Integrated Basin Reporting – Floodplains

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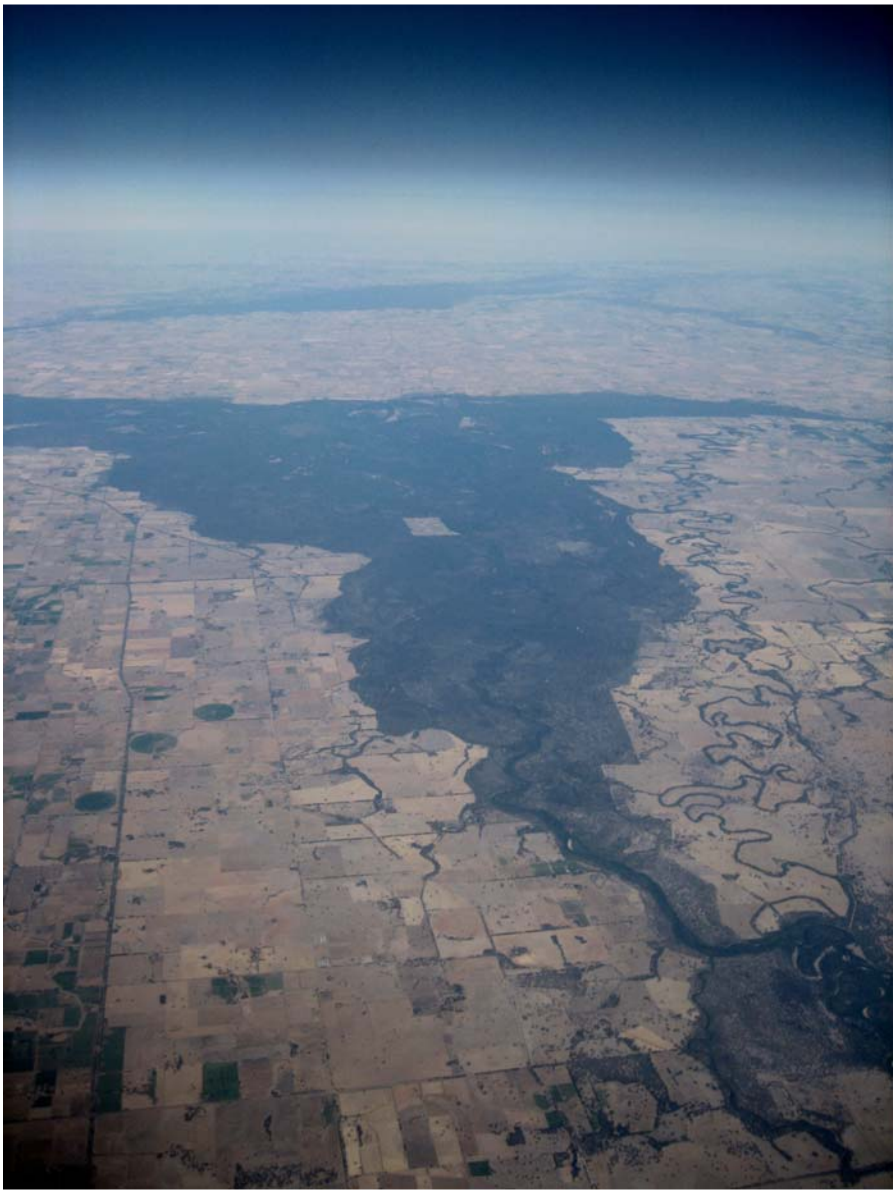

MURRAY-DARLING BASIN COMMISSION

The Murray-Darling Freshwater Research Centre

Integrated Basin Reporting – Floodplains
A report prepared for the Murray-Darling Basin Commission by the Murray-Darling Freshwater Research Centre

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Executive summary

Healthy floodplains are critical for maintaining healthy rivers. Lateral exchanges of energy, water, biota and nutrients with the river channel affect the habitat, biota and metabolic functioning of both systems, with particular significance during floods**.** Given that healthy floodplains are critical for maintaining river and that they appear to be under threat, it is important to ensure that their management achieves the delicate balance between anthropogenic and system requirements. Achieving this balance requires system understanding, assessment of system condition and threats and coordinated management. These requirements represent significant challenges within the Murray-Darling Basin given the vast area of land and the variation in climate, landscape and land use covered by the Basin. The purpose of this chapter is to review the role of the Commission in floodplain management by assessing the coverage and adequacy of its programs and initiatives to address its objectives as they relate to floodplains.

The MDBC Strategic Plan (2005-2010) sets the Commission three primary objectives:

- Protection and enhancement of the Basin's shared environmental assets and water resources,
- Efficient and equitable delivery of water for productive and sustainable domestic consumption, environmental benefit and economic use, and
- Delivery of high quality advice to Council, and achievement of its endorsed priorities, through strengthened capacity of the Commission and the Commission Office.

A first step in achieving these objectives is defining the environmental assets. This task has been completed by a range of institutions unevenly across the MDB with a variety of floodplain, wetland, floral and faunal assets identified. The task is however, far from complete and this represents an impediment to the development of sustainable management practices.

The next step would be to develop a reference condition for the identified assets. In most instances there is limited data available from which to develop reference conditions for different floodplain environmental assets.

A brief review of data held by the MDBC reveals that there is a general paucity of data for floodplain condition and that the available data is often fragmented. However, more intensive assessments have been made for icon sites of the Living Murray Initiative supporting the general notion that floodplains are in poor condition with 'no intervention' projections predicting further declines to floodplain health.

The degraded condition of floodplains in the MDB can be broadly attributed to a number of threats that can be categorised as altered hydrology, climate change, landscape modification, alterations to biota and floodplain contamination. It is widely expected that the magnitude of these threats will increase in the future. In some instances the MDBC is in a strong position to assess the magnitude of the threat and its potential impact, but in some instances evaluation of the threat depends on data that is not currently available to the MDBC.

The MDBC recognises the importance of knowledge to underpin management response. It is clear from this review that there is scope to synthesise and integrate the data currently collected by the MDBC to generate an improved knowledge base upon which to base assessments. This internal initiative will present a number of challenges in terms of data management and integration. Such an initiative would benefit from collaboration with other initiatives that are attempting to develop data management and integration procedures, including W.R.O.N. and A.E.O.N.

Ultimately, achieving the MDBC objectives of protection of assets, water delivery and provision of advice will rely on integration MDBC programs with clear articulation of the roles of each program and management of the interactions. The MDBC currently have undertaken several initiatives to address threats to water availability including the Salinity Strategy, Algal Management Strategy, The Cap and the Risks to Shared Water resources, 3 further initiatives to address threats to environmental assets including the Native Fish Strategy, Northern Basin Strategy and TLM. Finally the MDBC has 2 programs that provide data to underpin assessment of condition, the RMWQMP and the SRA. The Risks to shared water resources provides a clear framework for addressing threats to water resources. There is no similar framework for examination of threats to environmental assets, although environmental assets are also vulnerable to hydrological alteration. Development of a risk framework for environmental assets would facilitate integrated reporting.

Overall integrated reporting on floodplain assets should be aligned with the strategic objectives of water delivery, protection of environmental assets and provision of advice. The major challenge facing the MDBC in this process is the fact that, of the recognised threats to water and environmental assets only a subset will be the focus of MDBC initiatives or programs while others will remain the subject of initiatives undertaken by other government agencies, including catchment management organisations. As a consequence, not only will there need to be greater data sharing, the reporting of progress on protecting water and environmental assets would benefit from improved understanding and reference to the initiatives and strategies of other institutions.

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Background

A floodplain is the relatively flat area of land surrounding a lowland river that is inundated when the river overflows its banks during floods. The Australian Institute of Engineers formally define floodplains as that area of land adjacent to river channels that is inundated by a 1 in 100yr flood. Floodplains are complex ecosystems which form an important part of our landscapes, supporting high productivity, diverse biota and aiding in carbon, water and nutrient cycling. As well as being important systems in their own right, they represent a critical component of riverine ecosystems. They also offer pleasant locations for human habitation, represent some of our most productive agricultural land and provide a range of other valuable ecosystem services such as the provision of clean water, food and fibre and regulation of climate and flooding.

Floodplain ecosystems

Despite low-grade topography, floodplains provide a high degree of habitat complexity due to the dynamic interactions between geomorphic elements contained within them. Floodplain geomorphic elements can be broadly defined as either water shedding areas (floodplain surface) or water retaining areas (wetlands). Billabongs (meander cut-offs), riverine lakes (deflation basins) and terminal wetlands (areas of dissipation of a distributary channel network) are the major types of wetlands found on floodplains.

Small scale differences in elevation across the floodplain lead to a spectrum of flooding frequencies and durations, and hence variable connectivity, of different geomorphic elements. The complex and dynamic mosaics of habitat patches present on floodplains may explain the 10 to 100 fold higher bio-diversity of floodplains compared to the main river channels with which they are associated. Given the variable nature of river flows, and hence floodplain inundation, in Australian systems, the associated “boom and bust” cycles of many floodplain biota is to be expected. This is particularly evident in the abundances of flora and fauna which either emerge upon inundation or migrate to take advantage of favourable conditions. As with other transitional ecosystems, floodplains (and particularly floodplain wetlands) can support very high, but potentially very variable, productivity. High metabolic rates lead to concurrent peaks in carbon, water and nutrient cycling, but again very high levels of both spatial and temporal variability occur.

Healthy floodplains are critical for maintaining healthy rivers. Lateral exchanges of energy, water, biota and nutrients with the river channel affect the habitat, biota and metabolic functioning of both systems, with particular significance during floods. Floodplains abundant natural resources has made them attractive systems for exploitation, but their intimate connection to other landscape components has meant that the side effects of development have become manifest in many areas, some quite distant from the site of impact.

Floodplains in the Murray-Darling Basin

Of the one million square kilometres of land comprising the Murray-Darling Basin (MDB), 6,306,000 ha of floodplains (6.1% of the Basin area, excluding reservoirs) are associated with the network of large and small rivers (Figure 1) (Kingsford et al. 2000). Over 30,000 wetlands have been identified in Basin floodplains, 11 of which (comprising 6,000 km^2) have been listed under the Ramsar Convention on Wetlands of International Importance.

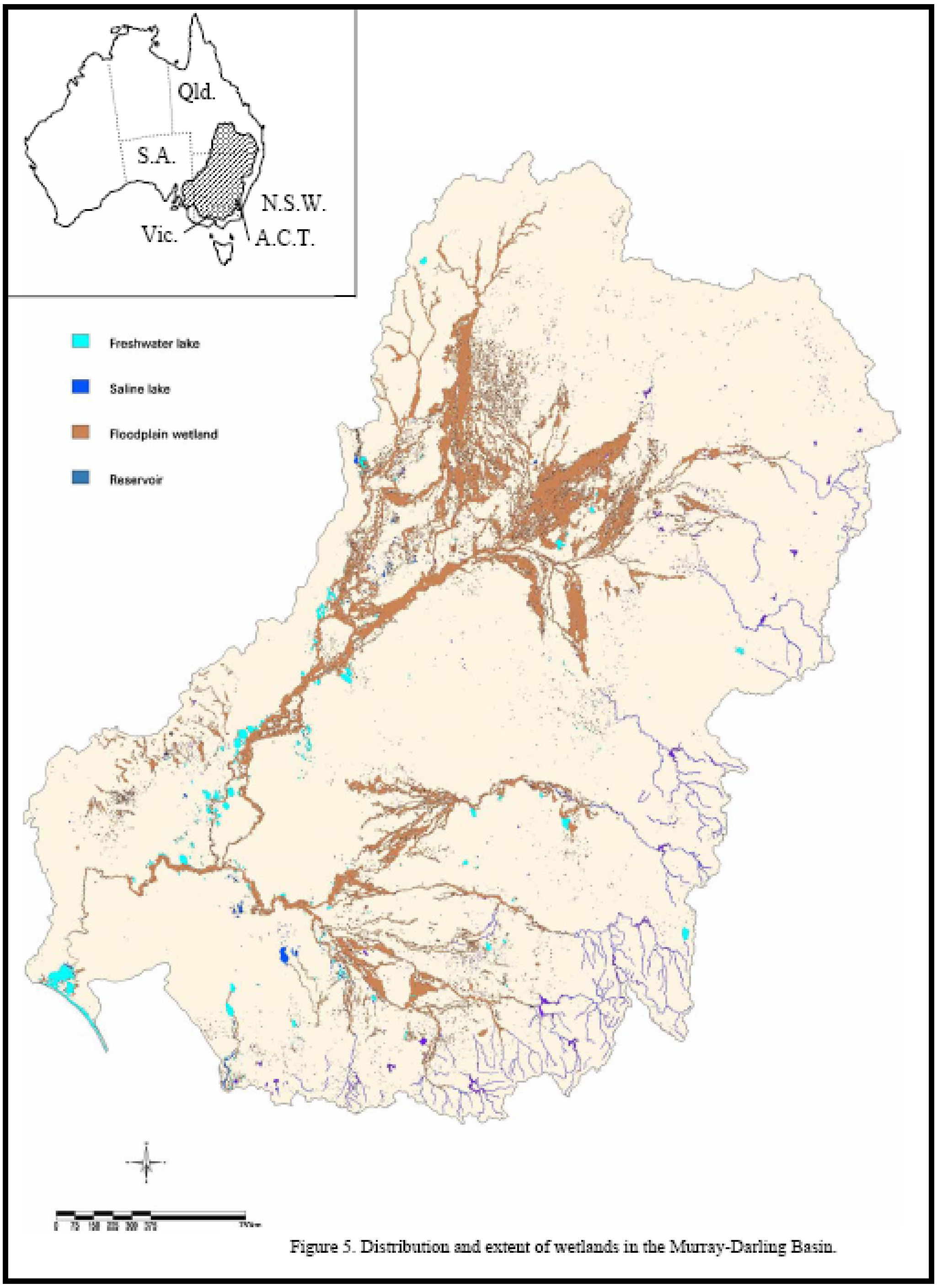

Figure 5. Distribution and extent of wetlands in the Murray-Darling Basin.

Figure 1. Map showing distribution of wetlands within the Murray-Darling Basin (Kingsford et al. 2000).

Floodplain degradation

Historically, floodplains have been a target for human settlement due to proximity to water (both for extractive uses and transportation), fertile alluvial soils and conveniently flat topography. Since European settlement, anthropogenic pressures on floodplains in the MDB have resulted in degradation of their condition. Impacts have included:

- water extraction and altered watering characteristics (flood frequency, duration, timing)
- reduced connectivity with rivers
- dramatic changes to biota (clearing, grazing, feral animals, weeds)
- dramatic changes in land use (agricultural, industrial, residential and recreation development)
- rising water tables and associated contaminants
- degradation of soils and accelerated rates of erosion

- channel modification and reinforcement (to constrain lateral migration) leading to a less dynamic floodplain habitat patch mosaic.

River Murray outflows are less than 25 % of those early in settlement. About a third of the Basin's floodplain area has been cleared of native vegetation and 20 – 60% of the remaining plants are introduced species. Land under agricultural production occupies 85% of the total Basin area, with 73% of this taken up by livestock production and 12% by cropping.

Given that healthy floodplains are critical for sustaining their biota, maintaining river health and performing ecosystem services, and that they appear to be under threat, it is important to ensure that their management achieves the delicate but dynamic balance between anthropogenic and system requirements. Achieving this balance requires both a reasonable understanding of ecosystem function and coordinated management. Both of these requirements represent challenges given the vast area of land covered by the Basin and the variation in climate, landscape and land use included in this area.

Achieving coordinated management is also complicated beyond the normal situation because floodplain ownership resides mostly with private land-holders and natural resource management is shared among around 145 local governments and at least 15 Catchment Management Organisations, 5 State or Territory Governments and the Federal Government. As a consequence, examples of one institution holding responsibility for the development and implementation of a management strategy would be rare.

Chapter Aim

The purpose of this chapter is to review the role of the MDBC strategies and initiatives in floodplain management by assessing the scope and remit of its programs and initiatives to address its objectives as they relate to floodplains. The overarching purpose of the Commission is to "Promote and coordinate effective planning and management for the equitable efficient and sustainable use of the water, land and other environmental resources of the Murray-Darling Basin". The Strategic Plan sets the Commission's direction for 2005-2010, outlining three primary objectives:

1. Protection and enhancement of the Basin's shared environmental assets and water resources,
2. Efficient and equitable delivery of water for productive and sustainable domestic consumption, environmental benefit and economic use, and
3. Delivery of high quality advice to Council, and achievement of its endorsed priorities, through strengthened capacity of the Commission and the Commission Office.

These objectives may be rephrased to clarify how they relate to floodplains, thus:

1. Protecting and enhancing floodplain ecosystems and/or defined environmental assets, by identifying and addressing threats.
2. Understanding the effects of floodplains on water delivery and the water requirements of floodplains to assist in providing suitable quantities and quality of water for environmental, domestic and industrial use.
3. Understanding how different infrastructure, practices, policies and institutional arrangements affect floodplain systems, to enable delivery of advice on management.

For all three objectives, an understanding of how floodplain ecosystems function is needed –without this, it is impossible to identify threats or how to address them, determine floodplain water requirements or the effects of floodplains on water quality and availability, and provide advice on floodplain management.

Conceptual Framework

The chapter addresses each objective in turn and within each objective follows the steps involved in the 'adaptive management process' (Bosch et al. 2004) or Pressure State Response management model of assessing the state of the asset (which requires definition of the asset), assessing the threat, or pressure and developing an appropriate response or intervention. This chapter develops its proposed response through an evaluation of the scope of current MDBC programs.

The chapter also uses a conceptual model of essential ecosystem attributes to provide a consistent approach to the evaluation of condition and management response. The conceptual model proposes that ecosystem attributes may be summarised into four categories – habitat, biota, metabolic functioning and connectivity:

Habitat.	Physico-chemical, hydro-geomorphic, climatic and structural conditions which allow specific organisms to occupy a given area.
Biota.	Composition, abundance and distribution of biological entities.
Functioning.	Biotic processes and interactions that maintain or change the composition, quantity and distribution of the biota.
Connectivity.	Transfer, exchange or movement of energy, water, biota, solutes and particles between system elements.

Utilisation of the conceptual model helps group threats, improves understanding of threats impact on the ecosystem and can help evaluate the effectiveness of management responses.

For floodplains, the relevant scale for considering aspects of these attributes is generally the landscape scale. Aspects of each attribute relevant to floodplains are outlined in Table 1 and graphically presented in Figure 2.

Table 1. Aspects of habitat, biota, metabolic functioning and connectivity relevant to floodplain ecosystems.

Habitat	Biota	Functioning	Connectivity
Climatic Solar radiation Temperature (min & max) Rainfall Evaporation Wind speed	**Composition** Broad community types, community composition, population structure	**Resource metabolism** Uptake, metabolism and outputs of energy, water, nutrients (and contaminants)	Transfer/exchange of **Energy**
Physico-chemical Water availability Water quality Air availability (e.g. gas exchange) Air quality Nutrient status Contaminants	**Abundance** Density, extent, relative abundance, biomass	**Persistence** Reproduction Growth/ productivity Recruitment Senescence/ morbidity	**Water** Transfer of water and associated gases, solutes and particles
Hydro-geomorphic Hydrology Flow characteristics Soil/ sediment characteristics Geomorphology	**Distribution**	**Homeostasis** Solute transportation Osmotic status Temperature control Transpiration Exudation etc.	**Biota** Biotic movement Biotic transfer of water, energy, solutes and particles
Physical structure Patch size Fagmentation Area:edge ratio Complexity Patch mosaics		**Biotic interactions** Succession Competition Parasitism Commensalism Habitat provision/ modification etc.	**Wind/ atmospheric/ gravity** Movement of particles

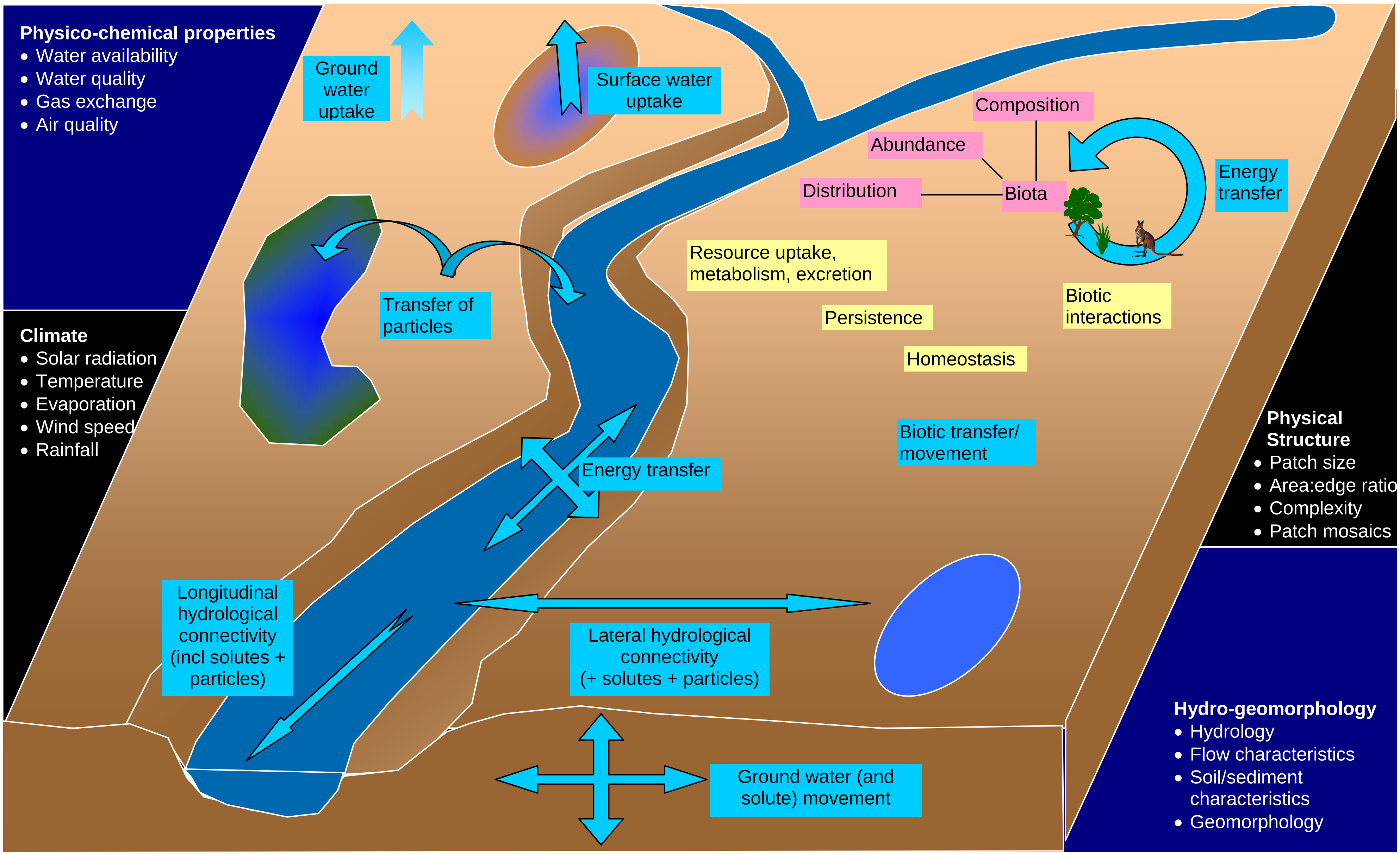

Figure 2. Aspects of floodplain biota, metabolic functioning and connectivity (colour-coded as per Table 1) set in a matrix of habitat variables.

In the following sections we address each objective by stepping through the definition of environmental assets, an assessment of condition and review management response using this template of floodplain ecosystem functioning. The major heading for each section relates to the overarching MDBC Objective while the subheading relates to the step (define, assess, response). The major focus of this report is on the first of the three objectives (summarised as protecting and enhancing environmental assets, delivering water and providing advice), as most of the data provided to the review team related to the first objective.

Objective 1a. Protect and Enhance Environmental Assets: Define specific environmental assets and determine their condition

Defining environmental assets

For any system, it is important to define which system elements or attributes are being considered when identifying threats, assessing condition and developing appropriate management strategies. Some environmental assets relating to floodplains have been identified in MDBC initiatives and by important external processes. Due to the diversity of uses to which floodplain ecosystems are put and the complex management environment, the definition of assets has been undertaken at a variety of scales and this creates the impression of overlap, however, this situation helps illustrate that even once an asset is defined it is probable that different stakeholders will value different components of the asset in different ways. The assets that have been defined cover the following floodplain elements and ecosystem components:

- Floodplain ecosystems
- Floodplain wetlands
- Floodplain vegetation
- Fish
- Birds
- Floodplain soils
- Floodplain water

Floodplain ecosystems

All floodplains represent important components of managing rivers and should be considered as part of integrated catchment management. Several floodplain systems in the Murray-Darling Basin have been identified as part of the Living Murray process as critical systems for targeted research and management, due to high ecological, cultural and/or economic values. The Living Murray (MDBC Pub. No. 36/06) has selected six Icon Sites to focus on improving environmental condition:

1. Barmah-Millewa Forest
2. Gunbower-Koondrook-Perricoota Forest
3. Hattah Lakes
4. Chowilla Floodplain and Lindsay-Wallpolla Islands
5. Lower Lakes, Coorong and Murray Mouth
6. River Murray Channel

All of these are floodplain systems, although the River Murray Channel is often a separate management unit, and the Living Murray First Step ecological objectives for this site are strongly related to floodplains.

Floodplain Wetlands

Over 30,000 wetlands have been identified in Basin floodplains, 13 of which (comprising 6,000 km^2) have been listed under the Ramsar Convention on Wetlands of International Importance (Table 2). A range of different wetlands within the Murray-Darling Basin are also targeted for research and management by the Murray Wetlands Working Group.

Floodplain Vegetation

Floodplain vegetation within the Murray-Darling Basin has been identified as a critical environmental asset in terms of composition (icon species, threatened species and invasive species), functioning and provision of habitat (e.g. associated with Ramsar wetlands). Projects targeting floodplain vegetation include The Living Murray, the Sustainable Rivers Audit Vegetation Theme Pilot and work by the Murray Wetlands Working Group.

Table 2. Wetlands in the Murray-Darling Basin that are of international importance and listed under the Ramsar Convention (Environment Australia 2001).

State	Wetland	Area (ha)
Queensland	Currawinya Lakes National Park	151,300
New South Wales	Macquarie Marshes Nature Reserve*	18,200
	Narran Lakes	5,500
	Gwydir Wetlands	823
	Fivebough and Tuckerbill	690
Victoria	Barmah Forest	28,500
	Gunbower Forest	19,450
	Hattah-Kulkyne Lakes	1,018
	Kerang Lakes	9,172
	Lake Albacutya	10,700
South Australia	Coorong and Lakes Alexandrina and Albert	140,500
	Riverland, including Chowilla Floodplain System	30,600
ACT	Ginini Flats	343

* The full extent of the Macquarie Marshes is some 200,000 hectares

Fish

Fish within the Basin are considered a high priority for research and management due to their iconic status within the general community and their importance in riverine food webs. Initiatives such as The Living Murray, the Native Fish Strategy and the Environmental Water Management Program all have provision for fish-floodplain interactions to be investigated or managed.

Birds

Waterbirds have been targeted for specific research in TLM projects and work by the Murray Wetlands Working Group. Additionally, the management objectives for many systems within the basin (e.g. Ramsar wetlands) are strongly related to the promotion of waterbird breeding. In addition there are a number of national treaties that require protection of habitat for migratory birds e.g. Japanese Agreement on Migratory Birds and the Chinese Agreement on Migratory Birds.

Floodplain Soils

While floodplain soils have been identified as being important to the functioning of floodplain ecosystems and their associated rivers, important to water delivery operations and critical to agricultural productivity on floodplains within the Basin, specific details of this asset have not been defined and no targeted research or management by the MDBC has occurred.

Floodplain Water

Floodplain water is being targeted by hydrological modelling of water movement through catchments, understanding surface water-ground water interactions, modelling diversions from flood waters and wetlands and assessing floodplain wetland, ground water surface water quality in MDBC initiatives such as The Living Murray, the Sustainable Rivers Audit, Hydrographic Analysis, the River Murray Wetland

Database, State of the Darling Hydrology Report, Land Surface Diversions Report and the Surface-Groundwater Connectivity Study.

For a broader overview of MDBC programs that target certain floodplain assets, see table 4.

Having summarised the assets that have been identified, the chapter will now review the availability of MDBC data to assess floodplain condition before summarising the condition of floodplain ecosystems.

Determining condition

Across the three MDBC objectives there exist 17 initiatives and key performance indicators. The first objective, protection and enhancement of water resources, captures a range of initiatives of relevance to floodplain management. While some initiatives do not specifically target floodplain health, initiatives aimed at protection and enhancement of rivers will both depend on floodplain management to succeed and may confer benefit to floodplain assets. There is, however, also a risk that initiatives targeting only river channels may be detrimental to floodplain processes where a river objective is satisfied at the expense of floodplain health (see threats section) (MDBC Pub. No. 08/06). Table 3 lists the major initiatives and strategies that align with MDBC Objective 1.

Data collection is not uniform across the Basin and it is mostly confined to the river channels with the exception of specifically targeted icon sites such as those identified in The Living Murray. There will however, be scope for data sharing between the various strategies. Table 3 lists data used by individual strategies while Table 4 is a tabulated summary of all data captured by the Commission.

Floodplain Monitoring and Data

There are only two MDBC programs that explicitly gather floodplain data: The Living Murray data associated with icon sites and the proposed S.R.A. vegetation component. In the case of TLM, it is clear that the assessment will not provide data on the overall condition of the Murray floodplain due to its focus on the icon sites. Over time, the SRA will provide information on the condition of floodplain vegetation, but not on other, as yet undefined, floodplain environmental assets.

The majority of monitoring effort by the Commission is focussed on the River Murray channel. These programs include hydrological and water quality (including salinity and macroinvertebrates) monitoring programs that were designed to assess the quality and quantity of water in the channel and were not designed to provide an assessment of floodplain condition. Due to the number of influences on channel water quality, including flow regime, drainage and groundwater inflows and infrastructure such as dams and weirs, the correlation between water quality and floodplain condition will be weak. This complex relationship is exacerbated when macroinvertebrate monitoring is considered because, in addition to water quality, macroinvertebrates respond to local habitat availability and disturbances that are influenced by the flow regime, channel morphology and the presence of snags and macrophytes. This is not to say that these indicators are insensitive to floodplain condition, just that they integrate a large number of influences and our existing knowledge is unable to disentangle the floodplain signal.

Initiatives in Table 3 have also been rated for effort specifically targeting the floodplain. All the programs are funded by the MDBC with the exception of the NSW Murray Wetlands Working Group program. The River Murray Wetland Database is a Geographic Information System and has commence-to-flow levels for over 4,000 wetlands along the Murray and lower Darling Rivers (http://www.mwwg.org.au).

There are also state agency run projects assessing wetlands but data is not readily available. This and other monitoring and data captured within the Basin (research institution, state agency etc) is not shared through a coordinated effort; indeed much will be published as scientific literature. Moreover, there is no known comprehensive review of this information or attempt to develop value adding between the Commission and State institutions with independent efforts.

Reference condition

In most instances there is limited data available from which to develop reference conditions for different floodplain environmental assets. In many instances this leads managers to use “natural” as a default reference condition despite difficulties associated with defining natural and a lack of knowledge about how far from natural is acceptable within the context of management objectives.

Considerable work has been undertaken to develop ways of generating synthetic reference conditions from a variety of historical data sources. While this important work will help us understand what landscapes may have looked like before European settlement there is still considerable work required to enable us to move away from using “natural” as a reference. The development of a reference that adequately reflects our management objectives will require improved system understanding and knowledge of the trade-offs between, for example, habitat area and ecosystem service provision or population viability.

Summary

This section suggests that the lack of reference condition and the lack of data collected on floodplain systems means that the MDBC does not currently have the capacity to rigorously assess floodplain condition across the MDB, although information is available for TLM assets. This situation will improve with the implementation of the S.R.A. vegetation component as it will both develop a reference condition for vegetation and collect floodplain data. The capacity of the MDBC to undertake assessments of floodplains could be improved through integration of the data gathered by all management institutions with responsibilities within the MDB

Table 3. Summary of MDBC initiatives, their objectives and data capture

Initiatives/Strategies	Objectives	Data	Objectives Specific for floodplains
The Living Murray	• To achieve a healthy working River Murray system for the benefit of all Australians. • Recover 500GL of water for the benefit of the six Icon sites and the biota on which these systems support. • To retain, restore, and/or improve icon sites ecosystems, habitats, and species of flora and fauna.	Combinations of condition and intervention monitoring for vegetation, fish and birds, water level monitoring. Monitoring activities also described in detail in. *The Barmah Millewa Forest – Icon site environmental management watering plan 2006-2007,* Appendix F. The Department of Natural Resources - technical advice and data	Yes
The Cap	To strike a balance between consumptive and in-stream uses and secure supply to existing diverters	Water accounting	
Basin Salinity Management Strategy	Sets end of valley targets for river salinity Control rise of salinity across all tributaries	Routine monitoring - River Murray (data is collected reach by reach scale at set distances).	No
Sustainable Rivers Audit	• Consistent Basin wide information on health of rivers • Pilot methods and indicators for floodplain vegetation are being developed	Macroinvertebrates - every two years in spring. River Murray – Central Murray Riverina and Lower Murray Valleys Fish - Species richness, biomass, abundance and diagnostic data. Every three years in autumn River Murray - Central Murray Riverina and Lower Murray Valleys	No but proposed for vegetation
Report of the River Murray Scientific Panel on Environmental Flows MDBC (1998)	Develop a flow management plan to maximise environmental benefits while meeting general requirements of existing users.		Yes
Floodplain Management Strategy 2002	Ensure that all Governments, floodplain users and stakeholders understand the importance of floodplains to the environment, the risks associated with floods and the trade-off required between development of floodplains, local protection, and upstream and downstream flood impacts. Encourage appropriate steps to manage risk, taking into account the social, economic and environmental cost and benefit		Yes
Floodplain Wetlands Management Strategy 1998	Eight objectives exists for this strategy and are summarised into three 3 outcomes: • Improve understanding of floodplain wetlands, • Integrated catchment plans and local action plans will address the needs more effectively; and • Wetland health will be improved.		Yes
Integrated Catchment Management Strategy	Policy framework		

Initiatives/Strategies	Objectives	Data	Objectives Specific for floodplains
Native Fish Strategy 05-06	To rehabilitate native fish communities in the MDB back to 60 per cent of their estimated pre-European settlement levels after 50 years of implementation through: • Rehabilitating fish habitat • Protecting fish habitat; • Managing riverine structures; • Controlling alien fish species; • Protecting threatened native fish species; • Managing fish translocation and stocking	Large-scale migrations, and passage time through fishways 1- 2 weeks several times a year River Murray from the sea to Hume Dam. Movement of adult Murray Cod between anabranches and main stem - Mullaroo Ck and Ulupna Ck Monitoring fish species response to re-snagging by measuring abundance, diversity and distribution - Yarrawonga to Tocumwal	Yes
Algal Management Strategy	• Reduce nutrient concentrations in the streams and storages in the Basin; • Improve stream-flow regimes and flow management; • Increase the community's awareness of the blue-green algal problem; and • Obtain better information and scientific knowledge of blue-green algae	Algal and physicochemical Routine –fortnightly (December to April) and monthly (May to November) Dartmouth and Yarrawonga, Mitta Mitta River below Dartmouth Dam Blue-green algal levels Monthly graduating to fortnightly in the summer months and weekly in times of high alert Hume Dam, Menindee Lakes, Murray, Lower Darling, Edward and Wakool Rivers and Billabong Creek	No
Report of the River Murray Scientific Panel on Environmental Flows	Identify changes in River Murray operations and lower Darling that should result in general improvements in river health whilst meeting current user needs.		Yes
River Murray Water Quality Monitoring Program	• To periodically report and assess water quality to understand variability and determine trends. • To provide data which will assist reporting against water quality objectives in the River Murray and will inform management of the River system. • To undertake additional investigations to characterise and understand the factors and processes affecting water quality and the river ecosystem, and inform management.	Physico-chemical, phytoplankton and macro- invertebrates – weekly or monthly in River Murray	No
Land Surface Diversions (2006)	• Provide an overview of the surface and groundwater hydrology of the Darling basin. • Outline the development that has occurred within the basin and the effect that this is having on river flows and groundwater resources. • Not to draw conclusions about the consequences of changes in river and groundwater flows on the environment; but to, • Provide a brief summary that can understood by non-technical audiences that can be utilised as a basis for discussion of future basin sustainability initiatives.		

Table 4. Summary of existing monitoring programs for the River Murray Channel
(from *River Murray Channel Icon Site Environmental Management Plan 2006-07*)

Attribute	Agency administering program	Proponent	Variables	Frequency	Spatial Scale	Time Scale
Water Quality	NFS/ TLM Knowledge generation projects Protection and enhancement of Murray Cod populations	Arthur Rylah Institute.	Anabranch vs. main stem water quality parameters.	Once a year for 2 weeks in May/June for 3 years.	Reach scale (Mullaroo Ck and Ulna Ck).	2004-07
	RMW Quality Monitoring Program	DIPNR, Goulburn-Murray Water, DWLBC/SA Water	Physico-chemical, phytoplankton and macroinvertebrates.	Routine – weekly or monthly	River Murray system.	Ongoing (since 1978)
	RMW Algal and Water Quality Monitoring (MSOMP)	Goulburn-Murray Water	Algal and physico-chemical.	Routine – fortnightly (December to April) and monthly (May to November	Reach scale (Dartmouth and Yarrawonga, Mitta Mitta River below Dartmouth Dam).	Ongoing
	Macro-invertebrate Monitoring	Goulburn-Murray Water	Macro-invertebrates	Routine	River Murray system.	Ongoing
	Water Quality Investigations, Reporting and Audit (Salinity)	DIPNR	Concentration and load trends	Routine	River Murray system (Murray and Lower Darling).	Ongoing
	Hume Dam Thermal Monitoring	DIPNR	Water temperature and electrical conductivity data	Routine	Reach scale (Hume Dam and downstream tributaries)	Ongoing
	Murray Darling Algae Investigations/Monitoring Program	DIPNR	Blue-green algal levels	Monthly graduating to fortnightly in the summer months and weekly in times of high alert	River Murray system and beyond (Hume Dam, Menindee Lakes, Murray, Lower Darling, Edward and Wakool Rivers and Billabong Creek)	Ongoing
	Salt Interception Scheme/Basin Salinity Management Strategy – RMW/ ICM Run of River Salinity Survey	DWLBC	Salinity and salt load data	Ad-hoc monitoring	RMC scale (no specific sampling sites, data is collected on a reach by reach scale at set distances).	Ongoing
	SRA Macro-invertebrates		Richness biodiversity, SIGNAL score standalone, AUSRIVAS observed/expected.	Routine - every two years in spring.	River Murray system scale – Central Murray Riverina and Lower Murray Valleys.	2005 - 2011

Attribute	Agency administering program	Proponent	Variables	Frequency	Spatial Scale	Time Scale
Hydrology	RMW Time series (Hydrographic) Data		Storage levels and volumes, flows, rainfall, hydrographic time series data, evaporation data, diversion, pumping and water order figures.	Routine – some sites are monitored on a daily basis whilst others are monitored on a weekly or monthly.	River Murray system scale.	Ongoing
Wetlands	NSW Murray Wetlands Working Group (MWWG) The River Murray Wetland Database (RMWD)		Vegetation surveys, bird counts, water quality and inundation levels. Impacts of river regulation on wetlands, vegetation, land use and commence-to-flow levels.	Before, during and after flooding.	RMC site scale (River Murray and Lower Darling). RMC site scale (Murray River floodplain in New South Wales and Victoria between the Hume Dam and the South Australian border, including the Edward-Wakool System).	
Physical/geomorphic	RMW Bank stability		Monitor: erosion rates of the river banks; flow rates of main channel vs. anabranches; and the effectiveness of bed control structures and groynes.	Once every three to five years.	Reach scale (Hume Dam to Yarrawonga).	Yet to be implemented
Fish	NFS/ TLM Murray River Fishway Assessment Program		Large-scale migrations, and passage time through fishways.	Once a year for 2 weeks in May/June for the next 3 years.	RMC site scale (Icon Sites to Hume Dam).	2001-05
	Protection and enhancement of Murray Cod populations; Re-snagging down stream of Yarrawonga; Boiling Downs habitat refuge project	Arthur Rylah Institute Arthur Rylah Institute Arthur Rylah Institute	Abundance, distribution of Murray Cod in anabranches vs. main stem. Monitoring fish species response to resnagging by measuring abundance, diversity and distribution. Monitoring the use of channel habitat.		Reach scale (Mullaroo Ck and Ulna Ck). Reach scale (Yarrawonga to Tocumal). Reach scale (Boiling Downs)	2004-07 2004-07 2005-08
	EWMP Instream and Riparian Habitat Restoration	NSW Fisheries, DIPNR (NSW), North-east CMA (Victoria) and DSE (Victoria).	Population growth rate, species distribution, species use of restored areas and the influence of co-variates.	May to July	Reach scale (Hume to Yarrawonga- priority areas).	7 yrs once implemented
	SRA	MDBC/ SRA	Species richness, biomass, abundance and diagnostic data.	Routine - every three years in autumn.	River Murray system scale (Central Murray Riverina and Lower Murray Valleys).	2005-2011

Summary of Floodplain Condition in the MDB

Given the availability of data to underpin a floodplain condition assessment, this section will provide a brief summary of our knowledge of floodplain condition within the MDB. Floodplains have been studied in an ad-hoc fashion with most effort only within the last 20-25 years but in this time floodplains have been progressively alienated from their parent rivers and the land converted for human use over the last 150 years. Much of the basins floodplain is generically reported as in poor condition and it is unlikely that there remains any unmodified component. General features of poor condition include the presence of weeds and pest animals, degraded river frontages, altered habitat, salt scalding and declines in native flora and fauna (Mackay & Eastburn 1990).

There is a general paucity of data for floodplain wetlands, however more intensive assessments have been made for icon sites of The Living Murray initiative supporting the general notion that floodplains are in poor condition with ‘no intervention’ projections predicting further declines to floodplain health.

A number of other floodplains or wetland areas have also been examined under a range of State, Federal or Catchment programs, including the Macquarrie Marshes, Narran Lakes, Gwydir River wetlands, lower Lachlan River and lower Murrumbidgee River. There are also a range of Basin wide data sets and remotely sensed imagery available such as the BRS Land Cover and Land Use data. It is possible that synthesis of these data would enable a more detailed assessment of floodplain condition in the MDB and improve capacity to achieve MDBC objectives on the floodplains.

The *Snapshot of the Murray-Darling Basin River Condition* further supports the proposition that floodplain condition is very poor in all zones. Norris et al. (2001) gives river condition maps that may be used as surrogate for floodplain condition. While hydrological disturbance is reported as ‘moderate’ this results in a 35 percent reduction in wetland types in the area from Hume Dam to Wellington, attributable to the permanent inundation of previously intermittently flooded wetlands. Floodplain inundation for all zones was also assessed as very poor with inundation patterns substantially modified.

It is probable that a far more comprehensive assessment of floodplain condition could be undertaken that would call on a variety of data sources currently held or in development by regional, State and Federal management agencies and research institutions. The foundation data sets to underpin this assessment would include hydrological (surface and groundwater), water quality, infrastructure, and remotely sensed land use, vegetation type and cover data.

Objective 1b. Protect and Enhance Environmental Assets: Identify threats to floodplain ecosystems

The management of water and environmental assets within floodplain rivers is inextricably linked to the management of floodplains due to the numerous lateral connections between river channels and associated floodplain habitats. Floods create complex and diverse habitat patch mosaics through the interaction of geomorphology and hydrological variability. Groundwater moves material through the landscape to the river channel, while the movement of biota is essential to the maintenance of healthy aquatic systems and the ecosystems services that they provide (Kingsford et al. 2004).

Floodplain modification has occurred throughout the Murray-Darling Basin due to numerous anthropogenic disturbances since European settlement (MDBC Pub. No. 36/04); to the point that it is unlikely that any unmodified floodplains exist within the basin.

Threats to Floodplain Ecosystems

Following is a summary, in no particular order, of the threats to floodplain ecosystems classified into the broad categories of altered hydrology, climate change, landscape modification, alterations to biota and floodplain contamination (Table 5). A more detailed description of these threats can be viewed in Appendix 1. Listed threats have been identified by the Murray Darling Basin Commission through its various programs and initiatives unless otherwise noted.

Table 5. Summary of threats and their resultant impacts to the floodplains of the Murray-Darling Basin. * indicates a threat that has not been identified by the MDBC through its various programs and initiatives.

Category	Specific Threat	Impact
Floodplain Contamination	Agricultural Runoff	Runoff of nutrients, herbicides, fungacides, antibiotics, vermifuges, insecticides, pathogens, pharmaceuticals, sediment, salinised runoff, altered pH & temperature runoff, dissolved gases
	Industrial Runoff	Runoff of nutrients, particles, salt, toxins, carcinogens, mutagens, hydro-carbons, radio-active material, trash, heavy metals, flammables, teratogens, altered pH & temperature runoff, dissolved gasses
	Sewage and Stormwater Runoff	Runoff of nutrients, chemicals, pharmaceuticals, sediment, pathogens and urban rubbish
	Air pollution	Particle fall out, altered air quality
	Salinity	Forced change in landuse, killing of biota, salt accumulation.
	Wetland acidification *	Fish kills, anoxia in the overlying water column, generation of noxious odours, mobilisation of metals from the sediments.
	Bushfires	Increased runoff carrying, ash, sediments, nutrients, organic matter
Altered Hydrology	River Flow management	Changed timing, duration and frequency of floodplain inundation
	Barriers to Connectivity	Dams, weirs, regulators and levee banks. Prevents water entering and/or exiting floodplain wetlands and channels
	Land Surface Diversions	Prevention of floodwaters from covering floodplain. Loss of sediment, nutrient and productivity generating waters. Farm dams preventing flow to floodplain and waterways
	Groundwater Extraction	Sustainable Extraction not identified.
	Groundwater Connectivity	Reversed hydrologic gradient, reduced wetland discharge, rising water tables
	Water Inputs	Excess stormwater, effluent & industrial discharge into wetlands, additional potential to pollute
	Bushfires	Initial increase in water yield, followed by a long term reduced water yield.
Climate Change	Global Climate change	Reduction in rainfall, increased evaportation, increase rainfall intensity, increase local flood events, reduced groundwater recharge, increase fire activity.

	Local climate change *	Altered biota types, and local connectivity patterns
Landscape Modification	Earthworks	Alterations to soil characteristics, drainage or filling of damp spots and wetlands, floodplain levelling, woody debris removal, spread of invasive species
	Channel Infrastructure	Restricts movements of particles, biota, propagules. Thermal pollution, Increases impervious surface areas, restricts channel meandering, reduces channel structural complexity, leaching of contaminants from construction materials.
	Floodplain infrastructure	Altered surface-ground water exchange, limited vegetation growth, effects on light, temperature, evaporation, wind and water flow patterns, leaching of contaminants from construction materials
Alterations to biota	Introduction of Invasive Species	Carp, gambusia, willows etc. reduce biodiversity, alter metabolic functioning
	Land Clearing	Increased erosion, raises groundwater tables, modifies soil structure/characteristics, eliminates native biota, facilitates invasive species.
	Changes to Community Composition*	Changes surface-groundwater exchange, soil characteristics, habitat value, organic matter cycling, erosion, filtration, climate variables and persistence of native community assemblages.
	Population structure changes*	Affects bio-diversity, native species persistence, metabolic functioning, ecosystem service provision.
	Altered biota density*	High levels of contaminant release. Reduce chance of reproductive success affecting bio-diversity, species persistence and floodplain ecosystem food-webs.
	Afforestation	Reduction in water yields, reduction in stream flow, reduction in salinity.

A summary of the different floodplain ecosystem attributes affected by each threat listed above is shown in Table 6 and Figure 3.

Of the MDBC programs TLM and SRA generate data that would facilitate identification of floodplain threats while the native fish strategy may contribute some fragmented data and improve our system understanding which will facilitate identification of threats. The River Murray Water Qulaity Monitoring Program (WQM) and the Basin Salinity Management Strategy (BSMS) could be considered sentinel programs whose data may alert us to potential problems in a region that may include floodplain issues, but further investigation would be required to determine causal relationships and identify threats.

The Risks Program has undertaken an evaluation and prioritisation of the threats to shared water resources within the MDB. Some of the threats identified, including farm dams and re-afforestation, relate to floodplain activities. While the Risks program enabled the quantification of the magnitude of risks, all the risks were identified through our understanding of the system. It is unlikely, although not impossible, that the Risks program would have identified new risks or threats.

This is where programs such as the SRA are so valuable because their assessment of condition may alert us to changes that need investigation that then reveal new threats.

Table 6. Floodplain ecosystem attributes affected by different threatening processes (more symbols indicates a greater affect). Final column lists whether any of the main MDBC programs address or assess threats, either through intervention (i) or assessement (a). (TLM=The Living Murray, TC=The Cap on MDB Diversions, SRA=Sustainable Rivers Audit, NFS=Native Fish Strategy, WQM=River Murray Water Quality Monitoring Program, RP=Risks Program).

Threat	Floodplain Attribute															MDBC Major Programs that address/assess threats
	Habitat				Biota			Functioning				Connectivity				
	Climate	Physico-chemical	Hydro-geomorphology	Physical Structure	Composition	Abundance	Distribution	Resource Metabolism	Persistence	Homeostasis	Biotic Interactions	Energy	Water	Biota	Wind/ atmospheric	
Altered hydrology																
Altered flow regime			XX	X				X			X	X	XX		X	TLM(i), RP(a), SRA(a)
Water extraction			XX	X		X		X			X		XX		X	TC(i)
Altered hydrological connectivity		X	XX		X		XX	XX	XX		XX	X	XX	XX		RP(a)
Rainwater harvesting	X	X	XX									X	XX			RP(a), TC(i)
Water inputs	X	XX	XX		X		X	XX				X	XX	X		
Climate change	XX		X		XX		X	X			X	X	X	X	X	RP(a), SRA(a)
Contaminants																
Salinisation		XX					X	X	XX	XX	X				X	BSMS(i, a), SRA(a), WQM(a), RP(a), TLM(a)
Acidification		XX					X	X	XX	XX	X				X	
Contaminated surface water		XX			X	X		XX		XX	X				XX	SRA(a), WQM(a),BSMS(i,a), RP(a), TLM(a)
Contaminated ground water		XX			X	X		XX	XX	XX	X				XX	SRA(a), WQM(a),BSMS(i,a), RP(a), TLM(a)
Thermal pollution	XX	X			XX	X	XX	XX	XX	XX	X	X				WQM(a)
Landscape modification																
Earth-works	X	X	XX	XX			X		X		X	X	X	X	X	WQM(a)
Altered soil characteristics		X	XX	X	X			X	X				X	X	X	BSMS(a)
Erosion/ sedimentation		XX	X	XX		X		X	XX	X	X	X	XX		X	WQM(a), RP(a)
Barriers to passage (e.g. fish)	X	X	XX				X				X	XX	XX	XX	XX	NFS(i, a), TLM(i, a)
Decreased landscape complexity	X	X	X	XX	XX	XX	X		X	X	XX	XX	XX		X	TLM(a), RP(a)
Increasing impervious surface area	XX		XX	X	X	X	X	X		X		XX	XX		XX	
Channel modification	X	X	X	X				X				X	X	X	X	RP(a), NFS(i, a)
Alterations to biota																
Introduction of invasive spp				X	XX	XX	XX	X	X		X	X	X	X		SRA(a), NFS(i, a), TLM(a)
Vegetation clearing	XX	XX	XX	XX	XX	XX	X	XX	X		X	X	X	X	X	RP(a), BSMS(i, a)
Changes to native biota	XX	X	X	X	XX	X	XX	X	XX	X	XX	X	X	X		SRA(a), NFS(i, a), TLM(a)

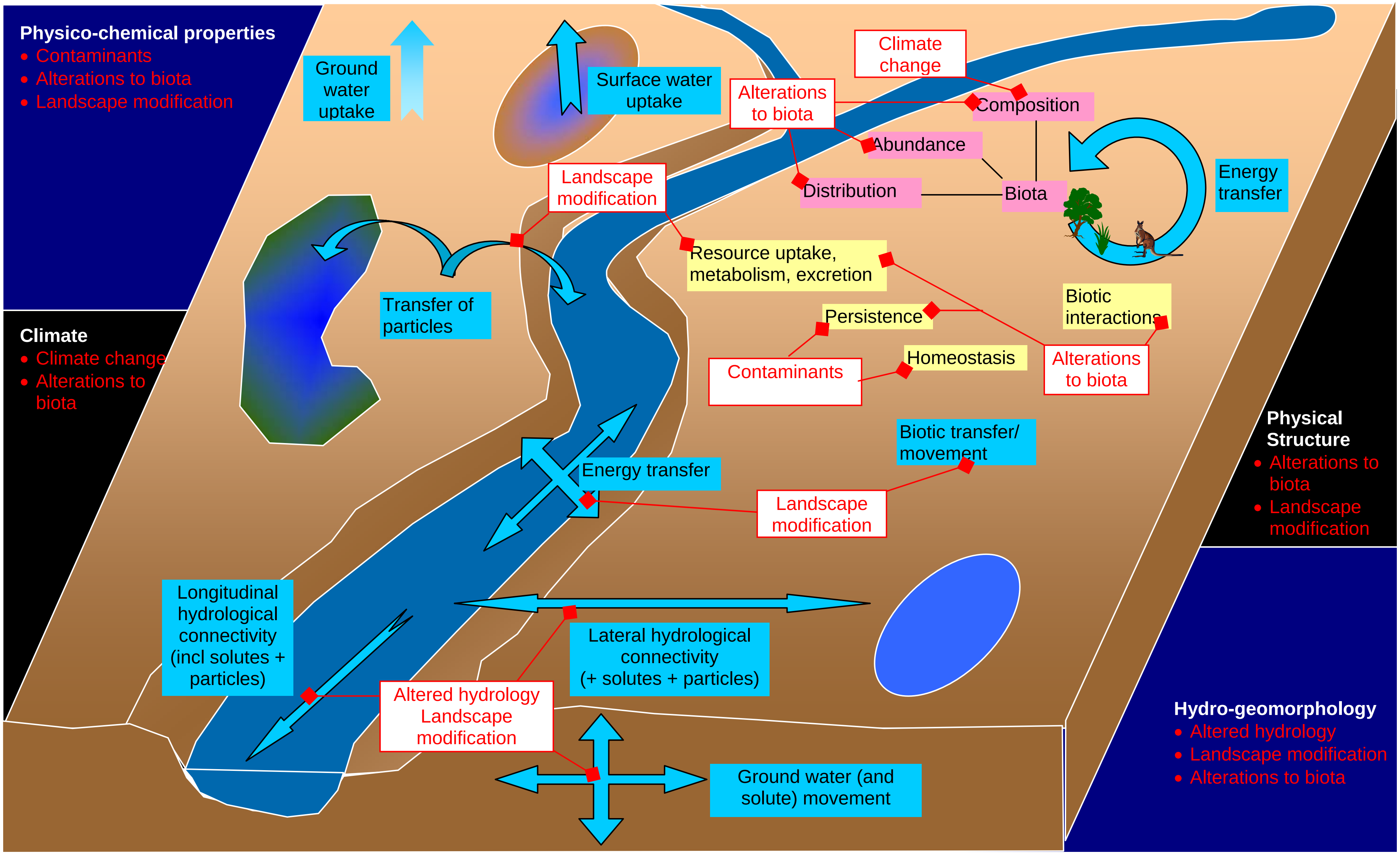

Figure 3. Major influences of threatening processes (red text) on floodplain ecosystems.

Objective 1c. Protect and Enhance Environmental Assets: Address floodplain threats

Objective

This section outlines The Murray Darling Basin Commission's ability to address or monitor floodplain threats through their existing programs, and/or through external avenues available to them. The selection of MDBC programs, initiatives and reports was determined by whether they had or will provide any baseline data relative to a threat. Non MDBC initiatives or programs were included if we knew that the MDBC had access to them. An Expert Panel assessed each program reviewing the best available data. Scores were influenced by the degree that a program, initiative or report addressed the threat specifically and spatially. For example, if a program only addresses the one threat but covers the entire basin, then that program would score a five. However the score would decrease if the threat was only addressed across a small part of the basin. Similarly, scores declined if the data was only partially related to the threat.

The crux of this section is contained in Table 7, which lists the threats, rates how well a program addresses or monitors the threat, highlights any potential interaction between programs to deal with a threat, and suggests other data that may be helpful.

The "Risks to the Shared Water Resources of the Murray-Darling Basin" report represents program that brought together data from a range of MDBC and non-MDBC sources, to combine them all in an integrated package that addresses threats to the basins water resources.

Guidelines to using the table

The capacity of the MDBC to assess, monitor and/or address threats to floodplain ecosystems given its present and past array of programs and initiatives is presented in Table 7. This table scores the ability of the programs and initiatives to provide data on, monitor or address specific environmental threats to floodplains. Synergies in data provision exist between many of the programs/ initiatives. For each threat, the best overall understanding will be gained by combining data from one of each coloured program for that row. Some threats require additional data to that currently available to the MDBC in order to obtain an overall understanding – these are noted in the last column (e.g. understanding the threat of wetland acidification requires data on soil characteristics). Some of the additional data requirements may be met by initiatives such as the Water Resources Observation Network (WRON) or the National Collaborative Infrastructure Scheme (NCRIS) through the Australian Ecosystem Observation Network (AEON) national hub.

Example use of the Table 7:

Example 1. To obtain an understanding of barriers to fish passage throughout the Basin, one would need to combine hydrology data from one of the light blue data sources with distribution mapping of dam/ weir/ lock locations from one of the green data sources.

Example 2. To determine the likely threat from invasive species, information about likely environmental conditions such as hydrology (light blue) and water quality (red) could be compared to the known environmental preferences of the invasive species (grey) and their current distribution patterns (dark green) to determine the likely spread of an invasive species.

Example 3. To determine the extent of change to hydrological connectivity, hydrological data (light blue) could be combined with data on wetland distribution (dark green) and commence to fill information (light blue) to determine inundation of wetlands. Floodplain connectivity analysis would require hydrological data to be combined with infrastructure data (levees and regulators) and a D.E.M. of the region. This sort of analysis is already possible along the Murray thanks to modelling work by the MDBC and CSIRO's Water for a Healthy Country Flagship Project.

Implications for MDB Programs

The review reveals that for the majority of the threats identified in Table 5, the MDBC has some data that relates to the threat, but that in many cases, the data does not directly address the threat. Similar to the analysis of the MDBC's capacity to identify threats the MDBC's capacity to quantify threats is heavily dependent on the TLM and SRA programs that generate data on floodplain condition. The BSMS may be considered a sentinel program whose data may alert us to potential problems in a region but the limited data on salt levels on floodplains means that further investigation would be required to determine the assets under threat or the magnitude of the threat. The Native Fish Strategy may also contribute some fragmented data and improve our system understanding which may facilitate quantification of threats. The RMWQMP will provide only limited assessment of floodplain threats due to its integration of a number of influences.

The Risks Program has undertaken an evaluation and prioritisation of the threats to shared water resources within the MDB. Five of the 6 threats identified relate to floodplain activities or characteristics. The Risks program brought together data and modelling from a variety of sources to quantify the magnitude of the threats as it could not have undertaken the assessment from MDBC data alone. A similar analysis could be attempted for other identified assets such as water quality, biodiversity or wetland condition. This was essentially the process undertaken in the lead up to TLM First Step, where the asset was River Murray health, but a comparison of the Risks Program with TLM suggests that as the complexity of the asset increases our capacity to evaluate the risk will become increasingly dependent on expert judgement as data to underpin condition assessment and our system understanding will be inadequate to provide more quantitative assessments. This is not to imply that such exercises are not useful, but that our expectations will need to be appropriate to the task. Certainly undertaking these exercises helps to identify critical knowledge gaps and may have value for this reason alone. This proposition is supported by the observation that the SRA grew out of attempts to assess the impact of the Cap.

Having determined the MDBC's capacity to quantify threats, the chapter will now examine the MDBC's response to threats given that many of the threats identified in Table 5 are the responsibility of other management institutions. There are several major MDBC programs that are specifically designed to address threats to consumptive use including;

- BSMS – This program was established to respond to the threat of increased salinity, primarily in river channels and has been successful in reducing salinity levels across the Basin. The effectiveness of the BSMS is currently the subject of a mid-term review.
- Algal Management Strategy – Established in response to a number of significant blue-green algal blooms, the strategy implemented a number of actions, including changes to drainage, flow modifications and community education programs. While there are still frequent blue-green algal blooms in wetlands and some storages in the MDB (e.g. Lake Hume) the strategy appears to have been successful in reducing the severity of blooms.
- The Cap, while not fully implemented has helped maintain equitable delivery of water for consumptive and environmental use.

Three further strategies were initiated to address declines in environmental assets that are driven by a range of threats. These strategies are;

- The Native Fish Strategy was developed to address declines in native fish communities and has undertaken a variety of interventions to restore habitat and connectivity for native fish and to address the threat of introduced carp.
- The Living Murray was initiated in response to concerns over the health of the Murray River. Its primary focus addresses the threat of altered hydrology for environmental assets but other threats are also considered. The program represents a significant commitment to sustainable management of the Murray River, but its effectiveness will not be known for a number of years.
- The Northern Basin Initiative has only just commenced, but will formulate a response to the numerous threats identified in the northern basin to underpin the development of sustainable management in the Northern MDB.

There are then 3 MDBC programs designed to improve the MDBC's capacity to manage the system and minimise threats. These programs include;

- The River Murray Water Quality Management Program has both provided data on water quality to underpin management decisions and invested in the development of new knowledge to improve system understanding. The data represents an underutilised resource for the MDBC.

- The Sustainable Rivers Audit. While still in development, this program will, over time, provide invaluable data on the condition of river valleys and alert managers to trends that may reveal new threats to the sustainable management of the Basin's natural resources.
- The Risks program identifies the magnitude of threats to shared water resources and provides the foundation for a management response.

The majority of other threats relate to landscape modification or alterations to the biota that are outside the jurisdiction of the MDBC. However, with all the identified risks there are overlaps between MDBC programs and core activities and the magnitude of threats. Recognition of the areas of overlap and incorporation of knowledge of the threats and impacts of management action will help improve outcomes and minimize risks. The following are some examples of these areas of overlap.

Example 1. MDBC has a role in water delivery that has, over time, become more sensitive to the impacts that operational decisions have on environmental assets. Examples include changing operations to reduce summer inundation of the Barmah forest and the development of predictive capacity for black-water events. There are almost certainly opportunities for harmonisation of water delivery for consumptive use and environmental considerations. The floodplain inundation models developed as part of TLM and Healthy Country now provide managers with the capacity to predict or review the hydrological and habitat implications of flow regimes. There is currently a proposal before the NWC to examine the potential for developing water delivery flow regimes that either minimise the environmental footprint or provide simultaneous environmental benefits. This project may act as a model for flow management within the MDBC.

Example 2. For NSW, the MDBC has referral role in development applications on floodplains and applications are forwarded to the MDBC by the other jurisdictions as a matter of courtesy. Our understanding of the effects of changes in vegetation and flow connectivity on floodplain assets and water quality should enable us to provide advice to jurisdictions on the likely impacts of proposed developments. Development of this capacity would require access to GIS data bases of existing floodplain infrastructure, digital elevation models, land use and land cover and groundwater information to review the current condition and predict the extent to which the proposed development is likely to impact shared natural resources.

Example 3. The BSMS is focussed on managing salinity within river channels. This focus means that decisions are taken that will have an impact on floodplain assets, but the associated trade-offs are not explicit within the process. Greater integration of surface and groundwater data and improved monitoring of salt concentrations within identified floodplain assets would help optimise environmental outcomes both within the main channel and on the floodplain.

Example 4. Building on the previous example, the MDBC's water delivery role, BSMS and interest in protection of environmental assets could be integrated to maximise the export of acid and salt from sensitive areas of the floodplain while having minimal impacts on consumptive users or the environment.

Table 7. Alignment of floodplain threats to data generating, monitoring and addressing capabilities of the MDBC.

Threats	MDBC Programs and Initiatives																						MDBC Reports									Non-MDBC			
	The Living Murray	Basin Salinity Management Strategy	The Murray Darling Basin Cap	Sustainable Rivers Audit	Native Fish Stategy	South East Australia climate Initiative	River Murray WQMP	Floodplain Management Strategy	Floodplain Wetland Management Strategy	Algal Strategy	National Eutrophication Management Program	National river Contaminants Program	Waterway Manangement Plan	National Mngt. Strategy for Carp Control	Landmark	CRP Directory for Dryland Ag	Watermark-ESP	Hydrographic Analysis	Salinity Hazard Mapping	Water Quality Investigations	Macroinvertebrate Monitoring	M-D Algal Investigations & Monitoring	Risks to Shared Water Resources Program	Snapshot of the MDB River condition	State of the Darling Hydrology Report	Land Surface Diversions Report	Surface-Groundwater connectivity study.	Impact of GW on Streamflow in the MDB Report	Wetland GIS of the Murray Darling Basin	Catchment Characterisation Project	Report on River Murray Sci Panel Env Flows	Bureau of Meteorology	Rv. Murray Wetland Database	Bureau of Rural Sciences	Additional data required
1. Altered hydrology	4, A			3		4												3					3		4	4	3	4	4		R	2	3		L,F,H,I
2. Groundwater extraction			2																				4		3		4	4				2			S,H,L
3. Surface water extraction	4		4															3					2		3	4						4	3		L,F,H,I
4. Altered hydrological connectivity	4			3		2												3					1			2			4				3		I, D
5. Rainwater harvesting			3			2									R	R	R	1					4		2	4	2					4			F, L
6. Water inputs											1	1											2												H
7. Climate Change						5																	4		2							4			V
8. Salinity	2	5, A		4			3			1		1			R	R	R		3	4		3	4				2		3						V,F
9. Wetland acidification		1				1						1						1	2						1				3				3		S
10. Contaminated surface water discharge		3		3		1	3				3		A		R	R	R		1	3		3	3	3	3		1			2				3	H,V,N
11. Contaminated groundwater discharge		3					1								R	R			1	1		1	3		3		3	3							S,
12. Thermal pollution							2																												
13. Modified soil character															R	R																			S,V

Threats	MDBC Programs and Initiatives																						MDBC Reports									Non-MDBC			
	The Living Murray	Basin Salinity Management Strategy	The Murray Darling Basin Cap	Sustainable Rivers Audit	Native Fish Stategy	South East Australia climate Initiative	River Murray WQMP	Floodplain Management Strategy	Floodplain Wetland Management Strategy	Algal Strategy	National Eutrophication Management Program	National river Contaminants Program	Waterway Manangement Plan	National Mngt. Strategy for Carp Control	Landmark	CRP Directory for Dryland Ag	Watermark-ESP	Hydrographic Analysis	Salinity Hazard Mapping	Water Quality Investigations	Macroinvertebrate Monitoring	M-D Algal Investigations & Monitoring	Risks to Shared Water Resources Program	Snapshot of the MDB River condition	State of the Darling Hydrology Report	Land Surface Diversions Report	Surface-Groundwater connectivity study.	Impact of GW on Streamflow in the MDB Report	Wetland GIS of the Murray Darling Basin	Catchment Characterisation Project	Report on River Murray Sci Panel Env Flows	Bureau of Meteorology	Rv. Murray Wetland Database	Bureau of Rural Sciences	**Additional data required**
14. Erosion/ Sedimentation	**1, A**			**3**		**1**	**3**						**A**		**R**	**R**	**R**			**1**			**2**	**3**						**3**				**3**	**V , N**
15. Barriers to passage (eg fish)	**3, A**			**4**	**5, A**	**1**												**2**							**1**	**1**	**1**				**R**		**2**	**4**	**I**
16. Decreased landscape complexity				**4**																			**1**	**2**						**3**				**3**	**D, V**
17. Increased impermeable surface area				**2**																														**3**	**S,V, H**
18. Channelisation																								**1**											**I**
19. Invasive species	**2**			**4**	**3**	**1**	**1**						**A**	**4**	**R**	**R**	**R**	**1**			**1**			**1**					**3**	**1**					**V,**
20. Land clearing	**1**			**4**																				**4**					**3**	**3**				**3**	**V,H**
21. Changes to native biota	**2, A**			**4**	**3, A**									**3**															**2**					**3**	**V,D,**

Main table coding:
Scores range from 1 (poor) to 5 (excellent). A = actions taken within the initiative to address threats; R = management recommendations provided within the initiative.

Colour coding shows data type relevant for a particular threat:

contaminants	biological data	climate change forecast	distribution mapping	salinity	hydrology	water models

Additional data codes:

D	D.E.M	V	Better vegetation data	F	Farm dam data	L	Rainwater harvesting data
I	Infrastructure and channel works	S	Data on soil characteristics	H	Catchment impervious surface area	N	SedNet model

Objective 2a. Deliver Water:
Understand effects of floodplains on water delivery

In terms of water delivery for domestic, industrial and environmental use, both water quantity and quality are important, with different degrees of importance for different uses within these categories. Floodplains affect water availability (quantity of water entering rivers which can be managed for domestic, industrial or environmental purposes) through evaporation rates, differential passage of surface water to ground water or across the floodplain, biotic and abiotic uptake and degree of connectivity with the river channel (Table 8, Figure 4). Water quality is influenced by the tendency of floodplain elements to add or remove solutes and particles (including contaminants) and the rates, prevalence and distribution of these processes in the landscape (Table 8, Figure 5).

Table 8. Effects of different floodplain system attributes on water availability and quality

Attribute	Water Quality	Water Availability
Habitat		
Climate	Temperature affects concentrations of dissolved gases	Rainfall Evaporation
Phys-chem	Soil nutrient status Presence of contaminants Soil adsorptive capacity	Soil water level
Hydro-geomorphology	Soil aggregation (tendency to erode) Soil composition (tendency for particles to be suspended and transported)	Soil infiltration rates Soil porosity Soil water retention Landscape slope
Physical structure	Complexity (filtering of particulates)	Complexity (baffling slows lateral travel, increasing infiltration)
Biota		
Composition	Differential contaminant uptake/ removal by different species/ life stages Differential excretion by different species/ life stages	Differential water uptake by different species/ life stages
Abundance	Total quantities of contaminant uptake and excretion	Total quantities of water uptake
Distribution	Spatial variability in contaminant uptake and excretion	Spatial variability in water uptake
Functioning		
Resource metabolism	Removal of particulates Removal of solutes (e.g. soil microbial uptake of dissolved nutrients) Addition of contaminants (e.g. excretion by fauna)	Water uptake
Persistence	Addition of particulates to water (e.g. dead biota, seed dispersal, bio-turbation) Inputs of solutes from leaching of dead biota Temporal variability in functioning	Temporal variability in functioning Fauna behavioural changes
Homeostasis	Physiological state of biota affects their ability to uptake, excrete	Physiological state of biota affects their ability to uptake, excrete
Biotic interactions	Biotic interactions affecting the ability of others to uptake, excrete	Biotic interactions affecting the ability of others to uptake, excrete
Connectivity		
Energy		
Water	Connectivity between floodplain and river allows the processes above to affect water before it enters river channel.	Connectivity between floodplain surface and ground water with river allows exchange of water to occur.
Biota	Transfer of particulates into water (e.g. birds transporting nesting materials)	
Wind/ atmospheric	Transfer of particulates from floodplain to water column (e.g. leaf litter)	

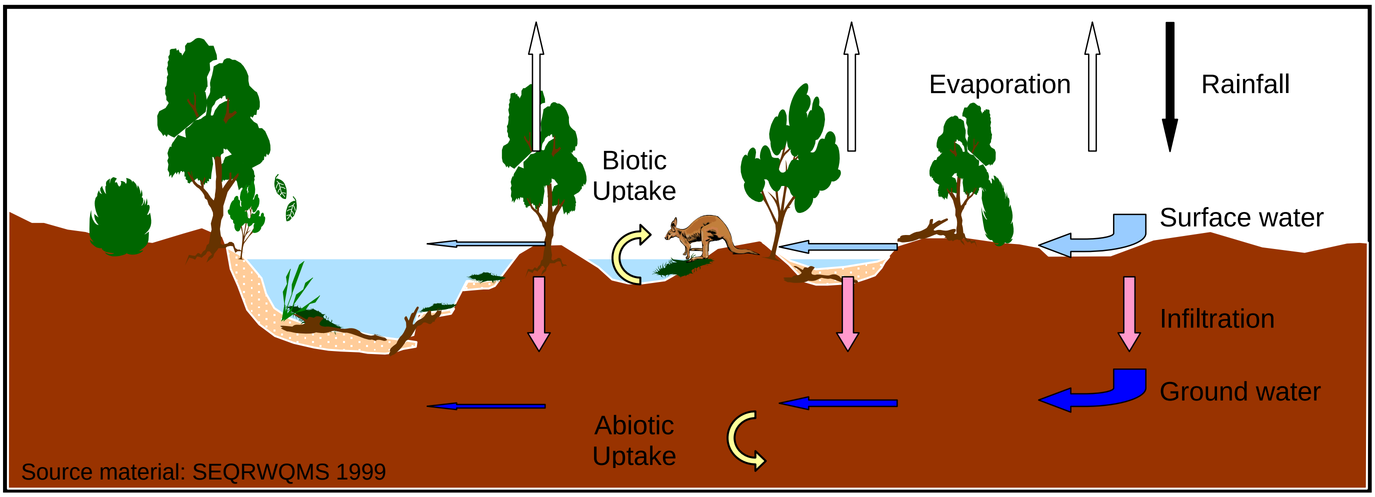

Figure 4. Floodplain processes affecting water availability. Rainfall (black arrow) may evaporate (white arrows), enter ground water (dark blue arrows) or move across the floodplain (light blue arrows). Biotic and abiotic uptake (yellow arrows) of both surface and ground water reduces the amount travelling toward the river. Ongoing infiltration (pink arrows) (enhanced by reduced flow speeds due to structural complexity), evaporation (enhanced by high temperatures and winds) and uptake are possible as water travels towards the river channel. Eventually water enters the channel if no barriers to movement exist.

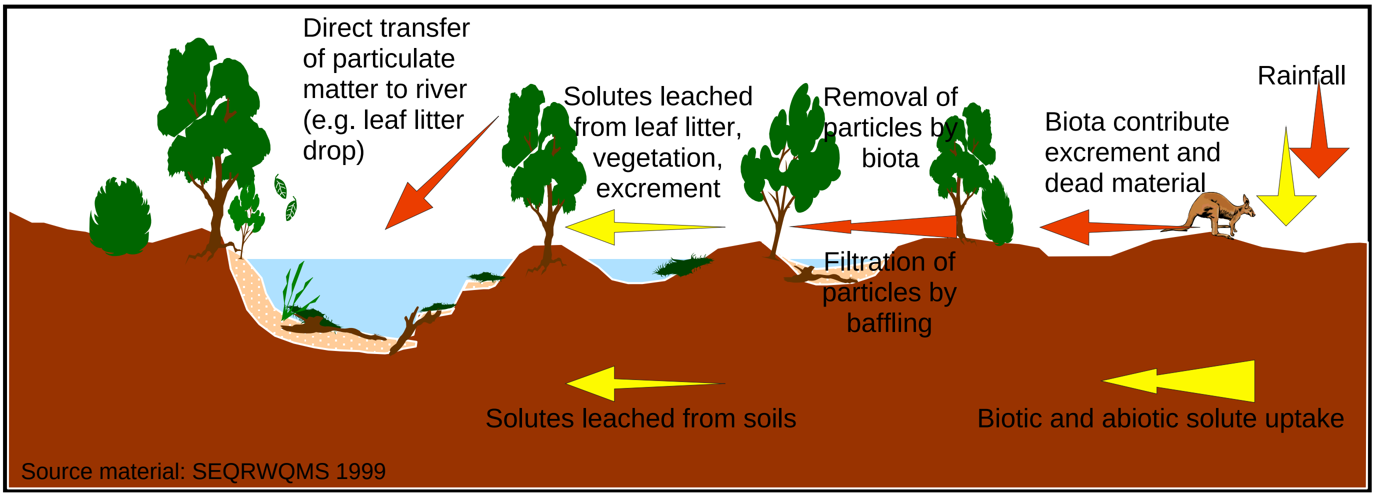

Figure 5. Floodplain processes affecting water quality. Water quality is influenced by the tendency of floodplain elements to add or remove solutes (yellow arrows) and particles (red arrows), and the rates, prevalence and distribution of these processes in the landscape. Arrow tapering indicates addition or removal. Rainfall may transfer solutes and particles from the atmosphere. Structural complexity reduces flow speeds and enhances filtration of particles. Solutes (nutrients and contaminants) leach from leaf litter, excrement, vegetation and soils. Solute uptake may be biotic (generally by autotrophs or microbes) or abiotic (adsorption to particles). Biota may also remove particles, but in turn contribute excrement and dead material and can increase suspended particle loads through bio-turbation. As well as being swept into the river channel by water moving across the floodplain, particulate matter can also enter the river by direct transfer (e.g. leaf litter drop). Temperature affects concentrations of dissolved gases and rates of most of the processes outlined above.

Threats to processes affecting the quantity and quality of water available for delivery and use for domestic, industrial and environmental use are outlined in Table 9. Each threat listed relates to one included in Table 7 (indicated by the number in the “Reference” column). By referring back to Table 7, MDBC programs and initiatives providing data on these processes can be determined. As noted above 5 of the 6 risks identified by the risks to shared water resources initiative arise from floodplain management reinforcing the importance of floodplain management to the quality and quantity of water available for consumptive and environmental use.

The MDBC programs that provide data on floodplain condition are TLM and SRA which both provide information on vegetation which is one of the major drivers of floodplain influence on water quality and quantity either directly or indirectly through its influence on the soil microbial community. The other MDBC programs either provide information on water quality in channel (RMWQMP, BSMS) which includes a flood-plain influence or provide data on issues that will only marginally influence water quality or quantity (NFS)

Table 9. Threats to processes affecting floodplain water quality and quantity.

Process	**Threat**	**Reference in Table 6**	**Major Programs that address/assess threats**
Rainfall	Climate change	7	Risks Program, BOM
Evaporation	Climate change Veg change Landscape modification	7 21 16	Risks Program, TLM, SRA SRA
Surface – ground water exchange	Impervious area Altered soil infiltration	17 4, 13	SRA TLM, SRA
Surface water movement	Changes to floodplain structural complexity	16	SRA
Altered biotic uptake	Biota composition, abundance	21	SRA, TLM, NFS,RMWQM
Altered abiotic uptake	Altered soil retentiveness, porosity	13	TLM,SRA
Transfer to the river channel	Barriers to floodplain-river connectivity	4	TLM,SRA, NFS, RMWQM
Rainfall	Climate change	7	Risks Program
Rain transported contaminants	Air quality Contaminated surface water discharge	----- 10	BSMS,SRA, RMWQM,
Particle filtration	Structural complexity Changes to slope	16 -----	SRA
Leaching of nutrients from floodplain surface	Altered biota Altered productivity/ metabolism Altered soil nutrient status Altered soil characteristics	21 ----- 13, 10, 11 13, 10, 11	SRA,TLM,NFS,RMWQM, SRA,BSMS,RMWQM,NFS SRA, BSMS,RMWQM, NFS

Objective 2b. Deliver Water: Determine floodplain water requirements

The geographical boundaries of the floodplain are still not understood, both in terms of their history or extent today given the degree of development and alienation from the river. Without clear definition of floodplain ecosystem assets and management targets determined by appropriate management agencies, it is not possible to determine floodplain water requirements.

However the *Wetland GIS of the MDB* (Kingsford et al 2000) maps the location and extent of wetlands into a Geographic Information System (GIS), from which it is possible to partition wetlands into river catchment areas or other relevant spatial scales. Combination of this data with other GIS data sets will enable spatial scale analysis of floodplain elements and assist in the knowledge of their requirements.

Four of the six icon sites for the *Living Murray* are floodplain assets, albeit without known reference condition, for protection and enhancement. While this represents a very small component of the floodplain, 500 GL of water will be allocated and shared between the four icon sites.

The MDBC is also funding research that utilises CSIRO's floodplain inundation model to identify optimal watering patterns for wetlands in order to maximise beneficial ecological outcomes and provide the MDBC, the Murray Wetlands Working Group and State agencies with the information needed for flow allocation for these wetlands (http://www.lwa.gov.au; project code UAD 23).

River Murray Water is currently addressing floodplain water requirements in light of the drought and has developed a proposal to disconnect wetlands on the basis of the amount of water they require.

Objective 3. Provide Advice: Determine effects of management on floodplains

Each of the programs of the MDBC arose from a need to address a specific target. Consequently natural overlap of objectives to target a common threat is limited by the intent of the objectives and the scale at which they operate. Much of the northern basin escapes monitoring activity and it is the area where BRS maps identify the least known condition. The Sustainable Rivers Audit, Basin Salinity Management Strategy, the Native Fish Strategy and the River Murray Water Quality Monitoring Program have basin wide coverage but little overlap in data collected. The Sustainable Rivers Audit however is expanding its themes and is poised to become a valuable data set for integrated comparisons between programs where integrated floodplain deliverables can be identified. The Living Murray conversely, has only four floodplain wetlands of focus and the relevance of management outcomes across the basin are not as strong.

The Risks to the Shared Water Resources of the MDB report does integrate threats to the Basins water resources, several of these can impact the floodplain however, it does not highlight how these threats impact floodplain assets. Where opportunities exist for collaboration between programs in MDBC and between MDBC and other institutions/agencies they have been identified in Table 6. and section 1c.

Knowledge gaps

Sustainable management of the MDB requires an understanding of the natural and anthropogenic systems on which we rely. As a consequence, incomplete understanding of the inter-dependencies of river and floodplain systems is in itself a threat to the resource and the MDBC's ability to provide advice on management. Some of the conceptual knowledge gaps identified by the Murray-Darling Basin Commission include:

- Incomplete understanding of the ecological processes that drive wetlands.
- Incomplete understanding of the environmental flow requirements for various ecosystem components.
- A lack of understanding of the connectivity between surface water and groundwater interactions.

In addition to these knowledge gaps there are a number of areas in which we have adequate conceptual understanding but inadequate data to either assess the resource or the magnitude of the threat. Some of the gaps identified by the MDBC include;

- Poor estimates of extraction (ground and surface water) in some areas of the basin.
- The need for better data on irrigation water use, losses, and return flows across the basin.
- Poor estimates of land surface diversions, and the number and capacities of farm dams.
- Spatially and temporally fragmented data monitoring floodplain assets throughout the Basin.

There is considerable investment in improving water resource information through the W.R.O.N. and the National Water Initiative that may help ameliorate these threats. The utility of the data generated or managed by these initiatives will depend on the ultimate scope and questions addressed by the W.R.O.N and NWI. As a consequence it is possible that the focus will remain on river channels. Even if this is the case the data sharing and management protocols should facilitate access to these data thereby helping MDBC programs integrate data across programs. For example improved access to water quality and land cover data combined with the SedNet model would enable better determination of sediment inputs from the floodplain.

The eWater CRC is in the process incorporating current system understanding into tools that will underpin operational decisions and planning processes. One of the challenges facing the MDBC will be to maximise its return from its investment in eWater by integrating the products developed by eWater with the data available through MDBC monitoring programs. Once again the detail of what will be possible will need to wait until the detail of eWater products becomes clear.

Management

As noted earlier natural resource management within the MDB is complicated by the number of institutions with around 145 local governments and at least 15 catchment management authorities involved. Collaboration becomes difficult when either different institutions use different protocols or models or where agreement cannot be reached. The MDBC has recognised that the use of different models to estimate surface diversions by the states represents a threat to sustainable management. Similarly, the failure to meter diversions; to set a cap for some MDB valleys in QLD, ACT and parts of NSW; or to limit groundwater extraction in some areas all represent threats.

Table 10 scores the affect of knowledge and management risks on the MDBC's ability to understand the threats, assess floodplain condition and manage or provide management advice for floodplains. The scoring of knowledge or management risk was undertaken by our Expert Panel, reviewing the data available to us. Scores were influenced by the degree that a risk addressed the threat specifically and spatially. For example, if a risk completely addresses a threat and it is a basin wide risk, then that risk would score a five. However the score would decrease if the threat was incompletely addressed and only partially covered the basin.

Table 10. Risks to the MDBC's ability to understand threats, assess condition and manage or provide management advice for floodplains on a basin wide scale.

Knowledge and Management Risks	Threats															
	Altered Hydrology	Climate Change	Salinity	Land Clearing	Loss/Change of Native Biota	Wetland Acidification	Erosion/Sedimentation	Invasive Species	Groundwater Extraction	Groundwater Quality	Fish Passage	Modified Soil Structure	Contaminated Surface Water Discharge	Contaminated Groundwater discharge	Management/Provide Advice re. Floodplain	Assessment of Floodplain Condition
Incomplete wetland understanding.			2		4	4		2		2	3		2	2	4	3
Poor knowledge of surface and groundwater interactions.	1	1	1						4	3				3	3	
Incomplete understanding of environmental flow requirements.	3		2		4	2	2	3			4				4	
Incomplete Cap implementation	5								4						4	
Water reform skills shortages	Insufficient information available to determine for each threat														5	3
Poor or no metering of surface water extractions	3								3						2	
No limit on GW extractions in some areas	1								2						1	
Inconsistent modelling & estimations of land surface diversions	3														3	
Poor estimates of groundwater extraction	2								4						2	
Insufficient return flow data	2		1							1			4	3	4	
Paucity of floodplain assessment data		3	3	5	4	4	4	4	3	3		4	4	4	2	5
Northern Basin																
Poor estimates of farm dams and capacities	3		2							1	1				2	

Conclusions

This brief review of the relationship between MDBC objectives and floodplain management within the MDB reveals a number of key issues, primarily that;

- Our conceptual understanding of floodplain ecosystem function underscores the interdependencies of floodplain and main channel habitats
- As a consequence of the interdependencies, achievement of the MDBC objectives cannot be achieved without harmonisation of main channel and floodplain management.
- Achieving MDBC objectives relies on an assessment of both asset condition and the magnitude of threats.

In reviewing the capacity of the MDBC to undertake assessments of assets and threats it became apparent that;

- Without clear definition of the assets, it is difficult to undertake any assessment.
- The limited data available indicates that MDB floodplains are extensively modified
- Due to the complex management environment within the MDB and the way in which we have responded to threats (through implementation of strategies) the data required to assess condition and threats is fragmented.

The MDBC recognises the importance of knowledge to underpin management response. It is clear that the performance of MDBC programs would be improved with access to integrated data from across programs. Examples from this review include water delivery, where access to that there is scope to synthesise and integrate the data currently collected by the MDBC to generate an improved knowledge base upon which to base assessments. This internal initiative will present a number of challenges in terms of data management and integration. Such an initiative would benefit from collaboration with other initiatives that are attempting to develop data management and integration procedures, including W.R.O.N. and A.E.O.N.

The next step would be to explore multi-jurisdictional data sharing arrangements to underpin more comprehensive assessment of condition and risk. While there is potential for this to be perceived as the MDBC exceeding its mandate, this could be avoided by ensuring both a clear value proposition for all participants in the data sharing and clear articulation of the roles of management institutions in achieving shared management objectives.

Ultimately, achieving the MDBC objectives of protection of assets, water delivery and provision of advice will rely on integration MDBC programs with clear articulation of the roles of each program and management of the interactions. The MDBC currently have undertaken several initiatives to address threats to water availability including the Salinity Strategy, Algal Management Strategy, The Cap and the Risks to Shared Water resources, 3 further initiatives to address threats to environmental assets including the Native Fish Strategy, Northern Basin Strategy and TLM. Finally the MDBC has 2 programs that provide data to underpin assessment of condition, the RMWQMP and the SRA. The Risks to shared water resources provides a clear framework for addressing threats to water resources. There is no similar framework for examination of threats to environmental assets, although environmental assets are also vulnerable to hydrological alteration. Development of a risk framework for environmental assets would facilitate integrated reporting.

Overall integrated reporting on floodplain assets should be aligned with the strategic objectives of water delivery, protection of environmental assets and provision of advice. The major challenge facing the MDBC in this process is the fact that, of the recognised threats to water and environmental assets only a subset will be the focus of MDBC initiatives or programs while others will remain the subject of initiatives undertaken by other government agencies, including catchment management organisations. As a consequence, not only will there need to be greater data sharing, the reporting of progress on protecting water and environmental assets would benefit from improved understanding and reference to the initiatives and strategies of other institutions.

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Appendix 1

Contaminants

Contamination of the floodplain, and more commonly its wetlands, derives from agricultural, industrial and urban activities. Return flows from agricultural enterprises may contain contaminants including excess nutrients, herbicides, fungicides, anti-biotics, vermifuges, insecticides, pathogens, pharmaceuticals, sediment and elevated salt levels which can accumulate in receiving wetlands (van Dijk 2006). Contaminants from other industries depends on the specific industry in question, but may include excess nutrients, particles, salt, toxins, carcinogens, mutagens, hydro-carbons, radio-active material, trash, heavy metals, flammables and teratogens. Urban storm water and sewage effluent outflows are known to flow into floodplain systems, although primary and secondary treatment of these sources has significantly improved in recent times. Despite treatment improvements, such sources still locally deliver significant amounts of nutrients, chemicals, pharmaceuticals, sediment, pathogens and urban rubbish to floodplains. Outfalls from agriculture, industry and urban areas may also have altered pH, dissolved gas concentrations and temperature which may affect floodplain biota and abiotic processes (MDBC Pub. No 36/04).

Air pollution caused by human activities is also of concern to floodplain systems, especially given the prevalence of human habitation on floodplain zones. As well as directly affecting air quality for floodplain biota, particles in the air can have indirect effects on floodplain ecosystems through their effects on light, temperature and precipitation. Noise pollution would also be expected to affect floodplain biota.

Of the contaminants listed, salinity has been identified by MDBC programs and initiatives as being of major concern to Basin floodplains (BSMS 2001). Although not identified in MDBC initiatives as a current threat, additional information on acidification has been included here as it is considered a critical emerging threat to floodplains in the MDB.

Salinity

Salt has been and continues to be a major threat to floodplains of the Murray-Darling Basin. Salt can be delivered to a floodplain through groundwater discharge, irrigation outflows, runoff, or delivered via the river channel. Floodplains may also become salty as rising water tables bring with them high concentrations of dissolved salts (MDBC 2001).

Each of the above scenarios may result from extensive vegetation clearing, removing deep rooted plants that previously used groundwater for their survival. Such plants kept the water table deep beneath the land surface. Without deep rooted plants, the water table rises, bringing salts that naturally occur in the soil profile with it (dryland salinity). Irrigation speeds up this process as excess water is added to groundwater stores, effectively raising the watertable to the surface (irrigation salinity). Increases in groundwater may also be caused by changes in groundwater hydraulics with salt water being maintained under floodplains or freshwater being pushed into groundwater areas due to river or storage operations (MDBC 2001).

Without regular flushing, salt accumulates in floodplain ecosystems, a process that is exacerbated by drought. A growing threat is that when floodplains are finally flushed after this current period of drought, large amounts of salt will be mobilised and flushed into rivers of the Murray-Darling Basin (MDBC 1998).

Acidification

Acidification arises from the interaction of hydrology with sulfidic sediments. Sulfidic sediments (potential acid sulfate soils) are considered a concern primarily in coastal regions, but mounting evidence indicates that they are also an issue in freshwater ecosystems, particularly those impacted by secondary salinisation. In a recent survey of 81 wetlands in the Murray-Darling Basin, more than 20% had evidence for the presence of sulfidic sediments at levels that could lead to ecological damage. When sulfidic sediments are present, drying can oxidise sulfidic minerals and generate acid (actual acid sulfate soils). This has been shown to have caused a significant fish kill in western NSW. Oxidation of sulfidic sediments can also cause other problems such as anoxia in the overlying water column, generation of noxious odours and mobilisation of metals from the sediments (Hall et al. 2006).

Bushfires

Bushfires destroy vegetation to varying degrees depending on the intensity of the fire. Post fire pollution due to increased runoff that carries contaminants such as ash, sediments, nutrients and organic matter are washed into waterways and reservoirs. Flash flooding is often prevalent post fire, depositing the above contaminants on upper catchment floodplains. Pollutant loads washed into waterways generally decreas over time as the catchments stabilise. Water yield is also impacted post fire. Initially yield will increase as less water is utilised by less vegetation. However, as the forest recovers, rapid regrowth occurs and water use will be greater than that of a mature forest, reducing the water yield of the catchments. This reduction may last from 20 to 200 years depending on the type of forest present and the intensity of the bushfire. The result of reduced water yield is reduced stream flows, decreasing the chance of floodplain inundation (van Dijk 2006).

Altered hydrology

Altered hydrology has increased flow predictability, reducing the natural variability required to drive floodplain processes. The hydrology of the Murray Darling Basin has been, and will continue to be, altered through water extraction, the construction of infrastructure to divert water, effluent releases and industrial discharge and through past and continued climate change (MDBC 1996).

Since the 1950's there has been a substantial increase in the quantities of water diverted from waterways and extracted from groundwater aquifers of the Murray-Darling Basin. Over two-thirds of the water that would naturally reach the ocean is now diverted for consumption, of which around 95% is used for irrigated agriculture. Basin wide, approximately 11% of water used for irrigation is from groundwater sources, however, in Queensland this figure jumps to 31% (van Dijk 2006). Utilisation of water for human purposes has diverted water away from floodplains, significantly altering habitat, ecosystem processes and the exchange of material between floodplains and river channels (MDBC 2004).

Aspects of altered hydrology which impact upon floodplains include:

- River flow management. Waterways of the Murray-Darling Basin have undergone significant changes to their flow regimes in order to provide water for agricultural and urban purposes. This has altered the timing, duration and frequency of floodplain inundation (MDBC 1998).
- Barriers to connectivity. The introduction of infrastructure such as dams, weirs, regulators and levee banks can further alter flows onto floodplains and into floodplain channels and wetlands, even when river flows are managed to achieve floodplain inundation. Additionally, these structures can prevent water draining from floodplains when they would otherwise be dry (MDBC 1998; Bewsher Consulting Pty Ltd 2006; MDBC Pub No. 07/07).
- Water extraction from floodplains. Water extraction from floodplain (Land Surface Diversions) wetlands alters the hydrology of that particular wetland. The act of diverting and capturing flood waters for later use alters the natural movement of floodwaters over the landscape. Such diversions prevent floodwaters from extending over the floodplain to the degree that they naturally would. By preventing floodwaters from covering the floodplain, biota located on large tracts of land miss the opportunity to receive life giving nutrients, fresh sediment and productivity generating waters (Bewsher Consulting Pty Ltd 2006; MDBC Pub No. 07/07).
- Groundwater extraction. Sustainable extraction limits have not been set for many aquifers. Compounding this stress is that water level and water quality monitoring is patchy, making it difficult to detect declining trends due to extraction (Bewsher Consulting Pty Ltd 2006; REM 2006; MDBC Pub No. 07/07).
- Groundwater Connectivity. Excessive extraction of groundwater has the potential to reverse the hydrologic gradient, such that groundwater may flow from stream to aquifer. Waterways and wetlands may also suffer when groundwater that would naturally discharge into them is pumped from aquifers. Conversely, floodplains like Chowilla are impacted by rising water tables high in dissolved salts caused by accessions to the water table and reduced drainage to the Murray River. Increases in the area of impervious surfaces in a catchment reduces water availability for ground underlying the impervious surface and increases runoff (Bewsher Consulting Pty Ltd 2006; REM 2006; MDBC Pub No. 07/07).

- Rainwater harvesting. Extraction of rainwater within the catchment prior to it entering the natural flow pathways (e.g. farm dams, roof capture to water tanks) decreases the overall quantity available to river and floodplain ecosystems (Bewsher Consulting Pty Ltd 2006).
- Water inputs. Irrigation, storm water and effluent releases and industrial discharge increase water inputs to localised parts of river and floodplain systems. Water may be discharged directly onto the floodplain surface or into wetland systems. Excess water from these sources often recharges groundwater systems. Return flows can carry large amounts of sediment, organic matter, nutrients, salt and other pollutants, all of which threaten the ecological integrity of floodplain ecosystems (van Dijk 2006).

Climate change

Changes to local and global climate patterns occur due to a number of natural and anthropogenic factors, however human activities generally cause far more rapid changes in environmental conditions.

Global climate change

Studies have shown that mean temperatures across the basin have risen at a rate of 0.17 °C per decade since 1950. The Inter-governmental Panel on Climate Change has ascribed this to an atmospheric increase in greenhouse gas concentrations. Trends in rainfall are difficult to state due to the natural fluctuation within the basin, however there is evidence of a sustained reduction in rainfall over the past 10 years. Climate change models predict that the greatest rise in maximum temperatures will occur in the North, while annual rainfall is predicted to decline throughout the basin.

In a climate of increasing temperatures and potential evaporation, any reduction in precipitation will significantly affect aquatic ecosystems and water resources. Predictions of stream flow changes suggest that reductions will be greatest in the south of the basin, and least in the north. Overall reductions in rainfall will further decrease the frequency and magnitude of floodplain inundation, which is likely to cause further declines in floodplain ecosystem condition. Increased evaporation of standing bodies of water on floodplains (e.g. wetlands) will reduce their permanence and water quality. Predicted increases in rainfall intensity that some climate change models suggest may result in an increase in local flood events, although these are unlikely to benefit the floodplain given the infrastructure in place.

A reduction in rainfall across the basin is also likely to reduce recharge to groundwater systems. Given the scarcity of water within the Basin, any decrease in rainfall or runoff is likely to mean further reductions in water availability for already stressed environmental assets on the Basin’s floodplains. Climate change is also likely to alter the frequency, duration and intensity of natural disturbances such as fires, scouring flows, floods, storms and drought (van Dijk 2006).

Local climate change

Activities such as alteration of vegetation composition and abundance, urbanisation, river infrastructure and industrial activities affect local solar radiation availability and uptake, temperature, precipitation, evaporation and wind speeds. These affect the types of biota able to persist in a location, rates of functioning and local connectivity patterns. The threat of local climate change to floodplain ecosystems has not been assessed in the Murray-Darling Basin.

Landscape modification

Floodplain physical structure may be modified through earthworks or the construction of in-channel or floodplain infrastructure (for agriculture, industry or urbanisation). Threats to floodplain ecosystems associated with each of these activities are outlined below. Of these, only altered hydrology, restrictions to connectivity and thermal pollution have been targeted by MDBC programs and initiatives.

Earthworks

- Alterations to soil characteristics – structure, compaction, porosity
- Altered hydrology through drainage of damp spots and wetlands
- Decreases in landscape complexity – floodplain levelling, wetland filling, woody debris removal
- Increased risk of spread of invasive species (Bewsher Consulting Pty Ltd 2006; MDBC 07/07).

Channel infrastructure

As well as altering flow patterns and hydrological activity, dams, weirs, regulators, culverts, levees, causeways, channel reinforcement and channelisation also cause:

- Restrictions to movements of particles, biota, propagules
- Thermal pollution downstream of dams negatively affects aquatic communities; heating of artificially pooled waters.
- Impervious surface area (reduce infiltration and increase runoff (ie altered surface-ground water exchange); limits capacity for vegetation growth)
- Restriction of channel meandering
- Reduction of channel structural complexity
- Possibility of leaching of contaminants from construction materials (MDBC Pub. No. 36/04)

Floodplain infrastructure

- Impervious surface area (reduce infiltration and increase runoff (ie altered surface-ground water exchange); limits capacity for vegetation growth)
- Buildings – local effects on light, temperature, evaporation, wind and water flow patterns
- Possibility of leaching of contaminants from construction materials (MDBC 1998).

Alterations to biota

Many anthropogenic activities have altered the composition, abundance and distribution of biota in rivers and floodplains, posing a number of different threats to floodplain ecosystems. Of these, MDBC programs and initiatives have to date focused on the introduction of invasive species in the Native Fish Strategy.

- Introduction of invasive species. Introduced species such as willows and carp compete with native flora and fauna, reduce bio-diversity and alter metabolic functioning in floodplain ecosystems (MDBC 07/05).
- Wholesale vegetation clearing. Extensive tracts of land within the Murray-Darling Basin have been cleared of native vegetation for various purposes. Among other things, land clearing increases erosion, raises the groundwater table, modifies soil structure and soil characteristics, eliminates native biota, and facilitates invasive species. When such changes occur on the floodplain it has an impact on floodplains and river channels through the transport of water, sediment and chemicals from affected areas through the landscape (van Dijk 2006).
- Changes to community composition. Replacement of deep-rooted vegetation with shallow-rooted species, removal of canopy species, replacement of native herbivores with sheep and cows, extinction of native species and localised dominance of one native over another are some of the many changes to community composition effected since European settlement. These changes alter surface-ground water exchange, soil characteristics, habitat value, organic matter cycling, erosion, filtration, climate variables and persistence of native community assemblages.
- Changes to population structure. Selective removal of certain species or population elements (e.g. through over-fishing, harvesting trees for timber and firewood removal) and cultivation of specific population structures (e.g. crop monocultures) affects bio-diversity, native species persistence, metabolic functioning and hence ecosystem service provision.
- Altered density of biota. Intensive farming of introduced species requires high inputs of energy and nutrients to maintain productivity and leads to high levels of contaminant release. Decreased density of native species reduces chances of reproductive success and hence affects bio-diversity, species persistence and floodplain ecosystem food-webs.
- Afforestation. Plantation forestry uses more water than unirrigated pastures or crops. Forests use more water through greater direct evaporation of rainfall from leaves, they access deeper soil water stores and have a greater exposure to drying winds. Plantation forests reduce the water yield of a catchment. In low rainfall areas the reduction in water yield due to forests is relatively small in comparison to that of high rainfall areas. Typically forestry is practiced in high rainfall catchments of the basin, where the impact on water yield will be the greatest. A reduction in water yield due to forestry is greatest in dry periods, resulting in reduced stream flows at such times. The result of reduced water yield is reduced stream flows, decreasing the chance of floodplain inundation (van Dijk et al. 2006).