



Australian Government



# Assessment of environmental water requirements for the proposed Basin Plan: **Lower Darling River System**

Published by Murray-Darling Basin Authority  
Postal Address GPO Box 1801, Canberra ACT 2601  
Office location Level 4, 51 Allara Street, Canberra City  
Australian Capital Territory  
For further information contact the Murray-Darling Basin Authority office  
Telephone (02) 6279 0100 international + 61 2 6279 0100  
Facsimile (02) 6248 8053 international + 61 2 6248 8053  
E-Mail [info@mdba.gov.au](mailto:info@mdba.gov.au)  
Internet <http://www.mdba.gov.au>

MDBA Publication No: 29/12

ISBN: 978-1-922068-37-8 (online)

© Murray–Darling Basin Authority for and on behalf of the Commonwealth of Australia, 2012.

With the exception of the Commonwealth Coat of Arms, the MDBA logo, all photographs, graphics and trademarks, this publication is provided under a Creative Commons Attribution 3.0 Australia Licence.



<http://creativecommons.org/licenses/by/3.0/au>

The MDBA's preference is that you attribute this publication (and any material sourced from it) using the following wording:

Title:           Assessment of environmental water requirements for the proposed Basin Plan:  
                    Lower Darling River System

Source:        Licensed from the Murray–Darling Basin Authority, under a Creative Commons  
                    Attribution 3.0 Australia Licence.

The MDBA provides this information in good faith but to the extent permitted by law, the MDBA and the Commonwealth exclude all liability for adverse consequences arising directly or indirectly from using any information or material contained within this publication.

Australian Government Departments and Agencies are required by the *Disability Discrimination Act* 1992 (Cth) to ensure that information and services can be accessed by people with disabilities. If you encounter accessibility difficulties or the information you require is in a format that you cannot access, please contact us

# Lower Darling Region

## Assessment of Lower Darling River System environmental water requirements

### 1. Introduction

The Water Act 2007 (Cwlth) established the Murray-Darling Basin Authority (MDBA) and tasked it with the preparation of a Basin Plan to provide for the integrated management of the Basin's water resources. One of the key requirements of the Basin Plan is to establish environmentally sustainable limits on the quantities of surface water that may be taken for consumptive use, termed Sustainable Diversion Limits (SDLs). SDLs are the maximum long-term annual average volumes of water that can be taken from the Basin and they must represent an Environmentally Sustainable Level of Take (ESLT).

The method used to determine the ESLT is described in detail within *'The proposed "environmentally sustainable level of take" for surface water of the Murray-Darling Basin: Method and Outcomes,'* (MDBA 2011). A summary of the main steps undertaken to determine the ESLT is presented in Figure 1. The assessment of environmental water requirements including specification of site-specific flow indicators at a subset of hydrologic indicator sites (Step 3 of the overall ESLT method) is the focus of this document.

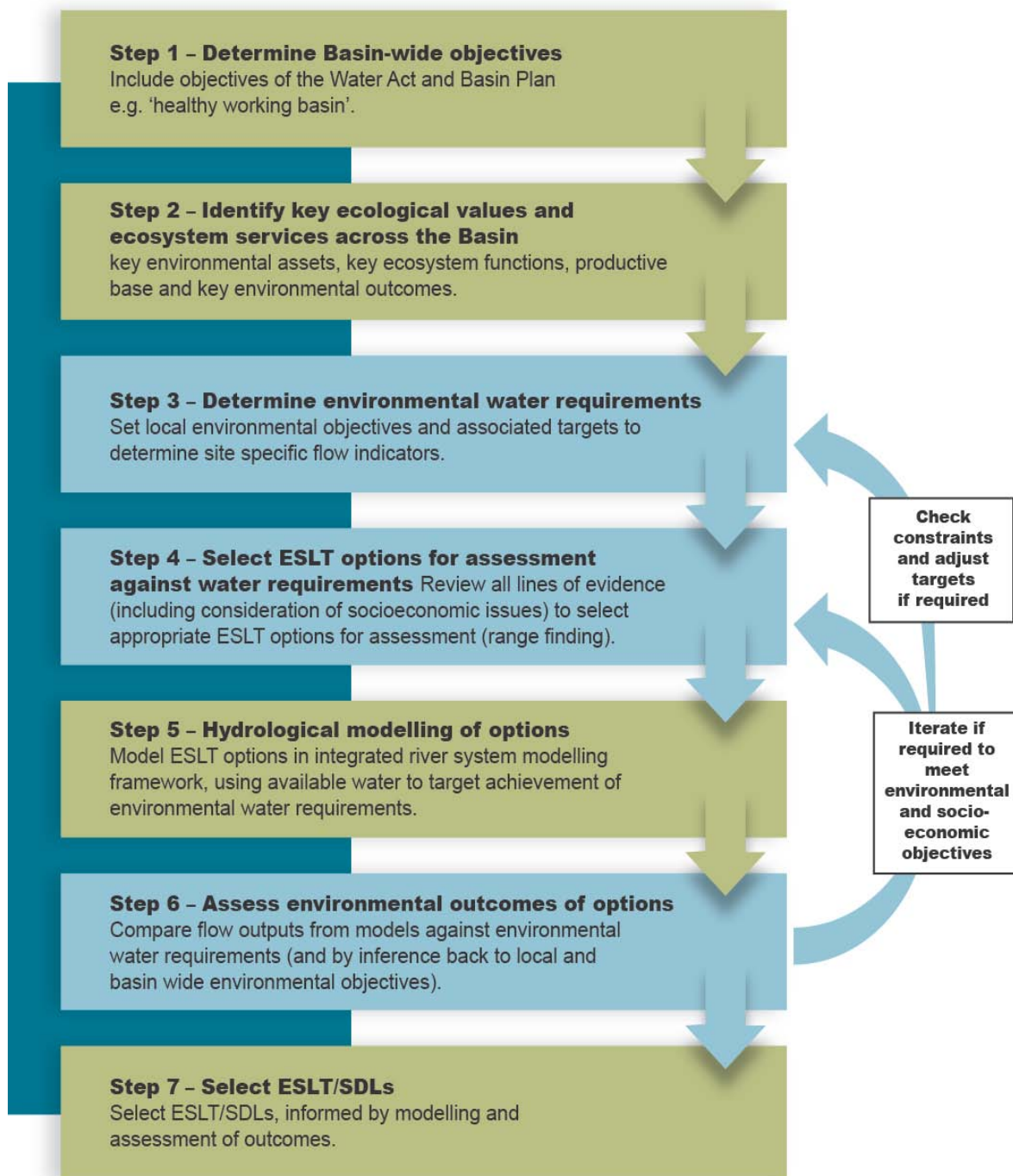
The work described herein is the MDBA's current understanding of the environmental water requirements of the Lower Darling River System. It is not expected that the environmental water requirements assessments will remain static, rather it is intended that they will evolve over time in response to new knowledge or implementation of environmental watering actions. Within this context, feedback is sought on the material presented within this document whether that be as part of the formal draft Basin Plan consultation phase or during the environmental watering implementation phase within the framework of the Environmental Watering Plan.

#### 1.1 Method to determine site-specific flow indicators

Assessment of environmental water requirements for different elements of the flow regime using the hydrologic indicator site approach is one of the key lines of evidence that has informed the proposed SDLs. Effort focussed on regions and parts of the flow regime with greatest sensitivity to the scale of reduction in diversions necessary to achieve environmental objectives, an ESLT and a healthy working Basin.

Within the overall framework of the ESLT method (Figure 1) the MDBA used an iterative process to assess environmental water requirements and develop site-specific flow indicators.

The hydrologic indicator site approach uses detailed eco-hydrological assessment of environmental water requirements for a subset of the key environmental assets and key ecosystem functions across the Basin. Effort focused on high flow (fresches, bankfull flows and overbank flows) requirements reflecting the prioritisation of effort on parts of the flow regime that are most sensitive to the determination of the ESLT and SDLs. The Lower Darling River System is one of the key environmental assets where a detailed assessment of environmental water requirements was undertaken.



**Figure 1: Outline of method used to determine an Environmentally Sustainable Level of Take.**  
(Source: MDBA 2011).

Detailed environmental water requirement assessments lead to the specification of site-specific flow indicators to achieve site-specific ecological targets. Flow indicators were expressed at a hydrologic indicator site or sites. Environmental water requirements specified at hydrologic indicator sites are intended to represent the broader environmental flow needs of river valleys or reaches and thus the needs of a broader suite of ecological assets and functions.

This report provides a description of the detailed eco-hydrological assessment of environmental water requirements for the Lower Darling River System including information supporting the development of site-specific flow indicators for the site (with reference to flows gauged on the Darling River at Weir 32). More information on how the site-specific flow indicators for the Lower Darling River System were used within the Basin-wide modelling process to inform the ESLT (i.e. Step 5 and 6 in Figure 1) can be found in the report *'Hydrologic modelling to inform the proposed Basin Plan: Methods and results'* (MDBA 2012).

A description of the detailed eco-hydrological assessments of environmental water requirements for other indicator sites are described in other documents in the series *'Assessment of environmental water requirements for the proposed Basin Plan'*.

## 1.2 Scope and purpose for setting site-specific flow indicators

The MDBA's assessment of environmental water requirements and associated site-specific flow indicators at hydrologic indicator sites has been used to inform the development of SDLs. This enables the MDBA to estimate the amount of water that will be required by the environment over the long-term to achieve a healthy working Basin through the use of hydrological models. Accordingly, site-specific flow indicators are not intended to stipulate future use of environmental water. MDBA expects that the body of work undertaken to establish these site-specific flow indicators will provide valuable input to environmental watering but this watering will be a flexible and adaptive process guided by the framework of the Environmental Watering Plan and natural eco-hydrological cues. It will be up to the managers of environmental water, such as the Commonwealth Environmental Water Holder, State Government agencies, and local communities to decide how best to use the available environmental water during any one year to achieve environmental outcomes.

## 2 Site location and extent

The Lower Darling River System hydrologic indicator site is located in south-western New South Wales at the end of the Darling River, upstream of its junction with the River Murray. It is marked by the towns of Menindee in the north and Wentworth in the south. For the purpose of this report the site is considered to comprise three distinct areas, or management units: the Menindee Lakes in the north, the Darling Anabranch in the west and the Lower Darling River in the east.

MDBA has used inundation extents as determined by Kingsford, Thomas and Knowles (1999) to define the lateral and longitudinal extent of the site to the confluence of the River Murray. The Directory of Important Wetlands in Australia dataset (Department of the Environment, Water, Heritage and the Arts 2001) was used to determine internal areas of the site. Spatial data used in Figure 2 is listed in Appendix A. Lake Tandou is excluded from the site because of its agricultural land use.

### 2.1 Menindee Lakes

The Menindee Lakes are located on the Darling River adjacent to the township of Menindee and approximately 110 km east of Broken Hill. The lakes cover an area of around 45,000 ha.

The Menindee Lakes storage scheme began in the 1960s and resulted in the construction of a series of small dams, weirs, regulators, channels and levees to contain Darling River floodwaters (NSW Department

of Land and Water Conservation 1998). The four main lakes within the Menindee storage — Wetherell, Pamamaroo (including Copi Hollow), Menindee and Cawndilla — have a full storage capacity of 1,731 GL. This amount, however, can be surcharged to 2,050 GL to mitigate adverse impacts of flooding.

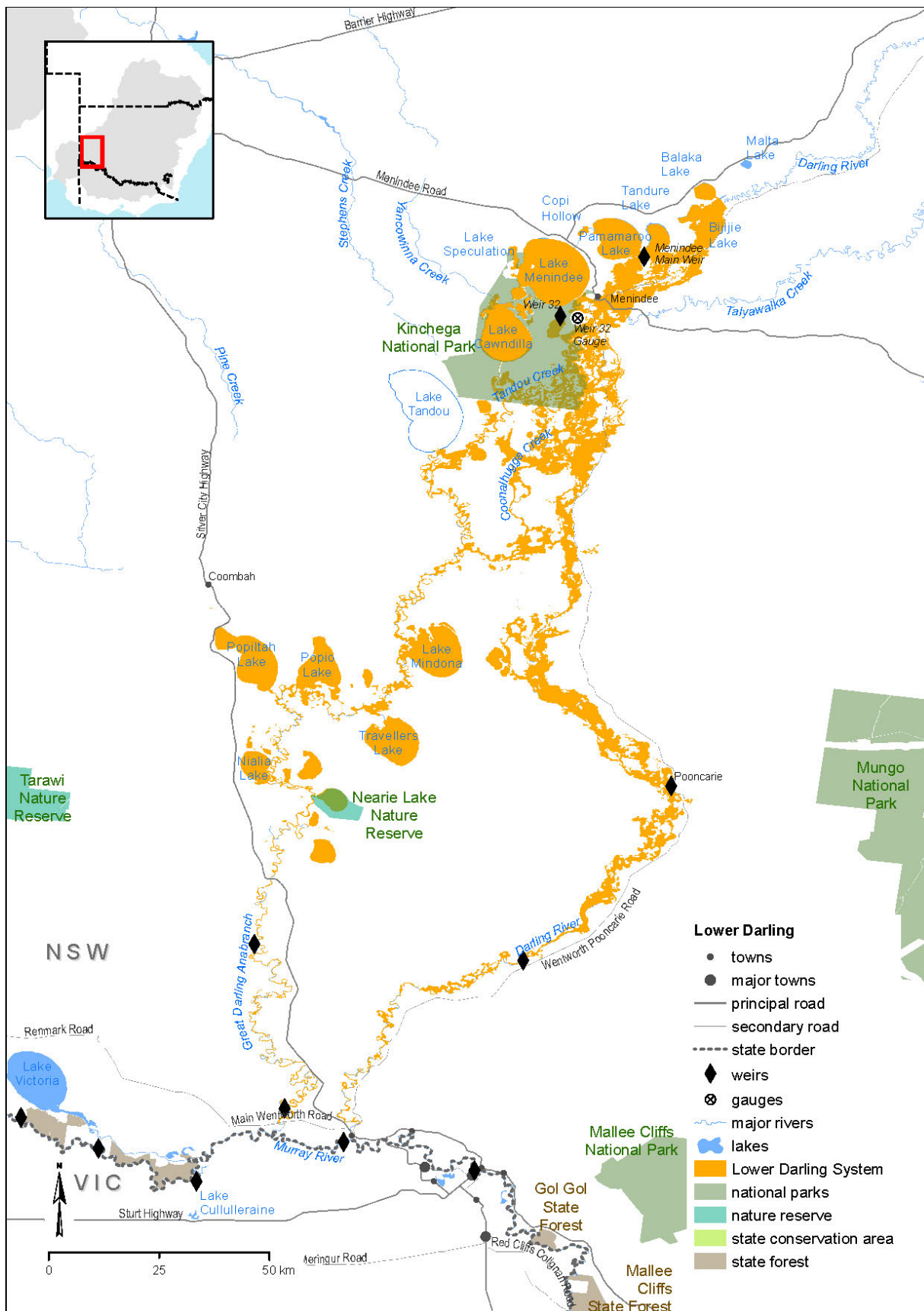
## **2.2 Darling Anabranch**

The Darling Anabranch covers around 630,000 ha, and can be broken into three components based on their hydrologic nature:

- lakes — there are 14 main lakes, including the northern and southern anabranch lakes;
- floodplains — although information on the characteristics of these floodplains is limited, they were included in the wetland survey conducted by King and Green (1993); and
- channel — the anabranch channel is the ancestral path of the Darling River; it extends 480 km from its offtake at the Darling River to its downstream junction with the River Murray, 15 km west of Wentworth.

## **2.3 Lower Darling River**

The Lower Darling River includes the river channel and adjacent billabongs and wetlands. The river extends from Menindee Lakes to the junction of the Murray and the Darling at Wentworth, covering approximately 1,400,000 ha.



**Figure 2: Location and extent of the Lower Darling River System hydrologic indicator site.**

### 3 Ecological values

Prior to the Menindee Lakes scheme, Lakes Menindee and Cawndilla supported large expanses of lignum (*Muehlenbeckia florulenta*), black box (*Eucalyptus largiflorens*) and river red gum (*E. camaldulensis*). Of these two lakes, Menindee was the most vegetated while Cawndilla (being deeper and holding water for longer) was predominantly an open-water lake. Descriptions at the time the Menindee Lakes scheme was being built (reported in Kingsford, Jenkins and Porter 2002) suggest that:

- Lake Menindee was fringed by black box and river red gum, with 40% (6,600 ha) of the lakebed covered in lignum reaching 4.5 m high, 30% (4,900 ha) covered by black box and the remaining area bare and colonised by aquatic species during flooding; and
- Lake Cawndilla was fringed by black box and river red gum, with 2% (100 ha) of the lakebed covered in black box and the remaining area bare and colonised by aquatic species during flooding.

Today, many of the lakes are open water with dead trees, and in places, the lakes are surrounded by black box and river red gum woodlands. It is estimated that permanent inundation has caused a total loss of 13,800 ha of lignum and 8,700 ha of black box (Kingsford, Jenkins & Porter 2002). The vegetation communities that formerly colonised the lakebeds provided organic matter and productivity for aquatic communities during flooding. They also provided important nesting sites for waterbirds. There are reports of thousands of black swans (*Cygnus atratus*) breeding in the lignum shrubland covering Lake Menindee in the early 1960s and again in the late 1970s, signifying the value of this habitat (Kingsford, Jenkins & Porter 2002).

Using annual bird survey data collected from 1983 to 2001, Jaensch et al. (2002) showed that waterbird communities on the regulated lakes in Menindee were less diverse and considerably less dense than waterbird communities found on unregulated lakes within the Murray–Darling Basin. These authors concluded that variable wetting and drying probably contributed to most of the increased diversity on unregulated lakes (Jaensch et al. 2002).

The Lower Darling River and Darling Anabranch ecosystems support important species that are listed in international agreements such as the Ramsar Convention, and include vulnerable and endangered species. Appendix B provides a summary of the conservationally significant species recorded at the site.

Hydrologic changes to the Lower Darling have reduced the health of fish populations within the river, with native species diminishing in abundance and alien fish species such as European carp (*Cyprinus carpio carpio*) increasing in number (Gilligan 2009). However, the Lower Darling has been identified as supporting an important population of Murray cod (*Maccullochella peelii peelii*) (National Murray Cod Recovery Team 2010). This assessment was based on the scale, size and integrity of the population (National Murray Cod Recovery Team 2010).

Reductions to flows that inundate in-channel bench surfaces have affected the health of river red gum trees growing on the high-level benches (Green et al. 1998), and have also potentially reduced the supply of leaf litter and organic matter transported into the main channel ecosystem (Thoms & Sheldon 1997). The construction of three small weirs along this stretch of channel has also affected fish movement and migration (Green et al. 1998).

The value of the Lower Darling River System is reflected in its rating against the criteria used by the MDBA to identify key environmental assets within the Basin. The MDBA established five criteria based on international agreements and broad alignment with the National Framework and Guidance for Describing the Ecological Character of Australian Ramsar Wetlands (Department of the Environment, Water, Heritage and the Arts 2008) and the draft criteria for identifying High Conservation Value Aquatic Ecosystems (SKM 2007). Based on the ecological values identified at Lower Darling River System, the site meets three of the five criteria (Table 1).

**Table 1 Assessment of the Lower Darling River System against MDBA key environmental asset criteria**

Criterion	Ecological values that support the criterion
1. The water-dependent ecosystem is formally recognised in international agreements or, with environmental watering, is capable of supporting species listed in those agreements	The Lower Darling River System is formally recognised in, or is capable of supporting species listed in the Japan–Australia Migratory Bird Agreement, the China–Australia Migratory Bird Agreement or the Republic of Korea – Australia Migratory Bird Agreement. For a full list of species listed under Commonwealth legislation that have been recorded in the Lower Darling River System see Appendix B.
3. The water-dependent ecosystem provides vital habitat	A number of water-dependent ecosystems within the Lower Darling River System provide drought refuge for waterbirds when the other lakes in the region have dried up (NSW National Parks and Wildlife Service 2007). During field surveys conducted in 1992, when western New South Wales was in drought, waterbirds were concentrated on the deeper anabranch lakes, Lake Nearie and Little Lakes, which suggests their value as drought refuges in the southern Basin (King & Green 1993).
4. Water-dependent ecosystems that support Commonwealth, State or Territory listed threatened species or communities	The Lower Darling River System meets this criterion because it supports species listed as threatened under state legislation. For a full list of species that have been recorded in the Lower Darling River System see Appendix B.

## 4 Hydrology

Water resource development in the Lower Darling River System has significantly altered the hydrology of this indicator site (Thoms et al. 2000). These changes are described below.

### 4.1 Menindee Lakes

In its pre-development state, the Menindee Lakes system was a series of nine ephemeral lakes which filled or partially filled with rising floodwaters through a series of small creeks. Flood frequencies of the different lakes varied from 1 in 2 years to 1 in 20 years (Kingsford, Jenkins & Porter 2002).

The climate of the Menindee area is arid with an average annual rainfall of only 200 mm and high evaporation rates. Owing to the shallowness of these lakes, the high evaporation rates (mean evaporation estimated to be 63 GL/month) result in significant volumes of water evaporating from these lakes when water is present (NSW Department of Land and Water Conservation 1998).

The lakes are jointly managed by the NSW Office of Water, the MDBA and State Water Corporation. Sharing of water between the States is managed by the MDBA and it controls the water release until the total water storage volume drops below 480 GL. At this point rights to the stored water and control of water

release is passed to the NSW Government and stays in their jurisdiction until the total lake storage increases to greater than 640 GL (this is referred to as the 480/640 Rule).

The Menindee Lakes scheme delivers water to South Australia to meet part of its annual entitlement (39% on average). As well as the allocation to South Australia, flows are released into the Lower Darling, to a maximum rate of 9,000 ML/d, to meet monthly target storage levels for Lake Victoria to hold it full over summer to minimise evaporation losses from the Menindee Lakes (Thoms et al. 2000), and to provide water to consumptive users along the Lower Darling.

When Menindee Lakes are not used to deliver water to the Murray, flows down the Lower Darling River are approximately 100–500 ML/d. In addition to releases to meet downstream demands, water is released from Menindee Lakes to mitigate flooding. When flooding occurs, a pre-release of up to 23,000 ML/d is released to create space for impending floods down the Darling (Thoms et al. 2000).

Significant changes to the hydrology of the lakes and their associated floodplains occurred after the Menindee Lakes storage scheme was built in the early 1960s. Most of the lakes in the system now experience too much flooding. Conversely, the 45,298 ha floodplain around the lakes now experiences reduced inundation frequencies (Kingsford, Jenkins & Porter 2002).

## 4.2 Darling Anabranh

The Darling Anabranh is normally dry, only flowing through to the River Murray under large flood events. Under current conditions the Darling Anabranh begins to flood when flows in the Darling River reach approximately 10,000 ML/d at Weir 32. Flows travel down Tandou Creek when the Darling River flows reach 20,000 ML/day.

Prior to development of the Menindee Lakes storage scheme the uppermost reaches of the Darling Anabranh flowed as much as two years out of three, but flows large enough to reach Nearie Lake, the lake furthest down the Anabranh, probably occurred in only 45% of years (Thoms et al. 2000).

Most of the 14 lakes which are included in the extent of the Darling Anabranh, fill via a feeder channel from the anabranh and only one lake is directly on-channel. The northern lakes are the largest with Mindona, Travellers, Popio and Popiltah Lakes all having areas of 6,700–10,000 ha and a full volume of 280–580 GL. The southern lakes from Nialia to Warrawenia are generally smaller with volumes less than 140 GL (Jenkins and Briggs 1995). Many of the lakes hold water for extended periods of time after significant flood events. Popiltah Lake can retain water for up to five years, and Lake Nearie also holds water for longer periods than the other lakes due to its greater depth. Other lakes such as Nialia are quite shallow and will begin to drain as soon as floodwaters recede (King and Green 1993).

Over the past 130 years, European settlers have lowered the main offtake of the anabranh to the Darling River which is likely to have increased the potential for flows down the anabranh. However, the reduction of flows in the Darling River caused by the Menindee Lakes storage scheme offset this effect, resulting in flooding frequencies in the lower Anabranh system similar to those experienced under without-development conditions (Thoms et al. 2000).

In the past, flows in the anabranh were dominated by a stock and domestic replenishment flow of 50,000 ML delivered over about three months from late winter to early spring. This flow was captured by a

number of small weirs constructed by landholders along the anabranch to pond water. These more permanent weir pools have influenced the nature of vegetation communities and limit fish passage along the anabranch.

A pipeline was completed in 2006 to deliver stock and domestic water to properties along the anabranch to improve flow transmission down the channel. Before the pipeline, only 3,000 ML was estimated as actually used for stock and domestic purposes out of a total flow volume of 50,000 ML (Earthtech Engineering 2004). The water savings from this project are committed to The Living Murray program to be used for environmental flows. However, because of drought, no flows were released down the anabranch between 2002 and 2010 (SKM 2009b). Significant flows occurred along the length of the anabranch in response to large flood volumes received from northern New South Wales in early 2010. This was the first flood event down the anabranch since 1998.

### 4.3 Lower Darling River

The hydrology of the Lower Darling River has been heavily modified by the operation of the Menindee Lakes storage scheme. Flow seasonality has been reversed, with higher flows now occurring in summer rather than in spring to autumn as under without-development conditions (Thoms et al. 2000). Winter flow variability has been reduced, with flows in the range of 200–500 ML/d occurring 65% of the time. Bankfull flows of greater than 10,000 ML/d previously occurred 25% of the time but now occur only 10% of the time under current development. The changes caused by the Menindee Lakes storage scheme together with other development in the Darling region have reduced annual flow volumes by 50% (Thoms et al. 2000).

## 5 Determining the site-specific flow indicators for the Lower Darling River System

### 5.1 Setting site-specific ecological targets

The objective setting framework used to determine the ESLT is outlined in the report *‘The proposed “environmentally sustainable level of take” for surface water of the Murray-Darling Basin: Method and Outcomes’* (MDBA 2011). In summary, the MDBA developed a set of Basin-wide environmental objectives and ecological targets, which were then applied at a finer scale to develop site-specific objectives for individual key environmental assets. Using these site-specific objectives, ecological targets that relate specifically to the Lower Darling River System were developed (Table 2). Information underpinning site-specific ecological targets is shown in Table 2.

**Table 2 Site-specific ecological targets for Lower Darling River System**

Site-specific ecological target	Justification of targets
<ul style="list-style-type: none"> <li>Provide a flow regime which ensures the current extent of native vegetation of the riparian, floodplain and wetland communities is sustained in a healthy, dynamic and resilient condition.</li> </ul>	<p>Species listed under several international agreements are found in the lakes along the Darling Anabranch, particularly Nearie Lake.</p> <p>The wetlands along the Lower Darling River provide feeding and roosting sites for waterbirds listed under several international agreements.</p>

Site-specific ecological target	Justification of targets
<ul style="list-style-type: none"> <li>• Provide a flow regime which supports the habitat requirements of waterbirds.</li> <li>• Provide a flow regime which supports recruitment opportunities for a range of native aquatic species (e.g. fish, frogs, turtle and invertebrates).</li> <li>• Provide a flow regime which supports key ecosystem functions, particularly those related to connectivity between the river and the floodplain.</li> </ul>	<p>The Lower Darling has been identified as supporting an important population of Murray cod (<i>Maccullochella peelii peelii</i>) (National Murray Cod Recovery Team 2010).</p> <p>Increased inundation of benches and wetlands would improve river red gum health and increase nutrient and organic matter supply to the main river channel.</p> <p>The ecological communities of the Lower Darling drainage system are listed as threatened under the <i>Fisheries Management Act 1994</i> (NSW).</p>

Site-specific ecological targets formed the basis of an assessment of environmental water requirements and the subsequent determination of site-specific flow indicators for the Lower Darling River system, as described below.

Information on the environmental water requirements of Menindee Lakes is contained in Appendix C.

## 5.2 Information used to determine site-specific flow indicators

### 5.2.1 Menindee Lakes

For many years the potential for water savings at Menindee Lakes has been discussed. With large evaporation losses there is potential for revised operating rules for Menindee Lakes to provide significant water savings and contribute to implementation of the Basin Plan. The environmental water requirements for Menindee Lakes described in this report are put forward with the aim of providing a constructive input to discussions on the future of Menindee Lakes. They are not mandatory or binding under the proposed Basin Plan. Changes to the operations of Menindee Lakes are outside the scope of the Basin Plan, as set out in the Water Act 2007. The achievement of the targets has also not been modelled as part of Basin Plan modelling. Implementation of a refined set of operating targets would require the agreement of Basin governments, and amendment of the Murray-Darling Basin Agreement. Actions to ensure the security of supply for consumptive users may also be required. The environmental water requirements should therefore be considered as an initial set of proposed requirements, subject to refinement, to contribute to a broader assessment of costs and benefits regarding the future of Menindee Lakes. Alternative options exist and a more detailed assessment and management plan will be required if the project proceeds.

To reflect this context, the proposed environmental water requirements for Menindee Lakes are included as an appendix to this document (Appendix C). Information on the spatial extent, ecology and hydrology of the Menindee Lakes has been included in the main body of the text as the lakes and their operation have a significant impact on hydrology and ecology of the Darling Anabranch and Lower Darling River.

### 5.2.2 Darling Anabranch

This management unit includes the anabranch channel, associated channels, floodplains and wetlands, and the larger anabranch lakes. The ecological targets and site-specific flow indicators set for the Darling Anabranch management unit are to provide a flow regime which:

- ensures the current extent of native vegetation of the riparian, floodplain and wetland communities is sustained in a healthy, dynamic and resilient condition;
- supports the habitat requirements of waterbirds;
- supports recruitment opportunities for a range of native aquatic species (e.g. fish, frogs, turtle and invertebrates); and
- supports key ecosystem functions, particularly those related to connectivity between the river and the floodplain.

The Darling Anabranh Management Plan (Nias 2002) proposed an environmental flow for the Darling Anabranh of 60 to 75 GL per release with a two-year frequency averaged over 10 years, along with requirements that:

- an end-of-stream flow should occur for each event;
- between 1,500 and 2,000 ML/d for 30 to 45 days should be released to the anabranh; and
- periods between environmental flows should not exceed three years.

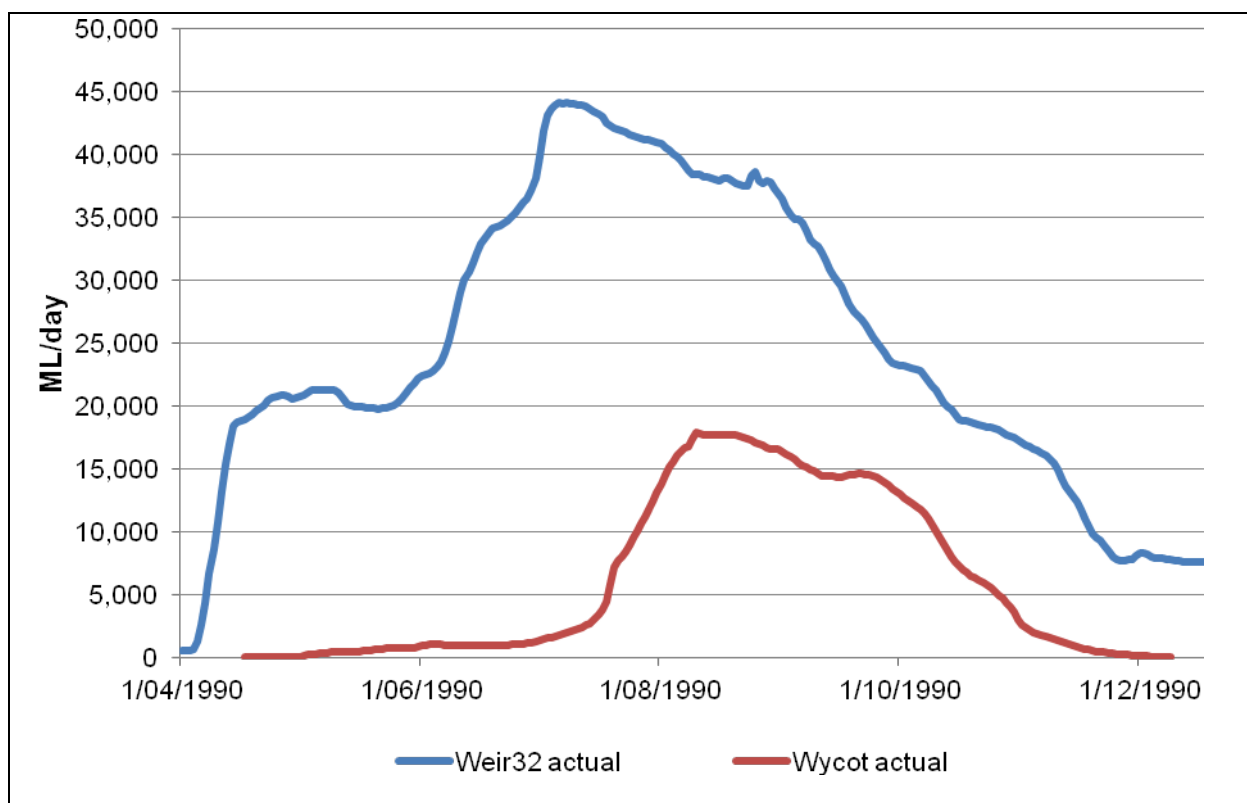
A flow of 1,500 ML/d has been reported to exceed the banks of the anabranh in many places (GHD 2008). Analysis of the modelled flow data at Wycot on the anabranh revealed that a flow of 1,500 ML/d for 30 days would have occurred with a frequency of 1 in 5 years under without-development conditions, and 1 in 10 years under current development scenario. Modelling suggests that a flow of 20,000 ML/d (measured at Weir 32) down the Darling River would provide a flow of around 1,500 ML/d down the anabranh; therefore, this threshold was adopted as one of the Darling Anabranh flow indicators, with a duration of 30 days for 1 year in 5.

Most information about the inundation thresholds of the wetlands, lakes and floodplains along the Darling Anabranh is anecdotal, and quantified data on flow levels for out-of-channel features is scarce (GHD 2008). King and Green (1993) undertook a wetland survey from 1990 to 1992 and noted the extent of inundation and duration of wetting that resulted from a large flood event in 1990. Successive field surveys in late 1992 provided some indication of the duration of inundation for many of the larger lakes and wetlands within the system. This level of inundation was used to inform the flow indicator to maintain the current extent of vegetation communities in the Darling Anabranh wetlands and floodplains.

The observed flows for the Darling River at Weir 32 and the Darling Anabranh at Wycot in 1990 are presented in Figure 3. As seen in the hydrograph, the flooding experienced down the anabranh in August 1990 (with an approximate peak of 17,000 ML/d) resulted from a peak flow of 45,000 ML/d at Weir 32. Analysis of modelled flow data suggests that under without-development scenario, a flow of this magnitude would have occurred 11 times between 1900 and 2009, with a return interval of approximately 10 years. Under the current development model scenario, it would have occurred 9 times over the same 109-year period, or approximately once every 12 years, indicating only a small change in frequency compared to the without development scenario. To maintain the health and resilience of the wetland and floodplain communities a frequency of 1 in 10 years is proposed.

Whilst the peak for this event reached 45,000 ML/d it is likely that the volume of the flow into the anabranh was a significant contributor to the extent of inundation in anabranh wetlands and floodplains. Flows above 25,000 ML/d will provide significant flow into the anabranh and it is likely that the duration of time that flow exceeds 25,000 ML/d is as significant as the actual peak. The flow event has therefore been

described as an extended period of flow above 25,000 ML/d at the Weir 32 gauge, including a shorter peak of 45,000 ML/d for 2 days. A duration of 45 days above 25,000 ML/d was selected after analysis of flow data and consideration of the time required to achieve sufficient volumes of inflow to achieve outcomes in the anabranch.



**Figure 3: 1990 flood hydrograph in the Darling River at Weir 32 and Darling Anabranch at Wycot gauge. (NSW Office of Water and Energy 2011).**

### 5.2.3 Lower Darling River

This management unit includes the main channel below Weir 32 and the associated wetlands and floodplains that occur when riverbanks are breached by floods along the Darling River.

The ecological targets and site-specific flow indicators were based primarily on findings presented in Green et al. (1998). This report identified the key flows required for a number of environmental and ecological outcomes (including wetlands, channel benches, water quality, riparian vegetation, fish, macroinvertebrates and waterbirds) along the Lower Darling from Menindee to Wentworth (see Table 4). The report's authors identified specific flow bands that would inundate a number of wetlands and bench surfaces as shown in Table 3.

The Lower Darling River ecological targets reflect the need to provide flows for:

- providing conditions suitable for fish passage;
- flushing the Lower Darling channel; and
- inundating a riparian wetlands and vegetation communities along the Lower Darling.

A minimum flow magnitude of 7,000 ML/d (suggested in Green et al. 1998) was adopted to meet these ecological targets.

**Table 3 Number of wetlands and in-channel benches inundated in various flow bands in the Lower Darling River (from Green et al. 1998)**

Wetlands			
Flow band (ML/d at Weir 32)	Number of wetlands flooded	Cumulative percentage of wetlands flooded	
<7,000	15	13	
7,000 to 17,000	63	68	
17,000 to 29,000	25	90	
>29,000	11	100	
In-channel bench surfaces			
Flow band (ML/d at Burtundy)	Number of benches sampled	Cumulative percentage of benches flooded	
		Number of benches (%)	Bench area (%)
4,000 to 11,000	10	42	15
11,000 to 17,000	7	71	43
17,000 to 22,000	3	84	54
22,000 to 23,000	2	92	94
<23,000	2	100	100

A second target was chosen for the Lower Darling River to maintain riparian river red gums and higher level wetlands in good condition. From Table 3, it appears that a significant increase in wetland inundation (68% of wetlands inundated) occurs at a flow level of 17,000 ML/d at Weir 32. This flow level is also likely to inundate a proportion of low level bench surfaces and associated fringing river red gum found throughout the reach. Thus, 17,000 ML/d at Weir 32 was considered an appropriate flow level to inundate both fringing river red gums and wetlands. Wetlands along the Lower Darling River can hold water from between 7 to 12 months after inundation (Shaikh, Green & Cross 2001). The suggested flow frequency of two and four years in 10 would reinstate a more natural wetting and drying regime and is broadly consistent with the frequency of inundation specified for vigorous growth of river red gums in Roberts and Marston (2011).

The recommended duration of these two flow events (7,000 and 17,000 ML/d) is based on analysis of flow data, to align with typical events experienced in the Darling. Further, more detailed ecological studies would be required to prescribe a duration on the basis of specific ecological needs. The recommended frequency of flows is based on understanding of the frequency of flows required to maintain healthy, dynamic and resilient vegetation communities, together with a cross-check with modelled without-development flows to ensure the recommended flows do not exceed our understanding of what would have occurred under natural conditions.

Flows described for the Darling Anabranh will also achieve outcomes in the Lower Darling River, particularly the higher elevation benches and wetlands. The outcomes of these flows have been taken into account when describing flow requirements for the Lower Darling River. Consequently it was considered unnecessary to include additional flows above 17,000 ML/d.

### 5.3 Proposed flow indicators

Based on the hydrology described in Section 4 and the environmental water requirements described in Sections 5.1 and 5.2, the MDBA has proposed five flow indicators for the Lower Darling River system (Table 4). The site-specific flow indicators for the Lower Darling represent an amalgam of information within existing literature, checked against analysis of modelled without development and baseline flow data. Site-specific flow indicators are expressed at Weir 32 on the Darling River, which generally represents the flow into the Lower Darling River and the Darling Anabranh.

Flow indicators as specified for high flow elements of the flow regime attempt to strike a balance between desirable flow threshold, duration and timing with desirable frequency and represent a variable flow regime that is consistent with the “without development” hydrology of the site. Where a discrepancy exists between the literature and inundation/hydrology modelling, an analysis of modelled without development flows has been used to guide the determination of site-specific flow indicators, particularly to ensure that the recommended flows are achievable and not greater than without development flows.

The site-specific flow indicators specified for the Lower Darling system should be read in their entirety to understand the environmental water requirements as multiple flow indicators will contribute to achieving each ecological target. This approach has been used because it is not possible to define a single flow threshold for each ecological component. As highlighted in Table 3, key ecological features such as wetlands and in-channel benches cover a wide range of flows and a single indicator would be misleading.

Generally, the flow indicator metric with the greatest level of uncertainty across the Basin is the definition of the desirable frequency of inundation, expressed as the proportion of years an event is required. This uncertainty is due to a number of reasons. Firstly, it is likely that there are thresholds for many plants and animals beyond which their survival or ability to reproduce is lost, but the precise details of those thresholds are mostly unknown or where there is information (for instance river red gum communities) our knowledge is evolving. It is also likely that vegetation communities would have experienced significant variability in their inundation frequency under pre-development conditions which subsequently makes specification of a single frequency metric deceptively certain. For many species and ecological communities the relationship between water provisions and environmental outcomes may not be threshold based, rather there could be a linear relationship between flow and the extent of environmental outcomes or the condition of a particular ecological species/community.

Recognising the degree of confidence in specifying a desirable frequency, ‘low–uncertainty’ and ‘high–uncertainty’ frequency of flow events have been specified (Table 4). For the low–uncertainty frequency, there is a high likelihood that the environmental objectives and targets will be achieved. The lower boundary of the desired range is referred to here as the high uncertainty frequency which is effectively the best estimate of the threshold, based on current scientific understanding, which, if not met, may lead to the loss of health or resilience of ecological communities, or the inability of species to reproduce frequently enough to sustain populations. The high–uncertainty frequencies attempt to define critical ecological thresholds. The high uncertainty frequency is considered to indicate a level beyond which the ecological targets may not be achieved.

It is recognised that periods between inundation events are an important consideration when trying to determine ecosystem resilience or thresholds of irreversible change. When investigating the environmental water requirements for the various sites, consideration was given to specifying a maximum period between events or metrics related to maximum dry. However, the literature regarding the tolerance of various floodplain ecosystems to dry periods is limited. In addition where this information exists, recommended maximum dry intervals often conflicts with the maximum dry experienced under modelled without development conditions.

Considering these issues, MDBA has not proposed a maximum dry period with the exception of a small number of sites across the Basin, which does not include the Lower Darling River system. Even so, the importance of maximum dry periods and their role in maintaining ecosystem resilience is recognised. Maximum dry periods between successful events is reported for hydrological modelling associated with the Lower Darling River system hydrologic indicator site (see MDBA 2012) despite reducing the maximum period between events not being the primary objective of the modelling process.

**Table 4 Site-specific ecological targets and associated flow indicators for the Darling Anabranh and Lower Darling River System**

Site-Specific Ecological Targets	Site-Specific Flow Indicators					Without-development and baseline event frequencies	
	Event			Frequency - proportion of years event required to achieve target		Proportion of years event occurred under modelled without-development conditions (%)	Proportion of years event occurred under modelled baseline conditions (%)
	Flow required (measured at Weir 32)	Duration	Timing				
				Low uncertainty (%)	High uncertainty (%)		
<p>Provide a flow regime which ensures the current extent of native vegetation of the riparian, floodplain and wetland communities is sustained in a healthy, dynamic and resilient condition.</p> <p>Provide a flow regime which supports the habitat requirements of waterbirds.</p> <p>Provide a flow regime which supports recruitment opportunities for a range of native aquatic species (e.g. fish, frogs, turtles and invertebrates).</p> <p>Provide a flow regime which supports key ecosystem functions, particularly those related to connectivity between the river and the floodplain.</p>	20,000 ML/d	30 days	January to December	20	14	27	10
	25,000 ML/d <sup>a</sup>	45 days		10	8	14	8
	45,000 ML/d <sup>a</sup>	2 days	January to December	10	8	10	7
	7,000 ML/d	10 days		90	70	95	57
	17,000 ML/d	18 days		40	20	47	18

a These two flow events are linked. That is, the flow event described is a flow of 25,000 ML/d or more for at least 45 days, including a peak of 45,000 ML or more for at least 2 days. The event is described in this way to reflect the pattern of actual flow events in the Darling and to ensure sufficient volume of flow into the anabranh to water wetlands and floodplain communities.

**Note:** Multiplication of the flow rate by the duration and frequency (proportion of years event required) does not translate into the additional volume of water the site needs to be environmentally sustainable. This is because part of the required flow is already provided under baseline conditions. Additional environmental water required is the amount over and above the baseline flows.

## 6 Flow delivery constraints

Basin wide environmental objectives have been developed within the context of being deliverable in a working river system that contains public and private storages and developed floodplains. To understand and assess the implications of key constraints on the ability to achieve flow indicators specified for the Lower Darling River system, MDBA has drawn upon a combination of existing information (e.g. Water Sharing Plans, operating rules of water agencies, flood warning levels) and practical knowledge of river operators supported by testing using hydrological modelling.

Flows downstream of Menindee Lakes are constrained by an operating rule that limits the maximum flow at Weir 32 to a channel capacity of 9,300 ML/d. This rule is intended to prevent water loss down the Darling Anabranch. Flows above 20,000 ML/d at Weir 32 will result in inundation of private property including houses in the township of Menindee.

The MDBA has a vision of a healthy working Basin that has vibrant communities, productive and resilient industries, and healthy and diverse ecosystems. The delivery of environmental flows as a managed watering event within a healthy working Basin is highly dependent on existing system constraints, accordingly the site-specific flow indicators have been classified into three broad types (Table 5). Consistent with this rationale, within the hydrological modelling process used by the MDBA to assess the achievement of site-specific flow indicators orders for environmental flows have been limited to be within the constraints represented by the baseline model. This limits the delivery of regulated flows to the Lower Darling River system.

Unless passing a flood through the Menindee Lakes system, the delivery of flows has been kept within river management constraints in the Lower Darling system. MDBA has not sought flows to meet site-specific flow indicators greater than 9,300 ML/d; and this is also assumed to be the maximum the Darling River can contribute to flows into the Lower Murray River unless the Darling is passing unregulated flows.

Flows required to inundate vegetation communities that are situated on high parts of the Lower Darling floodplain are largely dependent on unregulated flow events in wet years. Constraints, such as requirements not to flood private land and infrastructure, limit the ability to deliver these flows through active environmental water management.

**Table 5 Site-specific flow indicators and constraints for the Lower Darling River System and the effect of system constraints**

Site-specific ecological targets	Site-specific flow indicators and constraints
Lower Darling System (flows gauged downstream of Weir 32 on the Darling River)	
Provide a flow regime which ensures the current extent of native vegetation of the riparian, floodplain and wetland communities is sustained in a healthy, dynamic and resilient condition.	20,000 ML/Day for 30 consecutive days between January & December for 14% of years.
Provide a flow regime which supports the habitat requirements of waterbirds.	25,000 ML/Day for 45 consecutive days between January & December for 8% of years.
Provide a flow regime which supports recruitment	45,000 ML/Day for 2 consecutive days between January & December for 8% of years.

<p>opportunities for a range of native aquatic species (e.g. fish, frogs, turtles and invertebrates).</p> <p>Provide a flow regime which supports key ecosystem functions, particularly those related to connectivity between the river and the floodplain.</p>	7,000 ML/Day for 10 consecutive days between January & December for 70% of years.
	17,000 ML/Day for 18 consecutive days between January & December for 20% of years.

## Key

	<p><b>Achievable under current operating conditions</b></p> <p>Flow indicators highlighted in blue are considered deliverable as mostly regulated flows under current operating conditions.</p>
	<p><b>Achievable under some conditions (constraints limit delivery at some times)</b></p> <p>Flow indicators highlighted in yellow are considered achievable when delivered in combination with tributary inflows and/or unregulated flow events. They may not be achievable in every year or in some circumstances, and the duration of flows may be limited to the duration of tributary inflows.</p>
	<p><b>Difficult to influence achievement under most conditions (constraints limit delivery at most times)</b></p> <p>Flow indicators highlighted in brown require large flows that cannot be regulated by dams and it is not expected that these flows can currently be influenced by river operators due to the river operating constraints outlined above.</p>

## 7 Summary and conclusion

The Lower Darling River system is a key environmental asset within the Basin and is an important site for the determination of the environmental water requirements of the Basin. MDBA has undertaken a detailed eco-hydrological assessment of the Lower Darling River systems environmental water requirements. Specified flow indicators are indicative of a long-term flow regime required to enable the achievement of site-specific ecological targets in the Lower Darling and for the broader river valley and reach. Along with other site-specific flow indicators developed across the Basin at other hydrologic indicator sites, these environmental flow requirements were integrated within hydrological models to inform the ESLT. This process including consideration of a range of constraints such as those outlined in Section 6 is described in further detail within the companion report on the modelling process *‘Hydrologic modelling to inform the proposed Basin Plan: Methods and results’* (MDBA 2012).

The flow indicators in this report are used to assess potential Basin Plan scenarios. MDBA (2012) summarises how the proposed draft Basin Plan released in November 2011 performs against flow indicators for the Lower Darling River system.

## References

- Bewsher Consulting Pty Ltd 2000, *The natural hydrologic behaviour of the Menindee Lakes system — stage 2: data extraction and simulation*, NSW Department of Land and Water Conservation, Sydney.
- Department of the Environment, Water, Heritage and the Arts 2001, *A directory of important wetlands in Australia*, Australian wetlands database — spatial data, viewed November 2008, <[asdd.ga.gov.au/asdd](http://asdd.ga.gov.au/asdd)>.
- Department of the Environment, Water, Heritage and the Arts 2008, *National framework and guidance for describing the ecological character of Australian Ramsar wetlands, module 2 of the national guidelines for Ramsar wetlands* — implementing the Ramsar Convention in Australia, viewed 5 January 2010, <[www.environment.gov.au/water/publications/environmental/wetlands/module-2-framework.html](http://www.environment.gov.au/water/publications/environmental/wetlands/module-2-framework.html)>.
- Earthtech Engineering Pty Ltd 2004, *Darling Anabranh environmental impact statement for stock and domestic pipeline and reinstatement of environmental flows*, report for the NSW Department of Infrastructure, Planning and Natural Resources, Earthtech, Melbourne.
- GHD 2008, *Darling Anabranh Lakes management plan*, report prepared for the Lower Murray–Darling Catchment Management Authority, Mildura, Victoria.
- Gilligan, D.M, 2009, *Lower Murray–Darling catchment action plan 2004–2016: fish community monitoring report card for 2006–07*, NSW Department of Primary Industries, Cronulla, New South Wales.
- Green, DL, Shaikh, M, Maini, N, Cross, H & Slaven, J 1998, *Assessment of environmental flow needs for the Lower Darling River*, a report to the Murray–Darling Basin Commission by NSW Land and Water Commission, Sydney.
- Jaensch, R, Kingsford, RT, Jenkins, KM & Porter, JL 2002, *Waterbirds of Menindee Lakes*, Biosis Research Pty Ltd, Sydney.
- Jenkins, KM and Briggs, SV 1995, *Ecological management of lakebed cropping on the lakes of the Great Anabranh of the Darling River*. Final report, Australian Nature Conservation Agency.
- King, AM & Green, DL 1993, *Wetlands of the Lower Darling River and Great Darling Anabranh: progress report*, Murray–Darling Basin Commission, Canberra.
- Kingsford, RT, Jenkins, KM & Porter, JL 2002, *Waterbirds and effects of river regulation on the Menindee Lakes of the Darling River in arid Australia*, NSW National Parks and Wildlife Service, Hurstville, NSW
- Kingsford, RT, Thomas, RF & Knowles, E 1999, *Wetland GIS of the Murray–Darling Basin*, NSW National Parks and Wildlife Service & Murray–Darling Basin Commission, Canberra.
- Marchant, S & Higgins, PJ 1990, *Handbook of Australian, New Zealand and Antarctic birds volume 1: ratites to ducks*, Oxford University Press, Melbourne.
- MDBA (Murray-Darling Basin Authority) 2011, *The proposed “environmentally sustainable level of take” for surface water of the Murray-Darling Basin: Method and Outcomes*. Murray-Darling Basin Authority, Canberra.

MDBA (Murray-Darling Basin Authority) 2012, *Hydrological modelling to inform the Basin Plan*. Murray-Darling Basin Authority, Canberra.

National Murray Cod Recovery Team 2010, 'National Recovery Plan for the Murray Cod *Maccullochella peelii peelii*'. Department of Sustainability and Environment, Melbourne.

Nias, D 2002, *The Darling Anabranch Management Plan: a proposal for the future of the Darling Anabranch*, report for the Great Anabranch of the Darling Trust, Wentworth, New South Wales.

NSW Department of Environment, Climate Change and Water 2009, *Atlas of NSW wildlife*, viewed October 2009, <[www.wildlifeatlas.nationalparks.nsw.gov.au/wildlifeatlas/watlas.jsp](http://www.wildlifeatlas.nationalparks.nsw.gov.au/wildlifeatlas/watlas.jsp)>.

NSW Department of Land and Water Conservation 1998, *A review of the management of the Menindee Lakes storage*, issues paper, NSW Department of Land and Water Conservation, Sydney.

NSW Office of Water and Energy 2011, Continuous water monitoring network, <[www.waterinfo.nsw.gov.au/](http://www.waterinfo.nsw.gov.au/)>.

NSW National Parks and Wildlife Service as part of the NSW Department of Environment and Climate Change 2007, *Nearie Lake Nature Reserve draft plan of management*, NSW Department of Environment and Climate Change, Hurstville, New South Wales.

Roberts, J & Marston, F 2011, *Water regime for wetland and floodplain plants. A source book for the Murray–Darling Basin*. National Water Commission, Canberra.

Shaikh, M, Green, D & Cross, H 2001, 'A remote sensing approach to determine environmental flows for wetlands of the Lower Darling River, New South Wales, Australia', *International Journal of Remote Sensing*, vol. 22, no. 9, pp. 1737–1751.

SKM (Sinclair Knight Merz) 2007, *High Conservation Value Aquatic Ecosystems project - identifying, categorising and managing HCVAE, Final report, Department of the Environment and Water Resources*, 16 March 2007. [www.environment.gov.au/water/publications/environmental/ecosystems/hcvae.html](http://www.environment.gov.au/water/publications/environmental/ecosystems/hcvae.html)

SKM (Sinclair Knight Merz) 2009a, *Darling River water saving — Part B, Stage 1, Final report*, report to the NSW Department of Water and Energy, Sydney.

SKM (Sinclair Knight Merz) 2009b, *Darling River water saving — Part B, Stage 2, Draft report*, report to the NSW Department of Water and Energy, Sydney.

Taylor-Wood, E, McCormick, S, Mueck, S, Richardson, M & Jurick, M 2001, 'Vegetation/habitat mapping of inundated areas of Menindee Lakes', in S Moore & T Midgely (eds), *Menindee Lakes ecologically sustainable development project* (CD-Rom), NSW Department of Land and Water Conservation, Buronga, New South Wales.

Thoms, M & Sheldon, F 1997, 'River channel complexity and ecosystem processes: the Barwon–Darling River (Australia)', in N Klomp & I Lunt (eds), *Frontiers in Ecology: building the links*, Elsevier, Oxford, United Kingdom.

Thoms, M, Suter, P, Roberts, J, Koehn, J, Jones, G, Hillman, T & Close, A 2000, *Report of the River Murray Scientific Panel on Environmental Flows — River Murray — Dartmouth to Wellington and the Lower Darling River*, Murray–Darling Basin Commission, Canberra.

## Appendix A

### Data used in producing hydrologic indicator site maps

Data	Dataset name	Source <sup>a</sup>
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	New South Wales 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	New South Wales 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)

<sup>a</sup> Agency listed is custodian of relevant dataset; year reflects currency of the data layer.

## Appendix B

### Species relevant to criteria 1 and 4 for the Lower Darling River System

Species	Recognised in international agreement(s) <sup>1</sup>	Environment Protection and Biodiversity Conservation Act 1999 (Cwlth)	Fisheries Management Act 2004 (NSW)	Threatened Species conservation Act 1995 (NSW)
<b>Birds</b>				
Australasian bittern ( <i>Botaurus poiciloptilus</i> ) <sup>3</sup>				V
Australian bustard ( <i>Ardeotis australis</i> ) <sup>4</sup>				E
Barking owl ( <i>Ninox connivens</i> ) <sup>4</sup>				V
Black-breasted buzzard ( <i>Hamirostra</i>				V
Blue-billed duck ( <i>Oxyura australia</i> ) <sup>2, 3</sup>				V
Brolga ( <i>Grus rubicundus</i> ) <sup>3</sup>				V
Brown treecreeper ( <i>Climacteris picumnus</i> ) <sup>4</sup>				V
Bush stone-curlew ( <i>Burhinus grallarius</i> ) <sup>4</sup>				E
Caspian tern ( <i>Hydroprogne caspia</i> ) <sup>3</sup>	<input type="checkbox"/>			
Common sandpiper ( <i>Actitis hypoleucos</i> ) <sup>3</sup>	<input type="checkbox"/>			
Eastern great egret ( <i>Ardea modesta</i> ) <sup>3</sup>	<input type="checkbox"/>			
Freckled duck ( <i>Stictonetta naevosa</i> ) <sup>2, 3</sup>				V
Glossy ibis ( <i>Plegadis falcinellus</i> ) <sup>3</sup>	<input type="checkbox"/>			
Grey falcon ( <i>Falco hypoleucos</i> ) <sup>4</sup>				V
Hooded robin ( <i>Melanodryas cucullata</i> ) <sup>4</sup>				V
Lesser sand-plover ( <i>Charadrius mongolus</i> ) <sup>4</sup>				V
Major Mitchell's cockatoo (pink cockatoo)				V
Malleefowl ( <i>Leipoa ocellata</i> ) <sup>4</sup>				E
Red-tailed black-cockatoo ( <i>Calyptrorhynchus</i>				V
Redthroat ( <i>Pyrrholaemus brunneus</i> ) <sup>3</sup>				V
Sanderling ( <i>Calidris alba</i> ) <sup>4</sup>				V
Scarlet-chested parrot ( <i>Neophema splendida</i> ) <sup>4</sup>				V
Southern scrub-robin ( <i>Drymodes brunneopygia</i> ) <sup>4</sup>				V
Square-tailed kite ( <i>Lophoictinia isura</i> ) <sup>4</sup>				V
Stripe-faced dunnart ( <i>Sminthopsis macroura</i> ) <sup>4</sup>				V
Yellow-tailed plain slider ( <i>Lerista xanthura</i> ) <sup>4</sup>				V

Species	Recognised in international agreement(s) <sup>1</sup>	Environmental Protection and Biodiversity Conservation Act 1999 (Cwlth)	Fisheries Management Act 2004 (NSW)	Threatened species conservation Act 1995 (NSW)
<b>Fish</b>				
Freshwater catfish ( <i>Tandanus tandanus</i> ) <sup>2</sup>			E	
Murray cod ( <i>Maccullochella peelii peelii</i> ) <sup>2</sup>		V		
Silver perch ( <i>Bidyanus bidyanus</i> ) <sup>2</sup>			V	
<b>Mammals</b>				
Inland forest bat ( <i>Vespadelus baverstocki</i> ) <sup>4</sup>				V
Little pied bat ( <i>Chalinolobus picatus</i> ) <sup>3</sup>				V
<b>Plants</b>				
Bluebush daisy ( <i>Cratystylis conocephala</i> ) <sup>4</sup>				E
Burr daisy ( <i>Calotis moorei</i> ) <sup>4</sup>				V
Button immortelle ( <i>Leptorhynchos waitzia</i> ) <sup>4</sup>				E
Menindee nightshade ( <i>Solanum karsense</i> ) <sup>4</sup>				E
Phyllanthus maderaspatensis ( <i>Phyllanthus maderaspatanus</i> ) <sup>4</sup>				V
Purple-wood wattle ( <i>Acacia carneorum</i> ) <sup>4</sup>				V
Silky swainson-pea ( <i>Swainsona sericea</i> ) <sup>4</sup>				E
Speargrass ( <i>Austrostipa gibbosa</i> ) <sup>4</sup>				E
Violet swainson-pea ( <i>Swainsona adenophylla</i> ) <sup>4</sup>				V
Yellow Darling pea ( <i>Swainsona pyrophila</i> ) <sup>4</sup>				E
Yellow-keeled swainsona ( <i>Swainsona flavicarinata</i> ) <sup>4</sup>				
<b>Communities</b>				
Lowland Darling River aquatic ecological community <sup>2</sup>			E	

E = endangered V = vulnerable

1 Japan–Australia Migratory Bird Agreement, China–Australia Migratory Bird Agreement, or Republic of Korea – Australia Migratory Bird Agreement

2 Murray–Darling Basin Commission (n.d.)

3 NSW National Parks and Wildlife Service (2007)

4 NSW Department of Environment, Climate Change and Water (2009)

## Appendix C – Discussion on Environmental Water Requirements for Menindee Lakes

As described in Section 5.2.1 the environmental water requirements for Menindee Lakes described in this report are put forward with the aim of providing a constructive input to discussions on the future of Menindee Lakes. They are not mandatory or binding under the proposed Basin Plan. The environmental water requirements should therefore be considered as an initial set of proposed requirements, subject to refinement, to contribute to a broader assessment of costs and benefits regarding the future of Menindee Lakes.

### *Potential site-specific ecological targets*

**Table C1** Potential site-specific ecological targets for Menindee Lakes

Site-specific ecological target	Justification of targets
Lake Cawndilla and Lake Menindee	
Provide a flow regime which ensures the current extent of native vegetation of the fringing and wetland communities is sustained in a healthy, dynamic and resilient condition	The Menindee Lakes are a significant breeding site for migratory waterbirds listed under international agreements.  The Menindee Lakes provide vital refuge for waterbirds and other biota in times of drought.  Revised operations at Lakes Menindee and Cawndilla have the potential to enhance existing environmental values and reinstate a range of habitats which have declined extensively across the Basin, contributing to Basin wide outcomes such as enhanced waterbird populations.
Provide a flow regime which supports the habitat requirements of waterbirds and is conducive to successful breeding of colonial nesting waterbirds	
Provide a flow regime which supports recruitment opportunities for a range of native aquatic species (e.g. fish, frogs, turtles and invertebrates).	

### *Information used to identify potential site-specific flow indicators*

The Menindee Lakes management unit includes all the lakes within the Menindee Lakes storage scheme, from Malta Lake in the north to Lake Cawndilla in the south.

The potential ecological targets set for the Menindee Lakes are to provide a flow regime which:

- ensures the current extent of native vegetation of the fringing and wetland communities is sustained in a healthy, dynamic and resilient condition;
- supports the habitat requirements of waterbirds and is conducive to successful breeding of colonial nesting waterbirds; and
- supports recruitment opportunities for a range of native aquatic species (e.g. fish, frogs, turtles and invertebrates).

Reflecting the common options put forward for alternative operations at Menindee Lakes the focus for the flow indicators to support these ecological targets are to:

- conserve the existing flow regimes of the upper lakes ; and

- restore variability of flows in the Lakes Menindee and Cawndilla.

Less variable water levels in the Menindee Lakes have negatively affected the flora and fauna within these areas (Kingsford, Jenkins & Porter 2002). Reinstating a variable flow regime in either or both Lake Menindee and Lake Cawndilla would provide additional feeding habitats for resident waterbirds, which could increase their diversity and abundance, especially of some migratory shorebird species that inhabit this system (Jaensch et al. 2002). The drying of both Lake Menindee and Lake Cawndilla in 1995 and early 1996 was accompanied by significant increases in the number and density of birds using the lakes when they were refilled (Kingsford, Jenkins & Porter 2002). It is thought that a more variable flow regime in these lakes would also increase the diversity and abundance of aquatic plants, invertebrates and native fish, and has the potential to encourage terrestrial vegetation such as lignum and black box to re-establish in some parts of the lakebeds, which would provide roosting and breeding habitat for waterbirds (SKM 2009a).

Jaensch et al. (2002) made several recommendations for the environmental management of the Menindee Lakes system, including that:

- highest priority should be given to protecting and enhancing shallow freshwater marsh, recently exposed lakebed (mudflats), floodplain woodland and lignum swamp with *Eleocharis* sedgeland;
- current water regimes generally should be maintained at Malta Lake, Lake Wetherell, Bijijie Swamp and Lake Speculation because they exhibited the highest conservation value for waterbirds (however, the report also recommend delaying or slowing drawdown to increase breeding activity and use by some vulnerable species); and substantial drawdown, ideally at close to without-development rates, of at least one of the large open lakes (Lake Cawndilla or Lake Menindee) may be required if internationally significant numbers of migratory shorebirds are to be attracted to the system.

The potential ecological targets identified here for Menindee Lakes reflect recommendations made by Jaensch et al. (2002). The current operation trend for the Menindee Lakes storage scheme is to keep water levels in the upper lakes (i.e. Lakes Pamamaroo and Wetherell) as high as possible. It is envisaged that by using this strategy, these lakes would act as more secure water sources for the biota that inhabit the area and possibly provide drought refuges. Lake Wetherell also provides a relatively diverse range of habitats for the biota compared to the other lakes in the system (SKM 2009b).

Lakes Menindee and Cawndilla (the Lower Lakes) experience more variable flow regimes under both without-development and current conditions, although the degree of variability has been reduced with current development. Without development, these lakes would fill every second year and stay inundated for an average of 0.8 years for Menindee and, because of its increased depth, 4 years for Cawndilla (SKM 2009b). Under current development, the lakes stay full for much longer, being inundated for an average of 4.3 years for Menindee and 11.4 years for Cawndilla (SKM 2009b). However, recently, both lakes remained dry for a 7-year period (2002–09) because of severe drought conditions and low inflows.

To enhance environmental outcomes a more variable flow regime could be reinstated to Lakes Menindee and Cawndilla, with flow indicators set around a range of identified lake levels (Table C2). These lake levels could be reached by filling the lake(s) and then drawing down at a rate consistent with the without-development rate of drawdown. The flow indicators are proposed as indicative of variable and adaptive management through a long-term environmental watering plan. Actual events would vary in their

characteristics in response to climatic conditions and to promote diverse vegetation communities (i.e. larger, more frequent watering in wet periods and smaller, less frequent watering in dry periods).

### ***56 m Australian Height Datum in Lake Menindee***

A low-level fill to 56 m in Lake Menindee is proposed in Table C2 in 80% of years. Filling Lake Menindee to this level would result in a lake level of around 53.8 m in Lake Cawndilla, corresponding to volumes of around 60 GL in Menindee and 50 GL in Cawndilla. At this level, approximately 10,000 ha of Lake Menindee and 6,200 ha of Lake Cawndilla would be covered in water to a maximum depth of around 1.5 m. This frequent filling event is expected to produce conditions suitable for the establishment of aquatic wetland species and lignum in the lower sections of Menindee's lakebed. The specific result in Lake Cawndilla would depend on rates of drawdown in the lake (see section on drawdown options below).

### ***56.5 m Australian Height Datum in Lake Menindee***

Bathymetry of Menindee and Cawndilla lakebeds suggests that the lakes are 'saucer' shaped. This means that as the lakes fill initially, large increases in surface area are seen with relatively small increases in lake level. Critical areas of the surface area to lake level relationship can be targeted to achieve maximum surface area of water coverage in the lakes for the least amount of water. Most of the surface area for Cawndilla is obtained at a lake level of around 54.5 m AHD. In Lake Menindee, this level is around 57 m AHD.

It is estimated that filling Lake Menindee to 56.5 m will fill Lake Cawndilla to around 54.5 m. At the 54.5 m level, 7,000 ha of Lake Cawndilla would be inundated and the lake would contain a volume of around 84 GL. At 56.5 m, approximately 13,000 ha of Lake Menindee would be inundated and the lake would contain a volume of about 116 GL, with a maximum depth of 1.8 m. If this event was provided in 50% of years it is anticipated that it would provide conditions suitable to the re-establishment of lignum and, potentially, river red gum communities in these areas of the lakes.

### ***57.5 m Australian Height Datum in Lake Menindee***

The height of connection through Morton Bulka is a significant constraint to filling Lake Cawndilla. A lake height of 57.5 m in Menindee will cause significant flows through Morton Bulka, and provide similar water heights in Lake Cawndilla to those experienced in Lake Menindee. At 57.5 m in both lakes, 14,800 ha (around 90%) of Lake Menindee is inundated to a maximum depth of 2.8 m and 9,900 ha (around 80%) of Lake Cawndilla is inundated to a maximum depth of 4.8 m. Inundating the lakes to this level in 15% of years is expected to provide conditions suitable for the re-establishment of black box and lignum communities over most of the lakebed.

### ***58.5 m Australian Height Datum in Lake Menindee***

The highest lake-filling indicator proposed in Table C2 is set to the estimated without-development lake-full levels of both Menindee and Cawndilla Lakes. The lake-full levels were informed by modelling undertaken by Bewsher Consulting (2000), as reported by Taylor-Wood et al. (2001). This report suggests the lake-full surface area of Lake Menindee was around 16,000 ha, which corresponds to a lake level of 58.5 m AHD. Lake Cawndilla was reported to have a without-development lake-full surface area of 9,400 ha, corresponding to a lake-level of 58.1 m AHD. Therefore, the height suggested for the largest lake-full level is

58.5 m in both lakes, corresponding to 410 GL in Menindee and 470 GL in Cawndilla. Providing this level in 9% of years would encourage the re-establishment of fringing black box communities.

### ***Drawdown options***

#### Lake Menindee

Lake Menindee drains via a channel between the lake and the Darling River. With the development of the Menindee Lakes scheme, the flow in the channel became regulated. This regulator restricts the peak capacity of the channel, and the lakes now drains at a slower rate than they would have done under without-development conditions.

If the operation of the lakes is reviewed, and Lakes Menindee and Cawndilla are returned to a more natural watering regime, this regulator could be closed during the filling of Lake Menindee to the intended level and then fully opened to allow Lake Menindee to drain as quickly as possible. Options to enhance the outlet capacity could be considered and may be beneficial to the achievement of environmental outcomes.

#### Lake Cawndilla

Under without-development conditions, the only way Lake Cawndilla drained was back through the channels of Morton Bulka to Lake Menindee; there was no other channel to or from the lake. During the Menindee Lakes scheme, a channel was cut between Lake Cawndilla and the Darling Anabranch, to provide flows out of the lake into the anabranch channel, and a regulator was installed in this channel to control flows. Therefore, water levels in Lake Cawndilla can be drawn down more quickly using the current infrastructure than under without-development conditions.

In exploring alternative operations, two options could be considered for the drawdown of water in Lake Cawndilla:

##### **Option 1 — no release from Lake Cawndilla outlet regulator**

Minimising the use of the regulator would mean that water would stay in the lake for longer and be drawn down by evaporation only once the lake reached below the level of Morton Bulka. The resultant longer duration of inundation in the lake would prevent the establishment of perennial species such as lignum, river red gum and black box, and would maintain the lake in a more open water state, similar to how it would have been without development. This strategy would have high losses and lower water savings.

##### **Option 2 — release water from the Lake Cawndilla regulator to provide anabranch flows**

By using the Lake Cawndilla outlet channel, water could be delivered to the anabranch, providing flows to Tandou, environmental flows to the anabranch and potentially flows to the Murray via the anabranch. Drawing down of Lake Cawndilla using the outlet channel would potentially return up to 160 GL of water, resulting in significantly improved water savings and potentially providing some environmental benefits to the anabranch. However, it would change the character of the lake from that under option 1. A faster rate of drawdown would reduce the duration of inundation, making the lakebed suitable for colonisation by perennial species such as lignum, river red gum and black box. It is unknown whether this would have a positive or negative environmental impact.

It is worth noting that under this proposal, Lakes Wetherell and Pamamaroo would be maintained as near-permanent water bodies, providing open water habitat that would not have existed prior to regulation, and providing a potential offset for open water habitat in Lake Cawndilla.

**Table C2 Potential site-specific ecological targets and associated flow indicators for Lakes Menindee and Cawndilla**

Site-Specific Ecological Targets	Site-Specific Flow Indicators					Without-development and baseline event frequencies	
	Event			Frequency - proportion of years event required		Proportion of years event occurred under modelled without-development condition (%)	Proportion of years event occurred under modelled baseline conditions (%)
	Flow required (measured at Weir 32)	Duration	Timing				
				Low uncertainty (%)	High uncertainty (%)		
<p>Provide a flow regime which ensures the current extent of native vegetation of the fringing and wetland communities is sustained in a healthy, dynamic and resilient condition</p> <p>Provide a flow regime which supports the habitat requirements of waterbirds and is conducive to successful breeding of colonial nesting waterbirds</p> <p>Provide a flow regime which supports recruitment opportunities for a range of native aquatic species (e.g. fish, frogs, turtles and invertebrates).</p>	56.0 m in Menindee^ 53.8 m in Cawndilla^	Fill to level and drawdown at near natural rate	January to December	80	80	81	85
	56.5 m in Menindee^ 54.5 m in Cawndilla^			50	50	50	80
	57.5 m in Menindee and Cawndilla^			15	15	16	70
	58.5 m in Menindee and Cawndilla^			9	9	9	58

^ Lake flows are presented as lake-full levels in metres above Australian Height Datum (AHD), which approximate the metres above sea level.