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MURRAY–DARLING BASIN AUTHORITY

Assessment of environmental water requirements for the proposed Basin Plan:

Hattah Lakes

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Murray region

Assessment of Hattah Lakes 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 Hattah Lakes. 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 (freshes, 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. Hattah Lakes is one of the key environmental assets where a detailed assessment of environmental water requirements was undertaken.

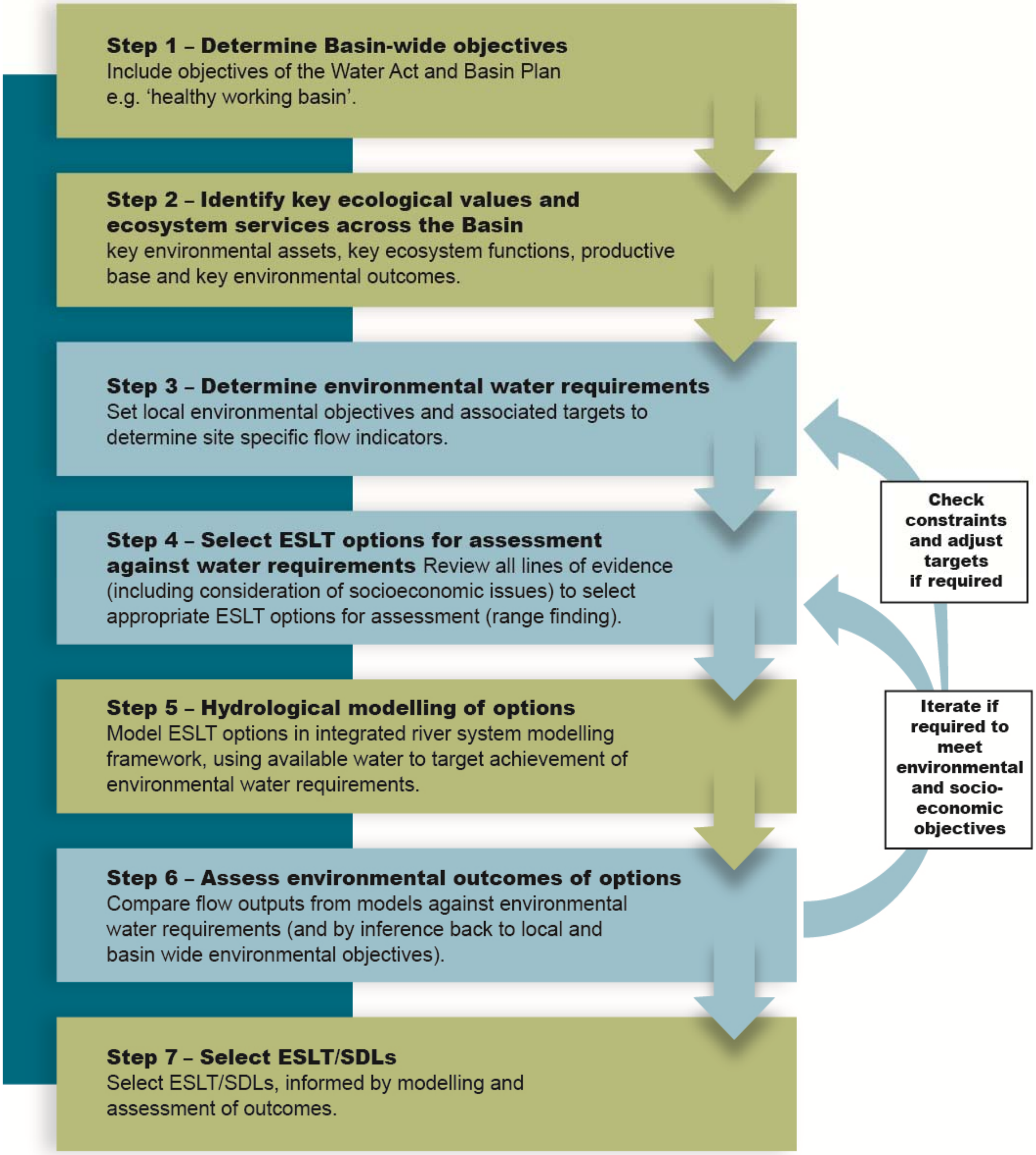

Figure 1: Outline of method used to determine an Environmentally Sustainable Level of Take (Source: MDBA 2011).

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 Hattah Lakes including information supporting the development of site-specific flow indicators for the site (with reference to flows gauged on the River Murray downstream of Euston Weir). More information on how the site-specific flow indicators for Hattah Lakes 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 Hattah Lakes hydrologic indicator site encompasses all the Hattah Lakes and their adjoining floodplain system in Hattah–Kulkyne National Park, north-west Victoria. The site is adjacent to the River Murray, in the triangle between the towns of Mildura, Robinvale and Ouyen (Figure 2).

The Hattah Lakes site covers an area of about 57,000 ha. The extent of the indicator site has largely been based on The Living Murray indicative icon site boundaries dataset (MDBA 2010). The Directory of Important Wetlands in Australia (Department of the Environment, Water, Heritage and the Arts 2001) and Ramsar Wetlands of Australia datasets were used to define small portions of the indicator site not included in The Living Murray indicative icon site boundaries extent. Spatial data used in Figure 2 is listed in Appendix A.

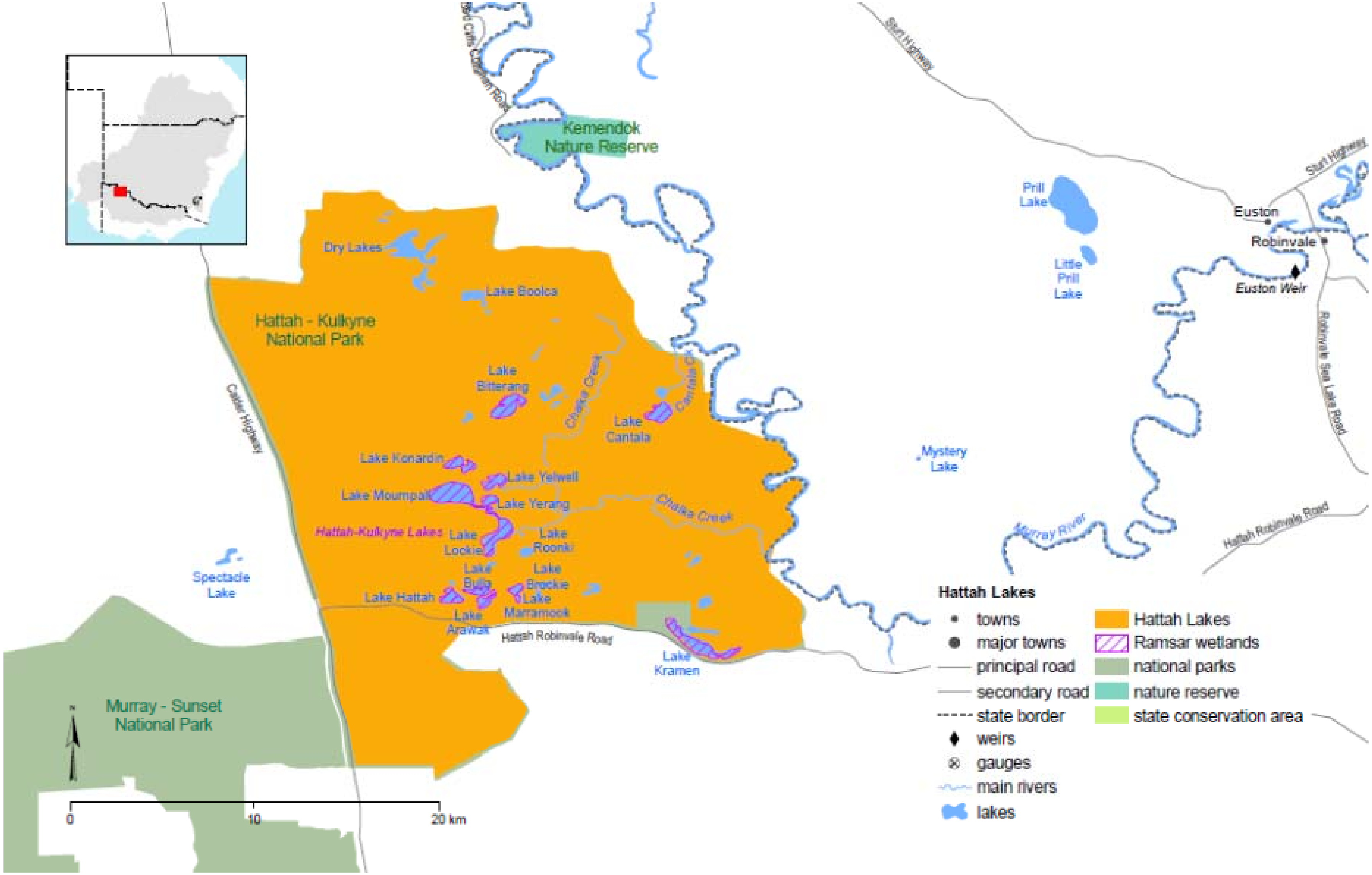

Figure 2 Location and extent of Hattah Lakes key environmental asset. Flow indicators are specified at River Murray downstream of Euston Weir.

3 Ecological values

Hattah Lakes is an icon site under The Living Murray river restoration program. The icon site component of the broader site consists of a mosaic of wetlands and watercourses with varying hydrology that covers approximately 13,000 ha, set within a wider floodplain of flood dependent vegetation communities. Ecological Associates (2005) outline the key ecosystem types that support the ecological values of the site:

- aquatic habitats such as Lake Bed Herbland, Intermittent Swampy Woodland and a small area of Riverine Grassy Woodland;
- lakes providing variation in the permanence of water from episodically flooded lakes to almost permanent lakes which are important in providing habitat for a wide range of waterbirds;
- river red gum (*Eucalyptus camaldulensis*) forest and woodland of various types and health, depending on inundation, with the lower areas supporting larger and denser river red gum forest;
- lignum (*Muehlenbeckia florulenta*) shrubland providing nesting sites for waterbirds and contribute organic matter to the lakes, which is important for macro-invertebrate and fish habitat and production;
- black box (*Eucalyputs largiflorens*) woodland in the high, drier zones; and
- integrated mallee and floodplain habitat which is important for the nationally Vulnerable Regent Parrot (*Polytelis anthopeplus monarchoides*).

Decline in the health of flood-dependent floodplain vegetation has been observed under the influence of the drought, coupled with the cumulative impacts of river regulation. Cunningham et al. (2009) used Landsat imagery and on-ground surveys to predict the condition of river red gum and black box stands at The Living Murray icon sites. The model suggested that only 3% of vegetation communities at Hattah Lakes were in good condition, with the remaining 97% considered stressed. This represents the largest extent of stressed vegetation stands across all The Living Murray icon sites (Cunningham et al. 2009).

Irrespective of the observed decline in ecological condition, Hattah Lakes still support important habitat and species that are listed in international agreements such as Ramsar, and include vulnerable and endangered species. Appendix B provides a summary of the conservationally significant species recorded at the site.

The ecological values of Hattah Lakes are reflected in the MDBA's assessment against the criteria used to identify key environmental assets within the Basin. The MDBA established five criteria to identify assets 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 Hattah Lakes, the site meets four of the five key environmental asset criteria (Table 1).

Table 1 Assessment of the Hattah Lakes against MDBA key environmental assets 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 Hattah Lakes 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. Hattah–Kulkyne Lakes was Ramsar listed as a wetland of international importance in December 1982. Twelve of the nineteen Hattah Lakes comprise the Ramsar site: Arawak, Bitterang, Brockie, Bulla, Cantala, Hattah, Konardin, Kramen, Lockie, Mournpall, Yelwell and Yerang lakes (Victorian Department of Sustainability and the Environment 2003). Species listed in international agreements that have been recorded at Hattah Lakes are in Appendix B.
3. The water-dependent ecosystem provides vital habitat	Eighteen waterbird species have been recorded breeding at the site, with an additional six waterbird species reported breeding in the surrounding floodplain (Ecological Associates 2005; MDBC 2006). The persistence of water in Hattah Lakes for several years between inflow events suggests the site is also an important drought refuge for waterbirds and aquatic fauna (Ecological Associates 2005). This was highlighted in annual waterbird surveys conducted in 2007 that recorded high waterbird numbers (16,097), mainly of grey teal (*Anas gracilis*), hardhead (*Aythya australis*), Eurasian coot (*Fulica atra*), Pacific black duck (*A. superciliosa*) and Australasian shoveler (*A. rhynchotis*).
4. Water-dependent ecosystems that support Commonwealth, State or Territory listed threatened species or communities	Species and communities listed as threatened under both Commonwealth and state legislation that have been recorded at the site are in Appendix B.
5. The water-dependent ecosystem supports, or with environmental watering is capable of supporting, significant biodiversity	Since annual waterbird counts began in 1983, 59 waterbird species have been reported at the site (Ecological Associates 2007a). In 17 out of 20 years, Pacific black ducks and Australian wood ducks were observed at the site during annual counts. The waterbirds observed in the highest numbers in any year were the grey teal (15,000 individuals), silver gull (10,000 individuals) and hardhead (6,000 individuals). High numbers of waterbirds are associated with flooding, which triggers increased biological productivity in the river system. In the 20 years since 1982, when Hattah–Kulkyne Lakes was Ramsar listed, abundances of over 5,000 waterbirds have been observed in five annual counts, with 24,000 being the highest number reported in any single year. All these high counts were associated with flooding events (Ecological Associates 2005).

4 Hydrology

Hattah Lakes contains well-defined wetland basins that historically have retained water for long periods after River Murray flow peaks recede. Most of the 19 lakes in the Hattah Lakes system are filled from the River Murray via the east arm of the Chalka Creek anabranch when flows in the River Murray exceed about 37,000 ML/d (SKM 2004). Table 2 presents River Murray flow thresholds required to inundate the lakes. Lake Lockie is the first of the lakes to fill, and when it is flooded, water flows into the southern and northern parts of the Hattah Lakes.

River regulation has reduced the frequency, duration and volume of flooding in Hattah Lakes (MDBC 2006; Ecological Associates 2007a; CSIRO 2008). CSIRO (2008) found that as a result of water resource development, both the average and maximum period between flows at which Hattah Lakes commence to fill has more than doubled (average period increased from 1.6 to 3.7 years; maximum period increased from 4.6 to 11.7 years). Flood volumes have also been greatly reduced, such that the average annual flood volume is now less than a fifth of the volume under without development conditions (from 2379 to 403 GL).

Table 2 Critical flow thresholds: Hattah Lakes (Source: SKM 2004; Ecological Associates 2007a; Ecological Associates 2007b).

Lake	Area (ha)	Flow in River Murray at Euston for lake to fill (ML/d)	Wetland water regime
Lockie#	141	36,700	Persistent temporary wetlands
Little Hattah	–	36,700	Persistent temporary wetlands
Hattah#	61	36,700	Semi-permanent wetlands
Yerang#	65	40,000	Persistent temporary wetlands
Mournpall#	243	40,000	Semi-permanent wetlands
Cantala#	101	45,000	Persistent temporary wetlands
Bulla#	40	45,000	Semi-permanent wetlands
Arawak#	40	50,500	Semi-permanent wetlands
Marramook	–	52,000	Temporary wetlands
Brockie#	28	53,000	Persistent temporary wetlands
Boich	–	54,000	Persistent temporary wetlands
Tullamook	–	55,000	Persistent temporary wetlands
Yelwell#	81	55,000	Persistent temporary wetlands
Konardin#	121	60,000	Persistent temporary wetlands
Nip Nip	–	65,000	Persistent temporary wetlands
Bitterang#	73	70,000	Persistent temporary wetlands
Kramen#	161	152,000	Episodic wetlands
Roonki	–	–	Persistent temporary wetlands
Boolca and Dry Lakes	Approximately 200	180,000	Episodic wetlands

#denotes Ramsar listed wetland

Studies of the site's hydrology and hydraulics relate water levels and River Murray flows to Hattah Lakes inundation (SKM 2004; SKM 2006; Ecological Associates 2007a; Ecological Associates 2009). Figure 3 shows the water regime classes and vegetation communities within the Hattah Lakes system. Hattah Lakes exhibit variation in inundation regimes from semi-permanent to episodic.

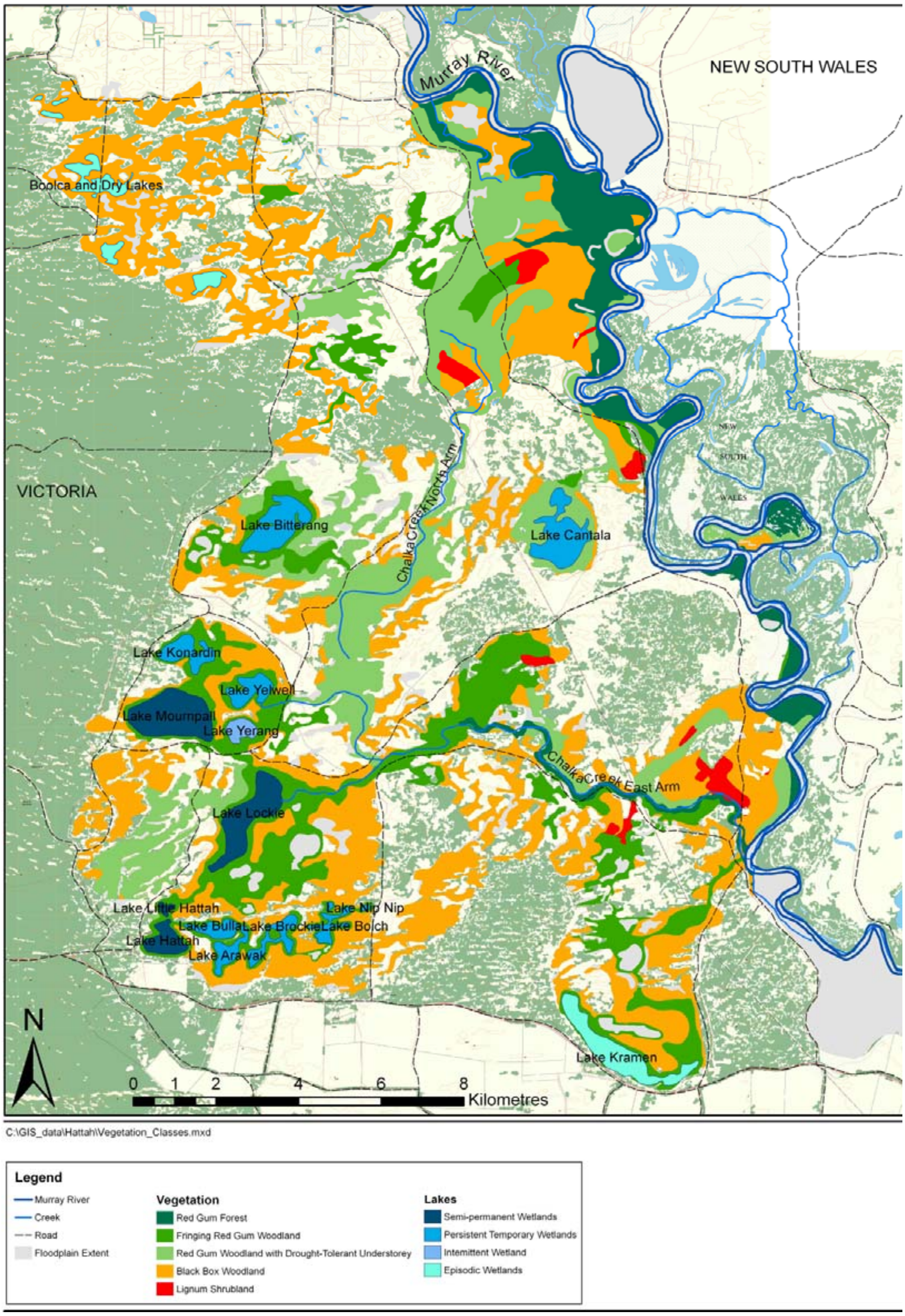

Figure 3: Water regime classes and vegetation communities: Hattah Lakes (Source: Ecological Associates 2007a).

5 Determining the site-specific flow indicators for the Hattah Lakes

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 Hattah Lakes were developed (Table 3). Information underpinning site-specific ecological targets is shown in Table 3.

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 Hattah Lakes, as described below.

5.1.Information used to determine site-specific flow indicators

5.2.1. Vegetation

Flood dependent vegetation communities are a critical component of the ecological character of the Hattah Lakes and accordingly the development of site-specific flow indicators to achieve the site specific ecological targets focused on assessment of the bankfull and overbank elements of the flow regime necessary to maintain flood dependent vegetation communities. A number of documents have been assessed to determine the flows required to achieve the site-specific ecological targets, as described below. However, it was found that no single existing plan or document sets out these requirements completely.

Ecological Associates (2009) related water levels to inundation of key habitat /vegetation types for central Hattah Lake. Based on analysis of a combination of vegetation mapping and a digital elevation model, the elevation at which at least 50% of each vegetation community is inundated was identified (Table 4). The relationships identified between water level and inundation of vegetation communities for the central lakes were assumed to be broadly representative of the entire Hattah Lakes hydrologic indicator site with the exception of the Dry Lakes system in the north which is known to have higher elevation and subsequent higher flow thresholds to inundate these areas (Ecological Associates 2007b).

Hydraulic modelling of Hattah Lakes (SKM 2006) was used to define the relationship between flows in the River Murray at Euston and ecologically relevant water levels defined by Ecological Associates (2009) analysis, as shown in Table 4. The modelling exercise divided the Hattah Lakes system into 47 different areas with similar flow-level relationships. These areas encompass both wetlands and surrounding floodplain and are therefore different to individual lake inundation thresholds shown in Table 2. The variable relationship between water level and flow illustrates the complex nature of inundation at Hattah Lakes, with different hydraulic controls in different parts of the landscape influencing the hydraulics of watercourses feeding into the Hattah Lakes system.

Table 3: Site-specific ecological targets for Hattah Lakes

Site-specific ecological targets	Justification of targets
• 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 • 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) • Provide a flow regime which supports key ecosystem functions, particularly those related to connectivity between the river and the floodplain	The site contains the Hattah–Kulkyne Lakes Ramsar site. Eleven of the twelve Ramsar listed wetlands are either semi-permanent or persistent temporary. All semi-permanent and persistent temporary wetlands are interconnected and have similar flow thresholds (see Table 2). Ecological Associates (2007a) identified semi-permanent and persistent temporary wetlands as the highest priority water regime class based on their conservation significance and the degree to which their water requirements are threatened. Lake Kramen, an episodic wetland, is the other Ramsar listed wetland and differs in its inundation regime to other Ramsar listed wetlands being inundated infrequently under natural conditions due its location high on the landscape. Hattah Lakes supports a variety of flood dependent vegetation communities. Fringing river red gum is central to the ecology of the lakes Ecological Associates (2007a). River red gum woodlands and lignum shrublands are very productive habitats that support bird foraging and breeding after flood events. Black box woodland is important habitat for a range of species. It also provides connectivity between floodplain and mallee vegetation communities, which is important for species such as the regent parrot, listed under the *Environmental Protection Biodiversity Conservation Act 1999* (Cwlth). Ecological Associates (2005) specify that a decrease in the area or a change in the distribution of wetland or floodplain vegetation communities would signal a change in the ecological character of the Ramsar site. This is consistent with ecological character descriptions from other Ramsar-listed indicator sites along the River Murray (e.g. Gunbower and Barmah forests) Hattah Lakes is an important area for waterbird breeding (Ecological Associates 2005; MDBC 2006). Supporting a large number and variety of waterbirds, including breeding habitat for many species is an important part of the ecological character of the site and to the maintenance of ecological diversity of the Robinvale Plains bioregion (Ecological Associates 2005). The site supports important habitat and species that are listed in international agreements such as Ramsar, and include vulnerable and endangered species such as Murray cod (*Maccullochella peelii peelii*) and Murray hardyhead (*Craterocephalus fluviatilis*). Achieving the targets for floodplain wetlands and waterbirds will ensure inundation of breeding and feeding habitats considered key for a range of fish, amphibian and water-dependent reptile and invertebrate species. Key ecosystem functions support fish, birds and invertebrates through habitat maintenance, energy transfer and facilitating connections between rivers and floodplains. Overbank flows supply the floodplains with nutrients and sediments from the river, accelerate the breakdown of organic matter and supply water to disconnected wetlands, billabongs and oxbow lakes. As the floodwaters recede, the floodplains provide the main river channel with organic matter. The hydrological connection between watercourses and their associated floodplain provides for the exchange of carbon and nutrients (Thoms 2003). The connections are considered essential for the functioning and integrity of floodplain-river ecosystems.

Table 4 Water levels and flows required to inundate selected habitat types for Hattah Lakes (Source: SKM 2006; Ecological Associates 2009).

Habitat type / water regime class	Water level (AHD)	Flow at Euston (ML/d)
Semi-permanent, persistent temporary and temporary wetlands	Up to 43 m	Up to 70,000
Fringing river red gum and river red gum forest	43–44 m	70,000 to 86,000
River rred gum woodland	44–44.5 m	86,000 to 124,000
Black box woodland	44.5–45 m	124,000 to 166,000

The MDBA has used hydraulic modelling undertaken by SKM (2006) to assess the relationship between flow and level for different areas of the Hattah Lakes system (Table 5). This analysis supports that there is a variable relationship between level and flow for different parts of the landscape.

In combination, elevation thresholds for flood dependent vegetation communities (Ecological Associates 2009) and flow-level information (SKM 2006) have been used to identify the flows required at Euston Weir to inundate the different habitat types (Table 4).

Ecological Associates (2009) provide recommendations for the frequency, duration and timing of flow events and maximum interval between flows to maintain key habitat types present at Hattah Lakes. Further information on water requirements of flood dependent vegetation communities, particularly Roberts and Marston (2011) was also reviewed. These recommendations, together with an assessment of without development flooding patterns, have been used to inform the site-specific flow indicators intended to achieve the ecological target of ensuring the current extent of native vegetation communities is sustained in a healthy, dynamic and resilient condition.

Table 5 Flow level relationships for various areas: Hattah Lakes (Source: based on MDBA analysis of SKM 2006).

Water level	43.00 m	43.50 m	44.00 m	44.50 m	45.00 m
Area	**Flow rate at Euston (ML/day)**				
Lockie	52,747	67,466	82,184	113,399	154,957
Little Hattah	65,618	74,741	83,863	113,399	154,936
Hattah	65,618	74,741	83,863	113,399	154,936
Bulla	69,161	76,743	84,325	113,399	154,936
Arawak	69,161	76,743	84,325	113,399	154,936
Marramook	70,802	77,671	84,539	113,399	154,957
Brockie	77,121	81,242	85,364	113,399	154,957
Boich	74,575	79,803	85,031	113,399	154,936
Tullamook	74,575	79,803	85,031	113,399	155,833
Nip Nip	72,944	78,882	84,819	113,399	154,936
Yerang	60,144	72,392	84,640	121,356	165,440
Mournpall	75,473	80,624	85,776	122,209	165,673
Yelwell	67,390	76,807	86,223	123,763	165,673
Konardin	76,319	81,079	85,838	122,209	165,673
Bitterang	92,871	102,669	128,955	164,776	230,500
Woterap	94,290	103,029	128,955	164,776	230,500
Cantala	81,361	86,497	110,447	147,508	223,806
Dry	194,375	211,043			

5.2.2. Other biota

There are numerous studies concerning the water-dependent vegetation communities of Hattah Lakes. The available eco-hydrological information does not extend to all water-dependent vegetation types that are located within the Hattah Lakes site e.g. lignum vegetation communities. Similarly, the understanding of flow-ecology relationships of other faunal groups is generally less well understood as there are fewer studies undertaken for these species. The MDBA is confident that the site-specific flow indicators determined to achieve the ecological targets relating to the current extent of native vegetation communities will also have valuable beneficial effects for lignum communities and on the life-cycle and habitat requirements of waterbirds, native fish, amphibians, and water-dependent reptiles and invertebrates (see below for further discussion). Key ecosystem functions associated with river and floodplain connectivity will also be enhanced.

Waterbirds

Overton et al. (2009) suggests that for successful breeding, colonial nesting waterbirds require 4–5 months of flooding in total, taking into account provision of breeding cues and time needed to lay and incubate eggs and fledge young. As described in the Hydrology section, Hattah Lakes retain water for long periods after flows recede and as such it is not considered necessary to provide long duration flow events to support successful waterbird breeding in Hattah Lakes.

Two key factors dictate that waterbirds do not need to breed every year on the same river system (Scott 1997). Firstly, Australian waterbirds are highly mobile and their mobility over large spatial scales is a defining characteristic (Scott 1997; Overton et al. 2009). Most of the 80 odd species of (non-vagrant) Murray-Darling Basin waterbirds that use inland wetlands have broad Australia-wide distributions and it is believed that individuals of most species are capable of dispersing at the scale of the continent (Overton et al. 2009). As such, prior to river regulation at least some individuals of the more mobile waterbird species have would have been able to seek suitable conditions for successfully breeding somewhere within the Basin in most years (Scott 1997).

Secondly, it is not essential for waterbirds to breed every year to maintain sustainable populations as they are generally long-lived (Scott 1997). Waterbirds become sexually mature at the age of one to two years and have a life expectancy ranging generally from 3-4 years for ducks, up to 8 years for larger birds such as ibis (Scott 1997).

These two key factors have informed the frequency of events for site-specific flow indicators intended to support the habitat requirements of waterbirds, including provision of conditions conducive to successful breeding of colonial nesting waterbirds. Specifically, it is desirable to provide multiple opportunities for successful waterbird breeding within the range of their life expectancy. The proposed flow indicators are consistent with this rationale.

Native fish

There is still debate in the scientific literature as to the relative role of flooding to fish community dynamics, and an understanding of the nature of 'fish ecology'-'river flow' interactions is by no means clear (Humphries et al. 1999, Mallen-Cooper and Stuart 2003, Graham and Harris 2004; King et al. 2009). For example, it has been suggested that some fish species, such as the conservationally significant Silver perch (*Bidyanus bidyanus*), which have been recorded at Hattah Lakes, require flow pulses or floods for spawning i.e. flood recruitment hypothesis (Humphries et al. 1999). Other factors such water temperature and day length, or the interaction of a range of environmental variables including flow, are suggested to also be important for native fish recruitment (King et al. 2009).

Despite the ongoing debate regarding the link between hydrology and fish ecology, available evidence supports that provision of flows that connect the river channel to the floodplain as well as in-channel flow variability are important to sustaining key ecological features such as native fish populations. Flow indicators described herein for the bankfull and overbank elements of the flow regime primarily based on the water requirements of flood dependent vegetation communities are expected to be sufficient to support life-cycle and habitat requirements of native fish including provision of cues for spawning and migration and access to food sources.

5.2.3. Environmental works

Environmental works at Hattah Lakes (built, under construction and/or proposed as part of the Living Murray Program) could assist with meeting environmental outcomes through the delivery of water through works instead of through the delivery of high flows. The effect of using the works both at this site and for the broader River Murray environmental assets needs further assessment and consideration of the trade-offs: Hattah Lakes may be able to be managed with less water to meet many of the same outcomes but if flows associated with outcomes that can be delivered by works are removed this could be detrimental to achieving environmental outcomes at sites outside of the command of the works. As such, the MDBA has not currently reworked the flow indicators to take account of the works being built at Hattah Lakes. The implications of doing this, including tradeoffs with other parts of the river, needs further assessment and will input into a future Basin Plan review.

5.2.4. 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 six flow indicators for Hattah Lakes (Table 6). The site-specific flow indicators for Hattah Lakes represent an amalgam of information within existing literature and vegetation inundation hydrodynamic modelling data, checked against analysis of modelled without development and baseline flow data. Site-specific flow indicators are expressed at River Murray downstream of Euston Weir, which generally represents the flow into Hattah Lakes.

Flow indicators as specified for the bankfull and overbank 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 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 Hattah Lakes 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 not possible to define a single flow threhold for each vegetation community. The flood dependent vegetation communities cover a wide range of flows (Figure 3) and a single indicator would be misleading.

Flows in excess of 180,000 ML/d are required to inundate the area around Dry and Boolca Lakes (Ecological Associates 2007a) where a significant proportion of the black box woodland community is located, see Figure 3. MDBA analysis shows that flows in excess of 180,000 ML/d occur infrequently — in 6% of years under modelled without development conditions. The current knowledge base suggests that black box is ecologically flexible and is an opportunistic user of water (Roberts and Marston 2011). Specifically, vegetation communities such as black box located on the higher elevation floodplains may not need to be fully inundated but benefit from flooding in the lower elevation through the flushing of groundwater reserves and refreshing soil water stores (Roberts and Marston 2011).

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Table 6: Site-specific ecological targets and associated flow indicators for Hattah Lakes

<table>
<tr><td rowspan="3">Site-Specific Ecological Targets</td><td colspan="5">Site-Specific Flow Indicators</td><td colspan="2">Without development and baseline event frequencies</td></tr>
<tr><td colspan="3">Event</td><td colspan="2">Frequency – proportion of years event required</td><td rowspan="2">Proportion of years event occurred under modelled without development conditions (%)</td><td rowspan="2">Proportion of years event occurred under modelled baseline conditions (%)</td></tr>
<tr><td>Flow required (measured at Euston) ML/day</td><td>Duration[a]</td><td>Timing</td><td>Low uncertainty (%)</td><td>High uncertainty (%)</td></tr>
<tr><td rowspan="6">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
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)
Provide a flow regime which supports key ecosystem functions, particularly those related to connectivity between the river and the floodplain</td><td>40,000</td><td>2 months in total (with 7 day minimum)</td><td rowspan="3">June to December</td><td>50</td><td>40</td><td>67</td><td>30</td></tr>
<tr><td>50,000</td><td>2 months in total (with 7 day minimum)</td><td>40</td><td>30</td><td>47</td><td>19</td></tr>
<tr><td>70,000</td><td>6 weeks in total (with 7 day minimum)</td><td>33</td><td>20</td><td>38</td><td>11</td></tr>
<tr><td>85,000</td><td>1 months in total (with 7 day minimum)</td><td rowspan="3">Preferably winter/spring but timing not constrained to reflect that high flows are dependent on occurrence of heavy rainfall and will be largely unregulated events</td><td>30</td><td>20</td><td>33</td><td>10</td></tr>
<tr><td>120,000</td><td>2 weeks in total (with 7 day minimum)</td><td>20</td><td>14</td><td>23</td><td>8</td></tr>
<tr><td>150,000</td><td>1 week total and minimum</td><td>13</td><td>10</td><td>17</td><td>5</td></tr>
</table>

a Duration is expressed both as a total and minimum duration, allowing multiple smaller flow events that met the minimum duration criteria to comprise a successful event. Minimum durations are therefore a subset of total duration and should not be read independently. MDBA analysis showed that if a minimum duration is not specified and individual events must meet the total duration criteria, this resulted in a significantly reduced proportion of years.

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.

Given the uncertainty regarding the importance of floods in maintaining black box woodlands at Hattah Lake in a healthy, dynamic and resilient condition and limitations imposed by current operational constraints (see Section 6) the MDBA has not proposed flow indicators to inundate the entire current extent of black box woodlands.

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. Secondly, vegetation communities are located across the floodplain, as highlighted by Table 4, and 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 5). 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.

For the Hattah Lakes a number of key sources of information were used to inform the high and low uncertainty frequencies. Site specific information such as Ecological Associates (2009) was complemented by more generic literature on water requirements of flood dependent vegetation communities, particularly Roberts and Marston (2011). These documents express the desired frequency as a range and the high and low uncertainty frequency flow indicator metrics attempt to encapsulate the broad water requirements represented by this range. Modelled flow data was used to verify if recommended frequencies were achievable and not greater than without development flows.

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 Hattah Lakes. 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 Hattah Lakes hydrologic indicator site (see MDBA 2012) despite reducing the maximum period between events not being the primary objective of the modelling process.

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 Hattah Lakes, 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 Hume Dam are typically limited to 25,000 ML/d under regulated flow conditions to minimise overbank flows and the associated inundation of agricultural land. This constraint prevents the release of flows, or adding water to augment natural flows, above 25,000 ML/d.

Constraints within tributaries of the Murray, particularly the Goulburn River and Murrumbidgee River, also influence the ability to achieve flow indicators specified for Hattah Lakes. Flooding and channel capacity constraints on regulated releases from Lake Eildon in the Goulburn River and Burrinjuck and Blowering Dams in the Murrumbidgee River (see MDBA 2011 for further detail) will act in combination with constraints in the Murray system to limit achievement of some flow indicators.

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 7). 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 Hattah Lakes.

Based on the information above, it is likely that environmental flow events with thresholds equal to or greater than 50,000 ML/d at Euston Weir will rely on supplementing tributary inflows with a regulated release from storage and their duration will be limited to the duration of the tributary in-flow.

Without addressing a range of constraints, it is likely that the 120,000 ML/d and 150,000 ML/d Hattah Lakes flow indicators are not deliverable under current river operations and are beyond the scope of a managed watering event. The achievement of site-specific ecological targets and flow indicators limited by constraints will be heavily reliant on large inflow events from a number of tributaries and potential storage spills.

Table 7: Site-specific flow indicators for Hattah Lakes and the effect of system constraints

<table>
<tr><th>Site-specific ecological targets</th><th>Site-specific flow indicators</th></tr>
<tr><td rowspan="6">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

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)

Provide a flow regime which supports key ecosystem functions, particularly those related to connectivity between the river and the floodplain</td><td>40,000 ML/d for a total duration of 60 days (with a minimum duration of 7 consecutive days) between June & December for 40% of years</td></tr>
<tr><td>50,000 ML/d for a total duration of 60 days (with a minimum duration of 7 consecutive days) between June & December for 30% of years</td></tr>
<tr><td>70,000 ML/d for a total duration of 42 days (with a minimum duration of 7 consecutive days) between June & December for 20% of years</td></tr>
<tr><td>85,000 ML/d for a total duration of 30 days anytime in the water year (with a minimum duration of 7 consecutive days) for 20% of years</td></tr>
<tr><td>120,000 ML/d for a total duration of 14 days anytime in the water year (with a minimum duration of 7 consecutive days) for 14% of years</td></tr>
<tr><td>150,000 ML/d for 7 consecutive days anytime in the water year for 10% of years</td></tr>
</table>

Key

	Achievable under current operating conditions Flow indicators highlighted in blue are considered deliverable as mostly regulated flows under current operating conditions.
	Achievable under some conditions (constraints limit delivery at some times) 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.
	Difficult to influence achievement under most conditions (constraints limit delivery at most times) 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.

7 Summary and conclusion

Hattah Lakes 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 Hattah Lakes environmental water requirements. Specified flow indicators are indicative of a long-term flow regime required to enable the achievement of site-specific ecological targets at Hattah Lakes 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 Hattah Lakes.

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Appendix A

Data used in producing 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	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)

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

Appendix B Species relevant to asset criteria 1 and 4 for Hattah Lakes

Species	Recognised in international agreement(s)[1]	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)	*Flora and Fauna Guarantee Act 1998* (VIC)
Amphibians and reptiles			
Carpet python (*Morelia spilota metcalfei*)[2]			E
Lace monitor (*Varanus varius*)[5]			V
Samphire skink (*Morethia adelaidensis*)[5]			E
Birds			
Australasian bittern (*Botaurus poiciloptilus*)[2]			E
Australian painted snipe (*Rostratula australis*)[5]	✔		CE
Barking owl (*Ninox connivens*)[2]			E
Black falcon (*Falco subniger*)[5]			V
Black-eared miner (*Manorina melanotis*)[2]		E	E
Blue-billed duck (*Oxyura australis*)[2]			E
Bush stone-curlew (*Burhinus grallarius*)[2]			E
Caspian tern (*Sterna caspia*)[2, 3]	✔		NT
Common sandpiper (*Actitis hypoleucos*)[5]			V
Diamond firetail (*Stagonopleura guttata*)[2]			V
Eastern great egret (*Ardea modesta*)[2, 3, 4, 5]	✔	V	V
Elegant parrot (*Neophema elegans*)[5]			V
Fork-tailed swift (*Apus pacificus*)[2, 3]	✔		
Freckled duck (*Stictonetta naevosa*)[2]			E
Glossy ibis (*Plegadis falcinellus*)[2, 3, 4]	✔		
Greenshank (*Tringa nebularia*)[2, 3]	✔		
Grey falcon (*Falco hypoleucos*)[2, 3]			E
Grey-crowned babbler (*Pomatostomus temporalis temporalis*)[2]			E
Ground cuckoo-shrike (*Coracina maxima*)[2]			V
Gull-billed tern *(Gelochelidon nilotica/sterna nilotica macrotarsa*)[2]			E
Inland dotterel (*Charadrius australis*)[5]			V
Intermediate egret (*Ardea intermedia*)[2]			CE
Latham's snipe (*Gallinago hardwickii*)[2, 3]	✔		
Little bittern (*Ixobrychus minutus dubius*)[2]			E
Little egret (*Egretta garzetta*)[2]			E
Magpie goose (*Anseranas semipalmata*)[2]			NT
Major Mitchell's cockatoo (pink cockatoo) (*Lophochroa leadbeateri*)[2, 3]			V
Mallee emu-wren (*Stipiturus mallee*)[2]		E	E
Malleefowl (*Leipoa ocellata*)[2]		V	E
Painted honeyeater (*Grantiella picta*)[2]			V
Painted snipe (*Rostratula australis* or *benghalensis*)[2, 3]	✔	V	CE

Species	Recognised in international agreement(s)[1]	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)	*Flora and Fauna Guarantee Act 1998* (VIC)
Plains-wanderer (*Pedionomus torquatus*)[2]		V	CE
Red-lored whistler (*Pachycephala rufogularis*)[2]		V	E
Red-necked stint (*Calidris ruficollis*)[2, 3]	✔		
Regent parrot (*Polytelis anthopeplus monarchoides*)[2, 3]		V	V
Royal spoonbill (*Platalea regia*)[5]			V
Scarlet-chested parrot (*Neophema splendida*)[5]			V
Sharp-tailed sandpiper (*Calidris acuminata*)[2, 3, 4]	✔		
Spotted bowerbird (*Chlamydera maculata*)[2]			E
Square-tailed kite (*Lophoictinia isura*)[2]			V
White-bellied sea-eagle (*Haliaeetus leucogaster*)[2, 3, 4]	✔		V
White-browed treecreeper (*Climacteris affinis*)[5]			V
White-throated needletail (*Hirundapus caudatus*)[2, 3]	✔		
Fish			
Freshwater catfish (*Tandanus tandanus*)[3]			E
Murray cod (*Maccullochella peelii peelii*)[2, 3, 4]		V	E
Murray hardyhead (*Craterocephalus fluviatilis*)[3]			CE
Silver perch (*Bidyanus bidyanus*)[3]			CE
Mammals			
Common dunnart (*Sminthopsis murina murina*)[5]			V
Greater long-eared bat (*Nyctophilus timoriensis*)[2]		V	V
Plants			
Annual flat-sedge (*Cyperus nervulosus*)[2, 5]			E
Australian broomrape (*Orobanche cernua* var. *australiana*)[5]			V
Bristly love-grass (*Eragrostis setifolia*)[5]			V
Buloke (*Allocasuarina luehmannii*)[2]			L
Buloke mistletoe (*Amyema linophylla orientale*)[5]			V
Button rush (*Lipocarpha microcephala*)[5]			V
Cane grass (*Eragrostis australasica*)[5]			V
Desert jasmine (*Jasminum didymum lineare*)[5]			V
Desert lantern (*Abutilon otocarpum*)[5]			V
Doubah (*Marsdenia australis*)[5]			V
Dwarf amaranth (*Amaranthus macrocarpus* var. *macrocarpus*)[5]			V
Dwarf flat-sedge (*Cyperus pygmaeus*)[5]			V
Dwarf swainson-pea *(Swainsona phacoides*)[2, 5]			E
Flycatcher (*Drosera indica*)[5]			V
Frosted goosefoot (*Chenopodium desertorum rectum*)[5]			V
Hoary scurf-pea (*Cullen cinereum*)[2, 5]			E

Species	Recognised in international agreement(s)[1]	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)	*Flora and Fauna Guarantee Act 1998* (VIC)
Jerry-jerry (*Ammannia multiflora*)[5]			V
Lagoon spurge (*Phyllanthus lacunarius*)[5]			V
Lax flat-sedge (*Cyperus flaccidus*)[5]			V
Pin sida (*Sida fibulifera*)[5]			V
Pop saltbush (*Atriplex holocarpa*)[2, 5]			V
Purple love-grass (*Eragrostis lacunaria*)[5]			V
Purple pentatrope (*Rhyncharrhena linearis*)[5]			V
Rabbit-ears twin-leaf (*Zygophyllum compressum*)[5]			V
Riverine flax-lily (*Dianella porracea*)[5]			V
Round templetonia (*Templetonia egena*)[5]			V
Sand sida (*Sida ammophila*)[5]			V
Silky glycine (*Glycine canescens*)[2, 5]			E
Silky swainson-pea (*Swainsona sericea*)[2, 5]			V
Silky umbrella-grass (*Digitaria ammophila*)[5]			V
Skeleton fan-flower (*Scaevola depauperata*)[5]			E
Slit-wing bluebush (*Maireana georgei*)[5]			V
Small water-fire (*Bergia trimera*)[5]			V
Spear-fruit copperburr (*Sclerolaena patenticuspis*)[5]			V
Spiked daisy-bush (*Olearia subspicata*)[5]			V
Spiny-fruit saltbush (*Atriplex spinibractea*)[5]			E
Spreading cress (*Phlegmatospermum eremaeum*)[5]			V
Spreading scurf-pea (*Cullen patens*)[2, 5]			E
Tall kerosene grass (*Aristida holathera* var. *holathera*)[5]			V
Toothed raspwort (*Haloragis odontocarpa* f. *octoforma*)[5]			V
Tough scurf-pea (*Cullen tenax*)[2, 5]			E
Twiggy sida (*Sida intricata*)[5]			V
Umbrella wattle (*Acacia oswaldii*)[5]			V
Upright adder's-tongue (*Ophioglossum polyphyllum*)[5]			V
Williamson's rice-flower (*Pimelea williamsonii*)[5]			V
Winged peppercress (*Lepidium monoplocoides*)[2, 4, 5]		E	E
Woolly copperburr (*Sclerolaena lanicuspis*)[5]			E
Woolly scurf-pea (*Cullen pallidum*)[2, 4, 5]			E
Yellow swainson-pea (*Swainsona pyrophila*)[5]			V

CE = critically endangered E = endangered L = listed NT = near threatened V = vulnerable

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

2 Ecological Associates (2005)

3 Victorian Department of Sustainability and Environment (2003)

4 Victorian Department of Sustainability and Environment (2009b); Heron & Joyce (2008)

5 Victorian Department of Sustainability and Environment (2009a)