

Appendix B — *Hydrologic indicator sites*

Introduction

The *Water Act 2007* (Cwlth) requires that the Basin Plan set environmentally sustainable levels of take for the Basin's water resources and that this take does not compromise key environmental assets (i.e. water-dependent ecosystems, ecosystem services and sites with ecological significance), key ecosystem functions, the productive base, or key environmental outcomes for the water resources. Assessing these water requirements has not been undertaken in the Murray–Darling Basin before.

The primary mechanism for achieving an environmentally sustainable level of take is the establishment of long-term average sustainable diversion limits. The approach taken for surface water combines two elements:

- an analysis of the environmental water requirements of fundamental physical, chemical and biological processes, known as 'hydrologic indicator sites for key ecosystem functions'
- an analysis of the environmental water requirement for specific sites, known as 'hydrologic indicator sites for key environmental assets'.

The first step in identifying environmental water requirements was to determine environmental objectives and targets required to protect and restore hydrologic indicator sites to meet the requirements of the *Water Act* — not to restore sites to their historical condition, but sufficient to protect their biological populations and ecological functions.

Once the environmental water requirements are determined, management of this water will be set out in new arrangements under the Basin Plan, which will describe the principles and methods to be used to determine priorities for applying an environmental watering framework.

Environmental objectives and targets

The Murray–Darling Basin Authority (MDBA) used the conceptual model presented in Figure B1.1 in devising ecologically sustainable flow regimes for the 18 hydrologic indicator sites for key environmental assets. A suite of standard and relatively high-level objectives were developed to align with the criteria for identifying key environmental assets. Objectives selected for each hydrologic indicator site were dependent on the criteria under which they were identified as being 'key'.

These objectives are to:

- conserve declared Ramsar wetlands consistent with their ecological character (criterion 1)
- protect and restore water-dependent ecosystems that support migratory birds listed in international agreements (criterion 1)
- protect and restore natural or near natural, rare or unique water-dependent ecosystems (criterion 2)
- protect and restore water-dependent ecosystems that provide vital habitat (criterion 3)

- protect and restore water-dependent ecosystems that support Commonwealth-, state- or territory-listed threatened species and/or ecological communities (criterion 4)
- protect and restore water-dependent ecosystems that support or are capable of supporting significant biodiversity (criterion 5).

These objectives were analysed in further detail to determine more specific environmental targets. Where the objectives for a site related to the presence of listed threatened species or species recognised in international agreements, the habitat requirements for those species were identified. Where the objectives related to conservation of Ramsar ecological character, the habitat types associated with that character were identified. Targets were set and flow requirements were determined to sustain those habitat types on the premise that by providing habitat in good condition, the biota would respond positively.

In determining water requirements and flow regimes to sustain the selected hydrologic indicator sites for key environmental assets, a range of species whose lifecycle depends on flood events were identified for each site and their habitat needs defined. Species with similar requirements were grouped, and targets were selected to protect habitat types.

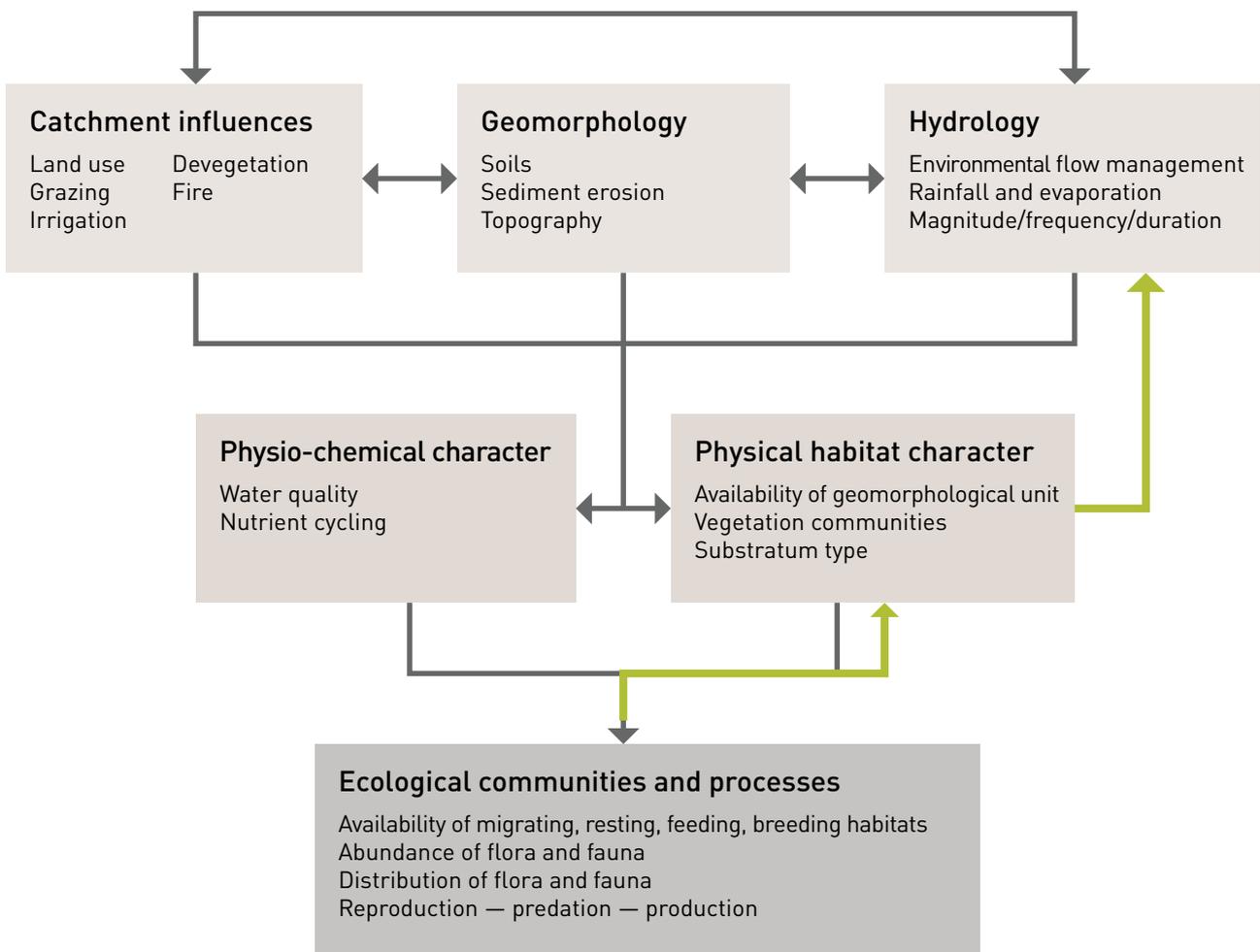


Figure B1.1 Conceptual model of the factors that influence ecological communities and processes within freshwater aquatic ecosystems

Note: green arrows show the process adopted by MDBA in devising targets based on the habitat requirements of significant species, to inform environmental water requirements.

Overall objectives

To protect and restore water-dependent ecosystems that support migratory birds listed in relevant international agreements.
 To protect and restore natural or near-natural, rare or unique ecosystems
 To protect and restore water-dependent ecosystems that provide vital habitat
 To protect and restore water-dependent ecosystems that support Commonwealth-, state- or territory-listed threatened species and/or ecological communities.

Habitat requirements

— Feeding and breeding
 — Feeding
 — Breeding/ nesting

Significant species (functional groupings where appropriate)

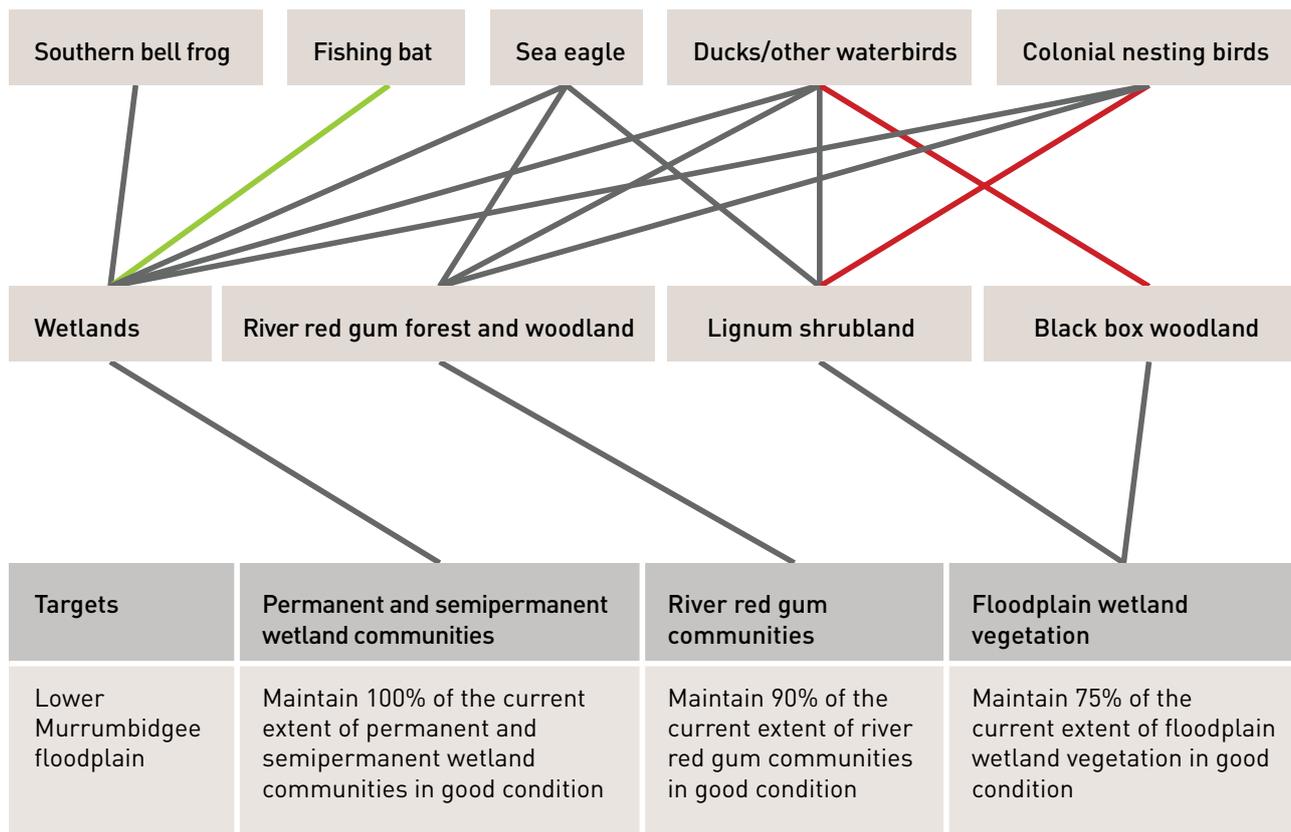


Figure B1.2 Link between significant species to habitat types and the associated vegetation targets set for the Lower Murrumbidgee River Floodplain

An example of the process used to link the significant species to their required habitats is presented for the Lower Murrumbidgee River Floodplain (Figure B1.2). This was done through knowledge of their habitat requirements, allowing formulation of targets to rehabilitate the identified habitat types (in most cases vegetation communities).

Where the targets associated with habitat types or vegetation communities were considered to provide a flow regime sufficient to meet the needs of other plants and animals represented in the objectives, no further targets were specified. Where it was considered that some important species would require additional flows, additional targets were specified.

The fact that particular species or groups of species are not explicitly mentioned in the targets should not be interpreted as reducing their significance. Rather, it reflects the nature of the task. This is not an environmental management planning process, but a hydrologic exercise to determine sustainable flow regimes.

Targets for vegetation communities and habitat types

Most vegetation-related targets selected for the 18 hydrologic indicator sites for key environmental assets aim to maintain the current extent of vegetation communities and rehabilitate their condition. Maintenance of current extent was adopted because restoring or increasing the extent of these communities would typically require land use change, which is outside the scope of the Basin Plan (Water Act s. 22(10)).

For declared Ramsar wetlands, current extent was taken as the extent of vegetation communities at the time of listing. For declared Ramsar wetlands with an 'ecological character description', this was used to define the extent of the vegetation communities. For declared Ramsar wetlands with no ecological character description, the best available information on the extent of vegetation communities at the time of listing was used.

For non-declared Ramsar wetlands, current extent was defined by the best available information. The age of this information varied among these 18 sites and was drawn from CSIRO, state and Commonwealth governments, private and public industry and other research providers. Inconsistencies in the age and quality of baseline information are recognised as a limitation.

Reductions in the frequency and duration of flooding enable both native and exotic terrestrial species better suited to the dryer conditions to colonise semipermanent wetland and floodplain areas (Thomas et al. 2009). The resulting change in species composition and diversity is a major issue for the health and condition of wetland and floodplain ecosystems (Bowen & Simpson 2006). To achieve section 3 objects (d)(i) and (d)(ii) of the Water Act it was therefore assumed that a degree of condition rehabilitation is required.

For declared Ramsar wetlands with ecological character descriptions that have detailed limits of acceptable change, these were used as a basis. However, the ecological character descriptions often do not define in detail the condition at time of listing.

The targets therefore typically propose rehabilitation to a condition described as 'good'. That means a sustainable long-term condition where the flora and fauna populations have sufficient resilience to survive extended drought and at the end of that drought have the capacity to successfully complete their lifecycles and breed.

The work of Seaman (2003) and Bowen and Simpson (2006), together with The Living Murray icon site condition reports, have been used to define 'good' condition more specifically. A vegetation community in good condition should retain its basic vegetation structure or the key features that enable this to be regenerated.

In addition, a community in good condition should contain core habitat areas that are buffered by remnants. For forest and woodland communities retention of basic vegetation structure should be based on maintaining tree health as measured by crown extent, with the preferred threshold for crown extent being greater than 90% across a stand. In the case of semipermanent and floodplain wetlands, species composition is a better indicator of structure. In these communities shrub and groundcover layers should contain minimal level of invasion by terrestrial (non flood-dependent) species.

In reading and interpreting this document it is important to recognise that the targets do not seek to restore the assets to their natural condition. The targets and their interpretation in defining environmental water requirements also recognise that condition of the assets will vary in response to climatic

conditions. The frequency of flow events, and therefore ecological condition, will respond to weather patterns and decline during periods of prolonged drought, even under natural conditions.

Targets for waterbirds

Waterbirds are particularly valuable in defining environmental water requirements for the hydrologic indicator sites for key environmental assets.

First, waterbirds are at the top of the food chain and therefore serve as useful indicators of overall ecosystem health (Scott 1997).

Second, waterbirds are a central element of the international agreements on which the Water Act is founded, and the Water Act makes specific reference to obligations to these agreements.

Waterbirds have a variety of requirements in terms of habitat and flow regime. In terms of these requirements they are often categorised as waterfowl (e.g. ducks) and colonial nesting waterbirds (e.g. ibis). Both categories of waterbird require healthy and productive habitats for food and nesting. In terms of water requirements the main difference between the two categories are their needs for successful breeding.

Waterfowl typically require shorter-duration flooding events to successfully breed. These requirements are often similar to those of wetlands and fringing vegetation communities. Colonial nesting waterbirds typically require longer-duration events for successful breeding and fledging of chicks.

For most of the 18 assets it was considered unnecessary to provide additional waterfowl-specific targets as the requirements of the species would be met by wetland and vegetation targets. This was generally not the case for colonial nesting waterbirds. Therefore assets with recognised importance for colonial nesting waterbirds, specific targets relating to colonial nesting waterbird breeding were required.

Other waterbird targets were specified to provide conditions to act as drought refuge for migratory species or to support resident waterbird populations. Both these aspects are considered important for the longevity of both migratory and resident bird species (Scott 1997).

Other targets

Targets for other ecological components were specified when it was felt their specific water requirements would not be met by the vegetation community/habitat type and waterbird targets; for example, targets for wetland connectivity and fish recruitment.

Flow regimes to meet targets

Flow regimes to achieve the objectives and targets were estimated, drawing upon existing literature (including scientific papers and project reports, management plans, ecological character descriptions and environmental flow reports) and expert advice (typically from state government agencies).

In most situations multiple sources of information were used to provide greater certainty to the flow regimes specified. In some instances the sources of information provided different recommendations and therefore the determination of an appropriate flow regime required interpretation across those multiple sources. When interpretation was required it was informed by analysis of flow data.

An example of identifying the environmental water requirements of a key environmental asset hydrologic indicator site is provided in Table B1.1.

How the environmental water requirements relate to modelled scenarios for without-development conditions and current arrangements is best shown in graphical form. To assist readers to understand the graphs in this appendix, an explanation is provided in Figure B1.3. The proportion of modelled years that a specified event occurs under different scenarios is shown as a shaded box. These figures are based on the modelled time frame of 1895 to 2009.

Table B1.1 Hypothetical example of identifying the environmental water requirements of a key environmental asset hydrologic indicator site

Target	Flow event			Proportion of years event required to achieve target (% of years)		Proportion of years event occurs under modelled without-development conditions (%)	Proportion of years event occurs under modelled current arrangements (%)
	Flow required	Duration required	Timing required	Low uncertainty	High uncertainty		
Maintain 100% of the current extent of permanent and semipermanent wetlands in good condition	20,000 ML/d	2 months	winter and spring	80	70	89	42
Maintain 100% of the current extent of river red gum forest in good condition	35,000 ML/d	1 month	winter and spring	60	40	75	28

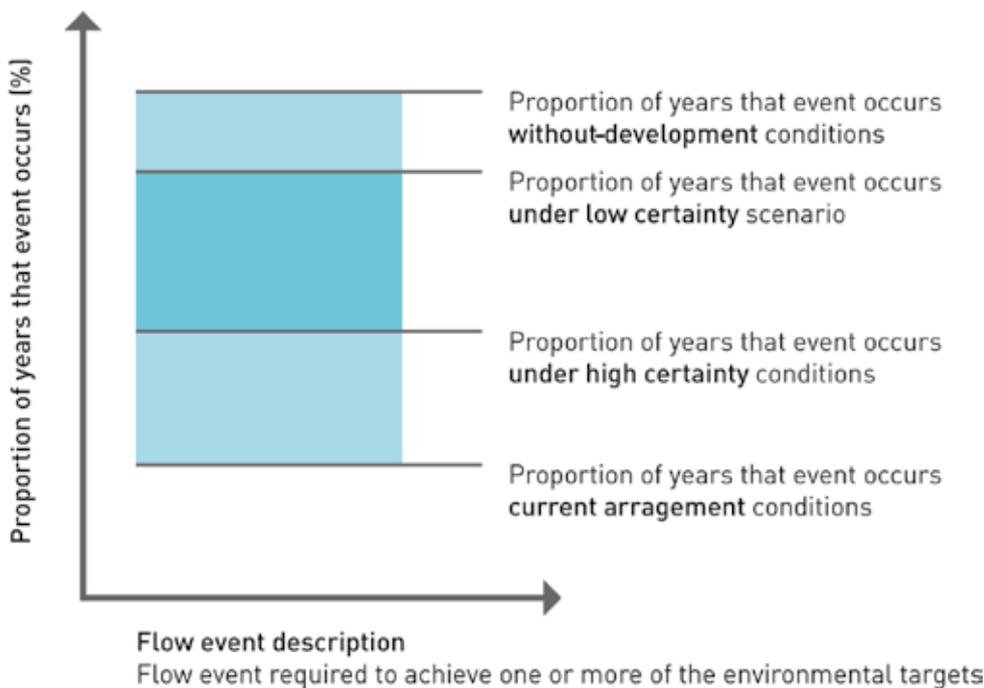


Figure B1.3 Explanation of the box plot graphs used to present environmental water requirements

Testing environmental flow requirements

Once the specific environmental water requirements were established for each hydrologic indicator site for key environmental assets, they were scrutinised by assessing them against the modelled without-development (natural) flow patterns and the flow patterns under current arrangements. This process ensured that the flow events specified were sensible in comparison to both conditions.

Managing drought

As mentioned above, the condition of the hydrologic indicator sites for key environmental assets will vary in response to climatic conditions and, the frequency of flow events — and therefore ecological condition — will respond to weather patterns and decline during periods of prolonged drought, even under natural conditions. For this reason, the frequency of events specified to meet indicator site targets are presented as long-term averages, with events occurring more often in wetter times and less often in drier times. Provision of more frequent inundation in wetter times will increase the resilience of communities, aiding survival during dry times.

During extended drought it is recognised that the larger flow events recommended for the hydrologic indicator sites will not occur. Without large rainfall events these flows simply do not occur. Habitat types associated with those flow events are typically the most drought tolerant, but they are also likely to suffer a temporary decline in condition during extended dry periods. Analysis of modelled without-development flows suggests this would also have been the case under without-development conditions.

The smaller flow events specified can be delivered during dry times, albeit at frequencies less than the long-term targets. These events are aimed at supporting the most water-dependent habitat types and drought refuges (such as permanent and semipermanent wetlands and closely fringing woodland communities like river red gums).

Providing these smaller flow events will sustain these sensitive communities to a greater extent than under current arrangements, but some temporary decline in condition will still be likely. Where works are proposed or are found to be feasible in the future, the environmental outcomes of these smaller flow events can be enhanced to deliver more significant outcomes during drought.

Figure B1.4 gives a sense of how the environmental water requirements might be delivered during an extended dry period. The graph shows modelled flows and potentially successful environmental watering events (for Riverland – Chowilla Floodplain) under without-development conditions, together with actual observed flows.

While there were no events that met the criteria under actual observed flows, changes to water sharing arrangements could deliver successful events in 4 of the past 10 years, providing water to wetlands and river red gum communities. It is recognised that the frequency over that period does not match the long-term average target but, together with increased flooding frequencies during wet periods, will improve greatly the condition of the site.

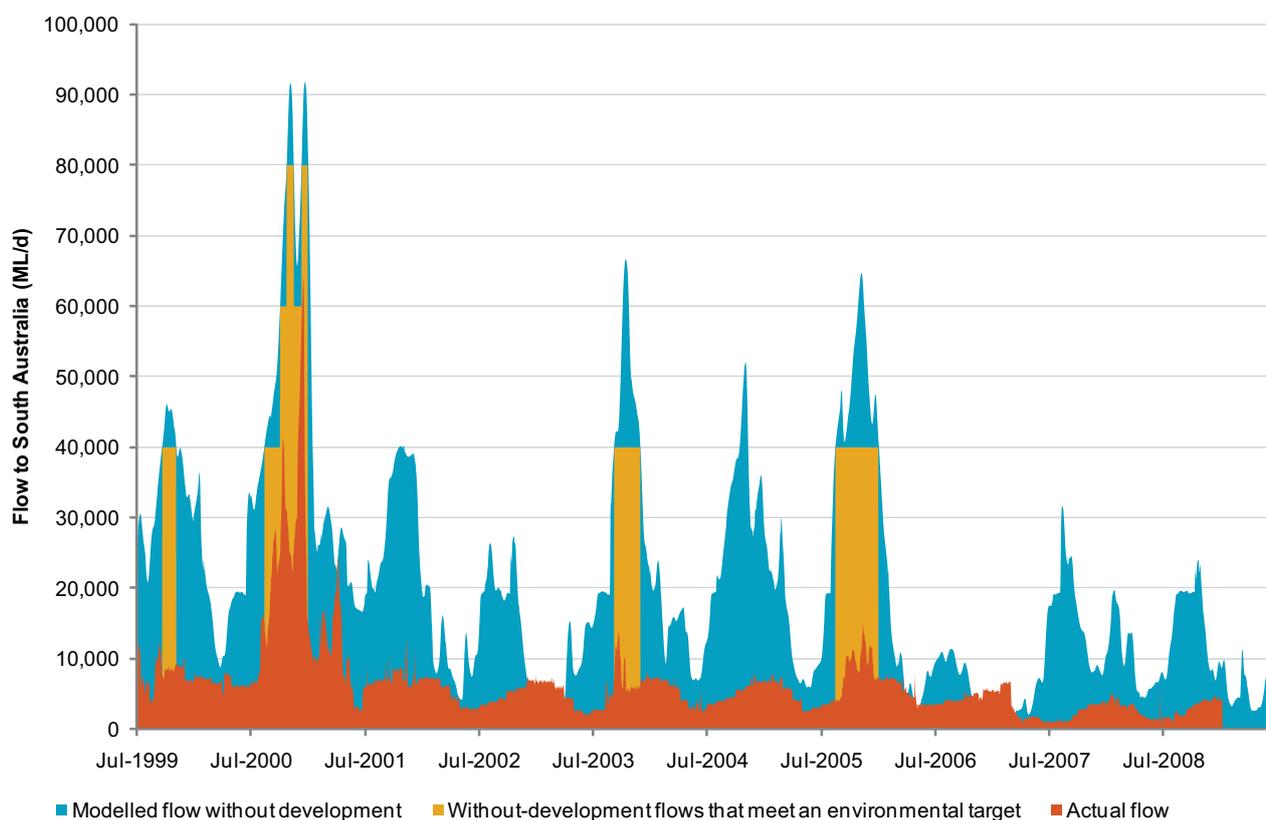


Figure B1.4 Potential environmental flow events for the Riverland – Chowilla Floodplain hydrologic indicator site, 1999–2009

Environmental works

Environmental works can provide mechanisms to water floodplain and wetland assets without the dependence on high river flows, achieving significant outcomes with less water. They are therefore an important consideration in determining environmental water requirements and long-term average sustainable diversion limits.

Works do not avoid the need to provide sustainable flow regimes. However, they can provide significant benefits and should form a part of the overall response to managing the Basin’s key environmental assets and key ecosystem functions. Works provide benefits in two main areas:

- improving environmental outcomes during times of drought
- enabling some environmental assets to be restored to a better condition than could otherwise be achieved.

Balancing the social, economic and environmental uses of water means it is not possible to restore flow regimes to their natural levels. The environmental impacts of water resource use are typically felt most during drought, when drought works provide the capacity to water parts of the floodplain that may otherwise not be watered due to competing social and economic uses of water. This is particularly important in maintaining drought refuges and other high-value areas.

Works also allow parts of the floodplain to be watered more often, potentially reinstating natural or near-natural inundation regimes. This allows these areas to be restored to a greater extent than is possible in other areas, providing biodiversity and important outcomes for threatened species and communities. Reinstatement of near-natural inundation regimes will also improve resilience of these areas to drought, adding value as drought refuges.

Impacts of works on environmental water requirements

Of the 18 hydrologic indicator sites for key environmental assets, only the Lower Murrumbidgee River Floodplain currently has infrastructure to enable watering of much of the indicator site. Under The Living Murray, large-scale works are also proposed, or under construction, at Gunbower–Koondrook–Perricoota Forest, Hattah Lakes and the Riverland – Chowilla Floodplain (at both Chowilla Floodplain and Mulcra Island).

One of the fundamental assumptions in selecting the 18 assets is that they can be used to define a representative flow regime that will enable watering of a multitude of other key environmental assets in a respective region or reach. At the four assets with existing or proposed works mentioned above, careful consideration of the impact of the proposed works was required to ensure the flow regime specified for that indicator site would be representative of the relevant region or reach.

Table B1.2 shows the impact of the existing or proposed works as a proportion of the reach represented by the indicator site. The table shows that, excluding the Lower Murrumbidgee River floodplain, the proposed works at each of the assets are likely to protect only a portion of the reach as a whole. For these assets, to ensure the flow regime specified is representative of the reach as a whole, the flow requirements for the assets were not modified by the works. While not influencing the long-term average environmental water requirements, the works will remain important in maintaining the values of those sites and managing drought conditions.

Table B1.2 Impact of existing or proposed works in a reach context

Key environmental asset hydrologic indicator site	Reach description	Area inundated by works
Lower Murrumbidgee River Floodplain	Murrumbidgee River floodplain between Hay and Balranald Area of floodplain estimated to be 120,000 ha. ^a	Lowbidgee Irrigation District 70,000 ha, or 60% of reach represented ^c
Gunbower–Koondrook–Perricoota	River Murray floodplain between Goulburn and Wakool Rivers. Area of floodplain regularly inundated is about 71,000 ha, while the broader floodplain has an area of about 180,000 ha. ^b	Gunbower works 5,000 ha ^d Koondrook works 16,000 ha ^d Total 21,000 ha or, 12–30% of reach represented
Hattah Lakes	River Murray floodplain between Murrumbidgee and Darling rivers. Area of floodplain regularly inundated is about 38,500 ha while the broader floodplain has an area of about 140,000 ha. ^b	Hattah works 5,600 ha ^d , or 4–15% of reach represented
Riverland – Chowilla Floodplain	River Murray floodplain between Darling River and Lower Lakes. Area of floodplain regularly inundated is about 130,000 ha, while the broader floodplain has an area of about 222,000 ha. ^b	Chowilla works 6,000 ha ^d Mulcra works 800 ha ^d Total 6,800 ha, or 3–5% of reach represented

^a Estimate based on analysis of wetlands mapping undertaken by Kingsford, Thomas & Knowles (1999)

^b Estimates based on data presented in Overton et al. (2006)

^c Estimate based on analysis of wetlands mapping undertaken by Kingsford, Thomas & Knowles (1999), and mapping of Lowbidgee Irrigation District (Combined Irrigation Areas of Australia Dataset, Bureau of Rural Sciences 2008)

^d Estimates based on The Living Murray unpublished data

For the Lower Murrumbidgee River floodplain the infrastructure of the Lowbidgee Irrigation District can be used to deliver water to an estimated 60% of the reach represented by the indicator site. The irrigation district works now provide the dominant mechanism to water this floodplain, and the environmental water requirements for the indicator site are based on using the works.

The remaining 40% of the indicator site will require high flows that overtop the river banks. Flows specified for the Mid-Murrumbidgee River Wetlands hydrologic indicator site will provide similar high flows, and flow indicators from the key ecosystem functions assessment will be used to assess the outcomes in the lower Murrumbidgee.

Risks

Flooding

Increasing the share of water provided to the environment of the Murray–Darling Basin brings with it the potential to increase the frequency of flooding of agricultural, commercial and residential assets. The environmental water requirements for the key environmental assets generally recommend flows up to the 5- to 10-year average recurrence interval flood, commensurate with the extent of low lying, flood-dependent vegetation and ecosystems.

These are flow events that occur relatively frequently where development in this zone is limited and controlled by planning authorities. Infrastructure in this zone, such as main roads and bridges, is generally designed to accommodate much larger floods. Most flood-prone towns are now protected by levees that accommodate much larger floods. The inherent risk of Basin Plan environmental flow delivery significantly affecting urban areas is therefore low.

However, while Murray–Darling Basin Authority believes implementation of the Basin Plan will not increase the likelihood of urban flooding, the potential consequences of flooding are significant and warrant careful consideration in managing environmental watering activities. The Environmental Watering Plan will give due consideration to flooding risks, and river operators will continue to monitor and respond to flood risk.

Land use and land management practices

The Water Act (s. 22(10)) specifies that the Basin Plan may not deal with land use, the management of natural resources (other than water), and pollution. However, MDBA recognises that land use and land management practices can both assist and be detrimental to attainment of ecological objectives, including issues such as pest plant and animal control, unsustainable grazing practices, and land clearance. As the regulation of land management practices and land use planning are Basin state responsibilities, the Commonwealth and state governments will need to work cooperatively in these areas to realise the Basin Plan's objectives.

Gaps in knowledge base

MDBA is required to act on best available scientific knowledge when developing the Basin Plan (Water Act s. 21(4)(b)). In defining objectives, targets and environmental water requirements, MDBA has compiled an evidence base using scientific studies, monitoring data and quantitative models.

Much of this information has been prepared by government agencies, non-government organisations and industry associations. Where peer-reviewed science is available, MDBA has given this higher credence.

A key issue in assessing the environmental water needs of the Basin has been the availability of underlying data and knowledge. During the development of objectives, targets and environmental water requirements, significant gaps in the knowledge base were identified, resulting in a degree of uncertainty in setting environmental objectives and targets. To overcome this, MDBA has also used expert knowledge and judgement to inform decision making.

The following sections in this appendix provide detailed information for each of the 18 hydrologic indicator sites for key environmental assets. Spatial data used to define the extent of the indicator sites is listed in Table B1.3.

Table B1.3 Data used in producing the hydrologic indicator site maps

Data	Dataset name	Source ^a
Basin Plan regions	Draft Basin Plan Areas 25 May 2010	Murray–Darling Basin Authority 2010
Dam walls/barrages	GEODATA TOPO 250K Series 3 Topographic Data	Geoscience Australia 2006
Gauges	100120 Master AWRC Gauges	
Icon sites	Living Murray Indicative Icon Site Boundaries	Murray–Darling Basin Commission 2007
Irrigation areas	Combined Irrigation Areas of Australia Dataset	Bureau of Rural Sciences 2008
Lakes	GEODATA TOPO 250K Series 3 Topographic Data	Geoscience Australia 2006
Maximum wetland extents	Wetlands GIS of the Murray–Darling Basin Series 2.0 (Kingsford)	Murray–Darling Basin Commission 1993
National parks/nature reserves	Digital Cadastral Database	NSW Department of Lands 2007
National parks/nature reserves	Collaborative Australian Protected Areas Database — CAPAD 2004	Department of the Environment, Water, Heritage and the Arts 2004
Nationally important wetlands	Directory of Important Wetlands in Australia Spatial Database	Department of the Environment, Water, Heritage and the Arts 2001
Ocean and landmass	GEODATA TOPO 250K Series 3 Topographic Data	Geoscience Australia 2006
Ramsar sites	Ramsar wetlands in Australia	Department of the Environment, Water, Heritage and the Arts 2009
Rivers	Surface Hydrology (AUSHYDRO version 1-6)	Geoscience Australia 2010
Roads	GEODATA TOPO 250K Series 3 Topographic Data	Geoscience Australia 2006
State border	GEODATA TOPO 250K Series 3 Topographic Data	Geoscience Australia 2006
State forests	Digital Cadastral Database	NSW Department of Lands 2007
Towns	GEODATA TOPO 250K Series 3 Topographic Data	Geoscience Australia 2006
Weirs	Murray–Darling Basin Weir Information System	Murray–Darling Basin Commission 2001
Weirs 2	River Murray Water Main Structures	Murray–Darling Basin Authority 2008

a Agency listed is custodian of relevant dataset; year reflects currency of the data layer