment exclude non-flow options, the ERP report does clearly recognise the importance of non-flow management. I think the EM report could do more to emphasise that this is not a fault of the ERP but a constraint imposed by their terms of reference. On p. 50 of the EM report it is stated that ‘only volumetric aspects of flow are quantitatively assessed’. However, the ERP did also address changes to regulatory structures, and includes some non-flow indicators (salinity and algal blooms).

I am uncertain how great is the risk of the ERP system-level approach militating against targeted local management, as the EM report suggests. This would seem to depend on the way the accepted flow option is actually implemented.

Healthy working river

I also found the operational application of this concept by the ERP problematic. I don’t think ERP is treating a fully natural state as a target (EM report, p. 52), but I agree there does seem to be some discrepancy between the Ministerial Council Objectives (Table 1) and the ERP ecological outcomes (Table 2). Neither the objectives nor the outcomes are quantitative, measurable endpoints, so it is difficult to see how we will know in the future whether a ‘healthy working’ state has or has not been achieved.

On p. 53 the ERP refers to the possibility that the community might accept a ‘less scientifically rigorous definition of health’. I would argue that ecosystem health is a human value judgement, not a scientific concept, since I can see no objective reason for regarding a particular ecological state as healthiest – naturalness is a common choice but nonetheless subjective. Therefore scientific rigour is not relevant.

On p. 54 of the EM report, I think ‘does’ in the 2nd last line of the 2nd paragraph is intended to be ‘does not’.

The statement on p.54 of the EM report that Fig. 2 of the ERP panel shows the equilibrium point of the ‘do nothing’ scenario as ‘as much worse than the current condition as that condition is relative to a healthy state’ is incorrect. The figure actually shows the difference between current and equilibrium as about the same as the difference between current and the 1960-70 state. I agree that there seems to be little strong evidence to support the current steep decline in condition postulated by this figure, and it is hard to envisage what current environmental changes would drive such a decline. As explained above, I regard the discrepancy between the ARC environmental and biotic scores as much more likely due to differences in referencing than to lag effects.

The science behind the Living Murray.

The risk assessment process

I agree that the use of the term 'risk' is potentially misleading. 'Risk-based assessment' in the ERP report appears to simply mean probabilistic prediction (and an extremely vague prediction at that). I also agree with the EM report that the ERP's portrayal of the ecological response curves and associated environmental flow limits implies an empirical foundation that does not appear to exist. As EM indicates, these curves are purely hypothetical. The 'ecological score' is actually a mathematical transformation of the flow statistic to express the authors' perceived 'goodness' of differing levels of that statistic. A real ecological variable would not behave like the 'ecological score' because it would respond in a complex manner to a mix of many hydrological and non-hydrological factors, not to a single hydrological factor. The ½ and 2/3 thresholds are effectively arbitrary points on the perceived goodness continuum, and seem to have no defined relationships to measurable ecological endpoints. EM's report thoroughly dissects the approach and exposes such limitations.

Indicators and scoring

Although weir drown out is the **statistic** used in relation to fish barriers, the ERP report does include other measures in its structural recommendations. This could perhaps be clarified on p. 65 of the EM report. I don't understand the comment on p. 65 about mean summer flow being assessed only for the upper Murray. The chart atop p. 43 of the ERP report shows median (not mean) summer flow for other areas as well. The composite scoring on p. 30 of the ERP report is indeed odd since, for example a high, 2 mediums and a low gives the same overall result (medium) as 3 highs and a medium.

Options for aquatic environmental management

In the set of dot points at the top of p. 88 I'd suggest that alien species be added (and possibly desnagging).

The statement on p. 94 that flow is a 'secondary or minor' driver of connectivity and habitat degradation/loss is perhaps downplaying the role of flow a little too far. Certainly, loss of connectivity if often due to structures rather than flow change, and adverse habitat changes can occur for many reasons. However, there are circumstances in which lack of flow can be a major contributor to these processes.