DEPARTMENT OF PLANNING, INDUSTRY & ENVIRONMENT

Murray–Lower Darling Long Term Water Plan

Part B: Murray–Lower Darling planning units

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Acknowledgement of Traditional Owners

The Department of Planning, Industry and Environment pays its respect to the Traditional Owners and their Nations of the Murray–Darling Basin. The contributions of earlier generations, including the Elders, who have fought for their rights in natural resource management are valued and respected.

In relation to the Murray–Lower Darling catchment, the Department of Planning, Industry and Environment pays its respects to the Traditional Owners – the Bangerang, Barkindji, Barapa Barapa, Maljangapa, Maraura, Muthi Muthi, Ngiyampaa, Nyeri Nyeri, Tati Tati, Wadi Wadi, Wamba Wamba, Weki Weki, Yorta Yorta and Wiradjuri Nations – past, present and future. We look forward to building upon existing relationships to improve the health of our rivers, wetlands and floodplains including in recognition of their traditional and ongoing cultural and spiritual significance.

Figure 1 **Great egret.**
Photo: Natasha Childs

Abbreviations

AEW	Adaptive Environmental Water
ARI	Average recurrence interval
Basin Plan	Murray–Darling Basin Plan
CAMBA	China – Australia Migratory Bird Agreement
DO	Dissolved oxygen
DOC	Dissolved organic carbon
EWR	Environmental water requirement
FSL	Full Supply Level
GL	gigalitre
HEW	Held environmental water
JAMBA	Japan – Australia Migratory Bird Agreement
LDR	lower Darling River
LTWP	Long Term Water Plan
MDBA	Murray–Darling Basin Authority
MER	Monitoring, evaluation and reporting
mg/L	milligrams per litre
ML	megalitre
m/s	metres per second
NPWS	NSW National Parks and Wildlife Services
NSW	New South Wales
DPIE-BC	NSW Department of Planning, Industry and Environment – Biodiversity and Conservation Division
PCT	Plant community type
PEW	Planned environmental water
PU	Planning unit
ROKAMBA	Republic of Korea – Australia Migratory Bird Agreement
SDL	Sustainable diversion limit
WRP	Water resource plan
WRPA	Water resource plan area
WSP	Water sharing plan

Glossary

Alluvial	Comprised of material deposited by water.
Bankfull flow	River flows at maximum channel capacity with little overflow to adjacent floodplains. Engages the riparian zone, anabranches and flood runners and wetlands located within the meander train. Inundates all in-channel habitats including all benches, snags and backwaters.
Baseflow	Reliable background flow levels within a river channel that are generally maintained by seepage from groundwater storage, but also by surface inflows. Typically inundates geomorphic units such as pools and riffle areas.
Basin Plan	The Basin Plan as developed by the Murray–Darling Basin Authority under the *Water Act 2007*.
Biota	The organisms that occupy a geographic region.
Blackwater	Occurs when water moves across the floodplain and releases organic carbon from the soil and leaf litter. The water takes on a tea colour as tannins and other carbon compounds are released from the decaying leaf litter. The movement of blackwater plays an important role in transferring essential nutrients from wetlands into rivers and vice versa. Blackwater carries carbon which is the basic building block of the aquatic food web and an essential part of a healthy river system.
Cease-to-flow	The absence of flowing water in a river channel. Partial or total drying of the river channel. Streams contract to a series of isolated pools.
Cease-to-pump (access rule in WSP)	Pumping is not permitted: • from in-channel pools when the water level is lower than its full capacity • from natural off-river pools when the water level is lower than its full capacity • from pump sites when there is no visible flow. These rules apply unless there is a commence-to-pump access rule that specifies a higher flow rate that licence holders can begin pumping.
Constraints	The physical or operational constraints that effect the delivery of water from storages to extraction or diversion points. Constraints may include structures such as bridges that can be affected by higher flows, or the volume of water that can be carried through the river channel, or scheduling of downstream water deliveries from storage.
Consumptive water	Water that is removed from available supplies without return to a water resource system (such as water removed from a river for agriculture).
Dissolved Organic Carbon (DOC)	A measurement of the amount of carbon from organic matter that is soluble in water. DOC is transported by water from floodplains to river systems and is a basic building block available to bacteria and algae that are food for microscopic animals that are in turn consumed by fish larvae, small bodied fish species, yabbies and shrimp. DOC is essential for building the primary food webs in rivers and ultimately generates a food source for large bodied fish like Murray cod and golden perch and predators such as waterbirds.
Ecological asset	The physical features that make up an ecosystem.
Ecological function	The resources and services that sustain human, plant and animal communities and are provided by the processes and interactions occurring within and between ecosystems.
Ecological objective	Objective for the protection and/or restoration of an ecological asset or function.
Ecological target	Level of measured performance that must be met in order to achieve the defined objective. The targets in this long-term water plan are SMART (Specific/Measurable/Achievable/Realistic/Time-bound).
Ecological value	An object, plant or animal which has value based on its ecological significance.

Environmental water	Water for the environment. It serves a multitude of benefits to not only the environment, but to communities, industry and society. It includes water held in reservoirs (held environmental water) or protected from extraction from waterways (planned environmental water) for the purpose of meeting the water requirements of water-dependent ecosystems.
Environmental water requirement (EWR)	The water required to support the completion of all elements of a lifecycle of an organism or group of organisms (taxonomic or spatial), consistent with the objective/target, measured at the most appropriate gauge. Includes all water in the system including natural inflows, held environmental water and planned environmental water.
Flow category	The type of flow in a river defined by its magnitude (e.g. bankfull).
Flow regime	The pattern of flows in a waterway over time that will influence the response and persistence of plants, animals and their ecosystems.
Freshes	Temporary in-channel increased flow in response to rainfall or release from water storages.
Groundwater	Water that is located below the earth's surface in soil pore spaces and in the fractures of rock formations. Groundwater is recharged from, and eventually flows to, the surface naturally.
Held environmental water (HEW)	Water available under a water access right, a water delivery right, or an irrigation right for the purposes of achieving environmental outcomes (including water that is specified in a water access right to be for environmental use).
Hydrology	The occurrence, distribution and movement of water.
Hypoxic blackwater	Occurs when dissolved oxygen (DO) levels fall below the level needed to sustain native fish and other water dependent species. Algae which feed on dissolved organic carbon use oxygen in the water. When they multiply rapidly their rate of oxygen consumption can exceed the rate at which oxygen can be dissolved in the water, oxygen levels fall and a hypoxic (low oxygen) condition occurs. Dissolved oxygen is measured in milligrams per litre (mg/L). Generally native fish begin to stress when DO levels fall below 4 mgL. Fish mortality occurs when DO levels are less than 2 mg/L.
Key ecological value	A species that is selected for making conservation-related decisions based on relevant temporal and spatial criteria.
Large fresh	High-magnitude flow pulse that remains in-channel. May engage flood runners with the main channel and inundate low-lying wetlands. Connects most in-channel habitats and provides partial longitudinal connectivity, as some low-level weirs and other in channel barriers may be drowned out.
Lateral connectivity	The flow linking rivers channels and the floodplain
Long Term Water Plan (LTWP)	A component of the Murray–Darling Basin Plan, long term water plans give effect to the Basin-wide Watering Strategy relevant for each river system and will guide the management of water over the longer term. These plans will identify the environmental assets that are dependent on water for their persistence, and match that need to the water available to be managed for or delivered to them. The plan will set objectives, targets and watering requirements for key plants, waterbirds, fish and ecosystem functions. DPIE is responsible for the development of nine plans for river catchments across NSW, with objectives for five, 10 and 20 year timeframes.
Longitudinal connectivity	The consistent downstream flow along the length of a river.
Montane	Relating to mountainous country.
Overbank flow	Flows that spill over the riverbank or extend to floodplain surface flows.
Planned environmental water (PEW)	Water that is committed by the Basin Plan, a water resource plan or a plan made under state water management law to achieving environmental outcomes.

Planning Unit (PU)	A division of a water resource plan area based on water requirements (in catchment areas in which water is actively managed), or a sub-catchment boundary (all other areas).
Priority environmental asset	A place of particular ecological significance that is water-dependent and can be managed with environmental water. This includes planned and held environmental water.
Ramsar Convention	An international treaty to maintain the ecological character of key wetlands.
Recruitment	Successful development and growth of offspring; such that they have the ability to contribute to the next generation.
Refuge	An area in which a population of plants or animals can survive through a period of decreased water availability.
Regulated river	A river that is gazetted under the *NSW Water Management Act 2000.* Flow is largely controlled by major dams, water storages and weirs. River regulation brings more reliability to water supplies but has interrupted the natural flow characteristics and regimes required by native fish and other plant and animal to breed, feed and grow.
Riffle	A rocky or shallow part of a river where river flow is rapid and broken.
Riparian	The part of the landscape adjoining rivers and streams that has a direct influence on the water and aquatic ecosystems within them.
Small fresh	Low-magnitude in-channel flow pulse. Unlikely to drown out any significant barriers, but can provide limited connectivity and a biological trigger for animal movement.
Surface water	Water that exists above the ground in rivers, streams creeks, lakes and reservoirs. Although separate from groundwater, they are interrelated and over extraction of either will impact on the other.
Unregulated river	A waterway where flow is mostly uncontrolled by dams, weirs or other structures.
Very low flow	Small flow in the very-low flow class that joins river pools, thus providing partial or complete connectivity in a reach. Can improve DO saturation and reduce stratification in pools.
Water resource plan (WRP)	A document prepared by state authorities and accredited by the Commonwealth under the Basin Plan. The document describes how water will be managed and shared between users in an area.
Water resource plan area (WRPA)	Catchment-based divisions of the Murray–Darling Basin defined by a water resource plan.
Water sharing plan (WSP)	A plan made under the NSW *Water Management Act 2000* that sets out specific rules for sharing and trading water between the various water users and the environment in a specified water management area. A water sharing plan will be a component of a water resource plan.
Water-dependent system	An ecosystem or species that depends on periodic or sustained inundation, waterlogging or significant inputs of water for natural functioning and survival.

Glossary: Definitions and explanatory text for EWRs

Table 1 Definitions and explanatory text for Environmental Water Requirements

Flow category	Flows in rivers vary over time in response to rainfall, river regulation, extractions and other factors. The sequence of flows over time can be considered as a series of discrete events. These events can be placed into different flow categories (e.g. baseflows, freshes, bankfull, overbank and wetland flows) according to the magnitude of flow discharge or height within a watercourse, and the types of outcomes associated with the events (e.g. inundation of specific features such as channel benches, riparian zones or the floodplain). Flow categories used in LTWPs are illustrated and defined in Figure 9 and Table 7 in Part A of each LTWP.
Environmental water requirement (EWR)	An environmental water requirement (EWR, singular) describes the characteristics of a flow event (e.g. magnitude, duration, timing, frequency, and maximum dry period) within a particular flow category (e.g. small fresh), that are required for that event to achieve a specified ecological objective or set of objectives (e.g. to support fish spawning and in-channel vegetation). There may be multiple EWRs defined within a flow category, and numerous EWRs across multiple flow categories within a planning unit. Achievement of each of the EWRs will be required to achieve the full set of ecological objectives for a planning unit.
EWR code	Each EWR is given a specific code that abbreviates the EWR name (e.g. SF1 for small fresh 1). This code is used to link ecological objectives and EWRs.
Gauge	The flow gauging station that best represents the flow within the planning unit, for the purpose of the respective EWR and associated ecological objective(s). To assess the achievement of the EWR, flow recorded at this gauge should be used.
Flow rate or flow volume	The flow rate (typically ML/d) or flow volume (typically GL over a defined period of time) that is required to achieve the relevant ecological objective(s) for the EWR. Most EWRs are defined using a flow rate, whilst flow volumes are used for EWRs that represent flows into some large wetland systems.
Timing	The required timing (or season, typically expressed as a range of months within the year) for a flow event to achieve the specified ecological objective(s) of the EWR. In some cases, a preferred timing is provided, along with a note that the event may occur at 'anytime'. This indicates that ecological objectives may be achieved outside the preferred timing window, but perhaps with sub-optimal outcomes. In these instances, for the purposes of managing and delivering environmental water, the preferred timing should be used to give greater confidence in achieving ecological objectives. Natural events may occur at other times and still achieve ecological objectives.
Duration	The duration for which flows must be above the specified flow rate for the flow event to achieve the specified ecological objective(s) of the EWR. Typically this is expressed as a minimum duration. Longer durations will often be desirable and deliver better ecological outcomes. Some species may suffer from extended durations of inundation, and where relevant a maximum duration may also be specified. Flows may persist on floodplains and within wetland systems after a flow event has past. Where relevant a second duration may also be specified, representing the duration for which water should be retained within floodplain and wetland systems.

Frequency	The frequency at which the flow event should occur to achieve the ecological objective(s) associated with the EWR. Frequency is expressed as the number of years that the event should occur within a 10-year period. In most instances, more frequent events will deliver better outcomes & maximum frequencies may also be specified, where relevant. Clustering of events over successive years can occur in response to climate patterns. Clustering can be ecologically desirable for the recovery & recruitment of native fish, vegetation & waterbirds populations, however extended dry periods between clustered events can be detrimental. Achieving ecological objectives will require a pattern of events over time that achieves both the frequency & maximum inter-flow period, & the two must be considered together when evaluating outcomes or managing systems. Where a range of frequencies is indicated (e.g. 3–5 years in 10), the range reflects factors including the natural variability in population requirements, uncertainty in the knowledge base, and variability in response during different climate sequences (e.g. maintenance of populations during dry climate sequences at the lower end of the range, and population improvement and recovery during wet climate sequences at the upper end of the range). The lower end of the frequency range (when applied over the long term) may not be sufficient to maintain populations and is unlikely to achieve any recovery or improvement targets. As such, when evaluating EWR achievement over the long-term through statistical analysis of modelled or observed flow records, the LTWP recommends using a minimum long term average (LTA) target frequency that is at least the average of the recommended frequency range but may be higher than the average where required to achieve objectives. For example, for a recommended frequency range of 3–5 years in 10, the minimum LTA frequency should be at least 40% of years, but may be up to 50% of years at sites where a higher frequency should be targeted over the long term to ensure recovery in certain species/populations. Whilst these higher frequencies may exceed modelled natural event frequency in some cases, recovery in particularly degraded systems will be unlikely should lower (i.e. average) frequencies be targeted. Minimum LTA target frequencies in this LTWP are reported predominantly as the average of the recommended frequency range, however this may be refined during implementation of the LTWP and in future revisions of the LTWP based on the results of ongoing ecological monitoring.
Maximum inter-flow or inter-event period	The maximum time between flow events before a significant decline in the condition, survival or viability of a particular population is likely to occur, as relevant to the ecological objective(s) associated with the EWR. This period should not be exceeded wherever possible. *Annual planning of environmental water should consider placing priority on EWRs that are approaching (or have exceeded) the maximum inter-event period, for those EWRs that can be achieved or supported by the use of environmental water or management.*
Additional requirements and comments	Other conditions that should occur to assist ecological objectives to be met – for example rates of rise and fall in flows. Also comments regarding limitations on delivering environmental flows and achieving the EWR.

1. Introduction

To help manage the complexity of the Murray–Lower Darling Water Resource Plan Area (WRPA), the Murray–Lower Darling Long Term Water Plan (LTWP) has been divided into 37 planning units (PUs) (Figure 3 and Figure 4). Planning units delineate areas with a unique set of mechanisms for managing water for environmental outcomes. Planning units (PUs) are classified as either: a) regulated (or which can be affected by regulated water); or b) unregulated.

This document, which forms Part B of the LTWP, provides the following local-scale information for each planning unit.

- The location of priority environmental assets as identified through LTWP development.
- The ecological values, including native fish, frogs and waterbird species, and native vegetation communities that occur within the planning unit.
- For planning units that are regulated, or that can be affected by regulated water (PUs 1–19), environmental water requirements (EWRs), at representative gauges, to support achievement of the LTWP objectives and targets.
- For planning units that are unregulated (PUs 20–37), an evaluation of the impact of water resource development on local hydrology and recommended management strategies for mitigating these changes to meet LTWP objectives and targets.

The planning units are presented in two sections in this document.

- Section 2 contains PUs 1–19, which are regulated or can be affected by regulated water.
- Section 3 contains PUs 20–37 that are unregulated and unable to be influenced by regulated water deliveries.

Figure 2 **Gwynnes Creek in the Edward-Wakool system.**
Photo: Emma Wilson

Legend

Unregulated

Regulated, or affected by regulated water

N

0 35 70

Kilometers

Planning Units by Water Management Area

Mid Murray

1. Murray River - Hume to Yarrawonga
2. Murray River - Yarrawonga to Barmah
3. Murray River - Barmah to Barham
4. Murray River - Barham to Wakool Junction

Edward-Wakool

5. Edward River - Stevens Weir to Wakool River
6. Upper Wakool River and Yallakool Creek
7. Mid and lower Wakool River

Lower Murray

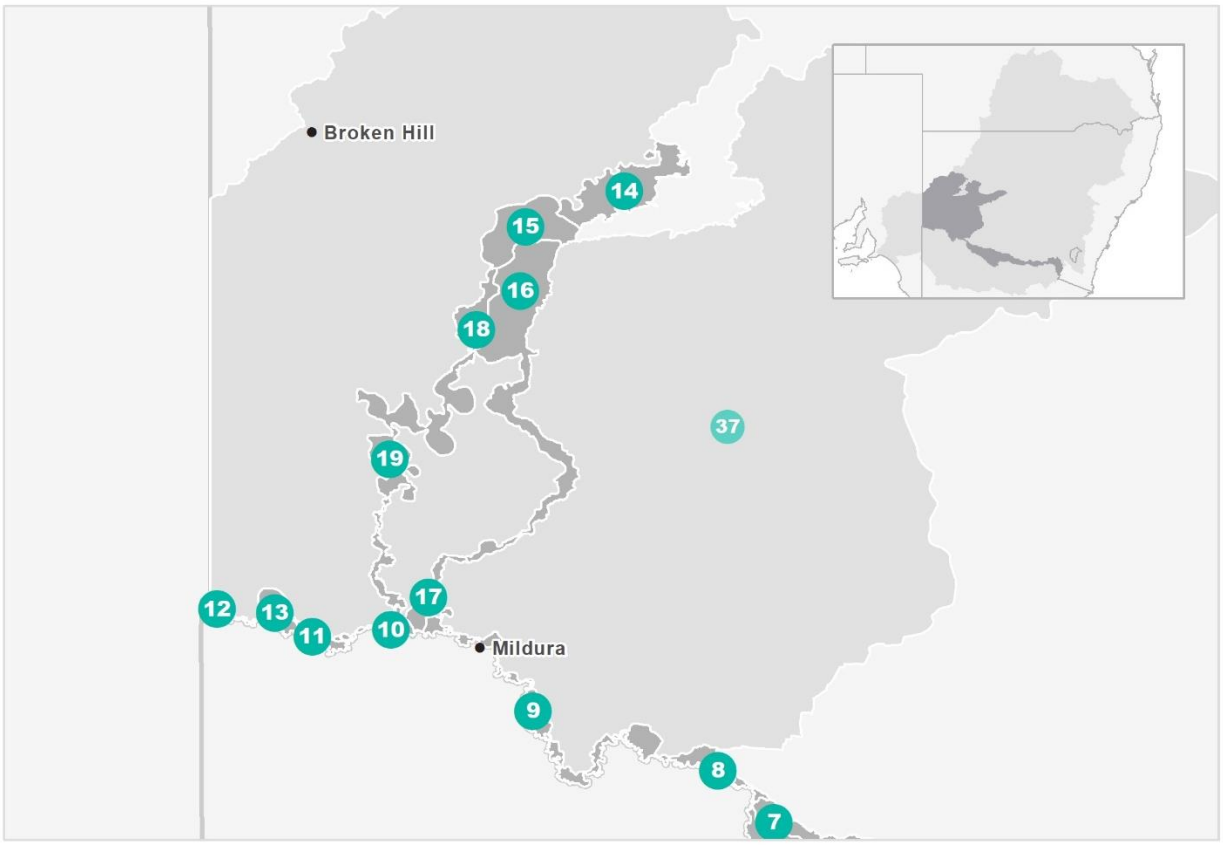
8. Murray River - Wakool Junction to upstream extent of Lock 15
9. Murray River - upstream extent of Lock 15 weir pool to Lock 10

(PU10, 11, 12, 13 not shown)

Zone B planning units

20. Indi Water Source
21. Upper Murray Water Source
22. Upper Murray tributaries - Sampy Plains
23. Upper Murray tributaries - Tooma
24. Maragle Water Source
25. Tumbarumba Water Source
26. Mannus
27. Lake Hume Water Source
28. Ournei Welaregang Water Source
29. Jingellic Water Source
30. Dorra Dorra Water Source
31. Hume Water Source
32. Albury Water Source
33. Majors Water Source
34. Lower Wangamong
35. Mulwala Canal - Mulwala to Lawson Syphon
36. Deniboota-Cadell-Moira
37. Lower Murray Darling Unregulated

Figure 3 **The eastern section of the Murray–Lower Darling WRPA showing the division of planning units into regulated (or affected by regulated water) and unregulated in the Long Term Water Plan**



Legend

Unregulated

Regulated, or affected by regulated water

N

0 35 70

Kilometers

Planning Units by Water Management Area

Edward-Wakool

7. Mid and lower Wakool River
(PU5, 6 not shown)

Lower Murray

8. Murray River - Wakool Junction to upstream extent of Lock 15
9. Murray River - upstream extent of Lock 15 weir pool to Lock 10
10. Murray River - Lock 10 to Lock 9
11. Murray River - Lock 9 to Lock 7
12. Murray River - Lock 7 to SA border
13. Frenchman's Creek and Lake Victoria

Lower Darling

14. Lake Wetherall
15. Menindee Lakes system
16. Lower Darling River - Weir 32 to downstream of Burtundy
17. Lower Darling River - Murray Lock 10 weir pool influence
18. Redbank and Tandou creeks
19. Darling Anabranch

Zone B planning units

37. Lower Murray Darling Unregulated
(PU20-36 not shown)

Figure 4 **The western section of the Murray–Lower Darling WRPA showing the division of planning units into regulated (or affected by regulated water) and unregulated in the Long Term Water Plan**

2. Planning units that are regulated or that can be affected by regulated water

In planning units that are regulated (or affected by regulated water) (PUs 1–19), discretionary[1] environmental water can be delivered (together with operational water, consumptive water and natural high flows i.e. dam spills) to help meet EWRs of priority environmental assets and functions.

Water can be delivered to priority environmental assets via regulated river flows ordered from storages or by diverting regulated (and potentially unregulated) water from rivers to floodplains and wetlands with the assistance of infrastructure (e.g. regulators, pumping, siphons or irrigation infrastructure). Environmental assets on the floodplain of major regulated rivers and creeks are also included in these planning units because these assets are influenced by the operating rules and protocols of major storages including during flood operations (e.g. air space management for Hume Dam and Menindee Lakes). Storage operating rules and river operations can influence the frequency and duration that floodplain vegetation is inundated, for example.

Therefore, although most floodplains, wetlands and many smaller creeks are located in 'unregulated' water sources according to the three water sharing plans relevant to the Murray–Lower Darling WRPA, these environmental assets are included in the regulated planning units in this LTWP because they can be influenced either directly through regulated water deliveries or indirectly via the operating rules and protocols of major regulating storages.

2.1 Priority environmental assets in regulated planning units

Priority environmental assets in regulated planning units include any environmental asset[2] identified using criteria in Schedule 8 of the Basin Plan (see Part A, Section 2) that can be managed through planned and/or held environmental water, often in combination with other river flows.

In this LTWP area this is considered to be defined by:

- environmental assets located on floodplains that are influenced by 1:10 year average recurrence interval (ARI) flood flows on major regulated rivers (Murray below Hume Dam, Edward–Wakool system, and lower Darling system). The 1:10 year ARI flood is considered the largest river flow that is significantly influenced (alteration of flood timing, duration or magnitude) by the operation of major storages in the Murray–lower Darling WRPA. These storages are unlikely to have a major influence on flows larger than the 1:10 year ARI flood.
- wetlands or creeks located outside the 1:10 year ARI floodplain but which can be managed with infrastructure assisted delivery of environmental water (e.g. use of irrigation infrastructure or pumping).
- the maximum inundation extent of natural lakes used as regulated storages (i.e. under surcharge operations). This includes the Menindee Lakes system and Euston Lakes.

[1] Discretionary environmental water includes held environmental water (HEW), adaptive environmental water. (AEW) and certain types of planned environmental water (PEW) where environmental water managers and holders have discretion over determining the timing, duration and magnitude of delivery.

[2] Environmental assets include permanent and ephemeral water features (rivers, creeks, wetlands and lakes) as well as floodplain areas that support ecological values (e.g. water-dependant vegetation).

2.2 Environmental water requirements

Environmental water requirements (EWRs) are defined for representative gauges in each regulated planning unit. These EWRs describe the flow (or inundation regime, in the case of large lake systems) to support ecological objectives and targets for all priority environmental assets in each planning unit. A guide to interpreting EWRs is provided in the Glossary.

Environmental water requirements can be met with discretionary environmental water, consumptive deliveries, operational flows (e.g. conveyance flows or bulk water transfers between storages), unregulated flows (i.e. spills from dams), or a combination of these.

In all planning units, most high flow EWRs (bankfull, overbank and, in some cases, also large freshes) cannot currently be met with regulated water deliveries due to existing flow constraints. Some of these EWRs will be able to be met with regulated deliveries when constraints are overcome as envisaged by the Constraints Management Strategy (these are shaded in orange in the EWR tables).

Medium and large overbank events can only be met with natural events and are indicated as such by grey shading. The largest overbank flows typically correspond with the 1:10 year ARI flood flow and are close to or just above Minor Flood Levels. Small and medium size overbank flows are typically well below the Minor Flood Levels at various locations in the Murray-Lower Darling WRPA.

Risks and constraints to meeting EWRs, together with strategies for addressing these, are presented in Section 5 of Part A of the LTWP.

Figure 5 **Burtundy Weir and fishway on the lower Darling River**
Photo: DPIE

2.3 Mid Murray water management area

PU1: Murray River – Hume to Yarrawonga

Priority environmental assets				
Rivers, creeks, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):				
• Murray River • Norman's Lagoon[3] • Hawdon's Lagoon • Mungabarina Lagoon • Murray River including in-stream habitat & fringing native vegetation • Horseshoe Lagoon	• Jingera Jingera Lagoon • Dights Creek • Yellowbelly Creek • Travellers Creek • Sheepdip Lagoon • Lesters Lagoon	• S Lagoon • Parlour Creek • Dead River • Common Creek • Deep Lagoon • Cook's Lagoon	• Dairy Lagoon[3] • Snake Lagoon[3] • Croppers Lagoon • Boiling Downs Creek • Collendina Lagoon • Bagnalls Lagoon	
Native fish[4]	• Australian smelt • carp gudgeon • dwarf flathead gudgeon	• flat-headed gudgeon • golden perch • mountain galaxias • Murray cod	• Murray crayfish • Murray–Darling rainbowfish • river blackfish • obscure galaxias	• flathead galaxias (P) • southern pygmy perch (P) • unspecked hardyhead • trout cod
Birds	95 water-dependent bird species recorded, including the following listed[5] waterbird species:			
	• Australasian bittern (E) • blue-billed duck (V) • brolga (V)	• Caspian tern (J) • cattle egret (J) • common sandpiper (C,J)	• eastern great egret (J) • freckled duck (V) • Latham's snipe (J,K) • magpie goose (V)	• marsh sandpiper (C,J,K) • sharp-tailed sandpiper (C,J,K) • wood sandpiper (C,J,K)
Native vegetation	16 water-dependent PCTs, including non-woody wetland and river red gum woodlands.			
Other species	• Bibron's toadlet • brown-striped frog • brown tree frog	• eastern sign-bearing froglet • giant banjo frog	• spotted marsh frog • Sudell's frog	• Macquarie turtle • eastern bentwing-bat (V)

[3] Historical records of the critically endangered flathead galaxias.

[4] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

[5] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Priority environmental assets				
	• common eastern froglet eastern banjo frog	• Peron's tree frog • Sloane's froglet (V)	• broad-shelled turtle eastern snake-necked turtle	• yellow bellied sheathtail-bat (V)
Unregulated WALs	There is 164 ML of unregulated entitlements in the PU, of which 127 ML are unregulated water access licences (WALs) for production. There are six production WALs <250 ML. They are mainly distributed in the upper third of the PU, but one is located on Sheepdip Lagoon & one is located on Croppers Lagoon.			

Table 2 **Environmental watering requirements for the Murray River – Hume to Yarrawonga**
Representative gauge: Murray at Doctors Point (409017)

Flow Category & EWR code[6]		Ecological objective[6] (Primary objectives in bold)	Flow rate (ML/d)[6] Murray at Doctors Point	Timing[6]	Duration[6]	Frequency[6] *(& LTA[7] Frequency)*	Maximum inter-event period[6]	Additional watering requirements[6]
Very low flows	VLF	Native Fish NF1 – survival & condition (all species) Ecosystem Functions (EF1, 2) – refuge habitat	>1300	All year	365 days minimum each year	Annual *(100%)*	60 days	Especially important post irrigation season when flows tend to fall
Baseflows	BF1	Native Fish: NF1–9 – condition & movement (all species) Native Vegetation: NV1 – in-channel Ecosystem Functions: EF1, 2, 3, 4, 8 – longitudinal connectivity along Murray; refuge habitat	>3000	All year	305 days minimum (186 days min in very dry years)	Annual *(100%)*	91 days	Allow temporal variability in baseflows in response to inflows from upstream. Although consideration should be given to requirements for a drying phase (BF3) in Murray River d/s Yarrawonga. Maximum rate of fall – 13% change in flow per day
Small fresh	SF1	Native Fish: NF1–9 – Dispersal/condition (all species) Native Vegetation: NV1 – in-channel non-woody Ecosystem Functions: EF1–7 – Variable in-channel habitat; water quality; transport of nutrients, sediment & carbon; small-scale productivity	>6000	Oct–Apr (or anytime)	10 days minimum	Annual *(100%)* (Ideally 2 events per year)	1 year	Maximum rate of fall – 13% change in flow per day
	SF2	Native Fish: NF1, 2, 3, 4 – Spawning (river specialist, generalist fish); recruitment/dispersal following spring breeding (flow pulse specialists, riverine specialists & generalists); possible spawning of flow pulse specialists; Native vegetation: NV1 – in-channel non-woody Ecosystem Functions: EF1–7 – as for SF1	>6000	Sep–Dec	90 days minimum	5–10 years in 10 *(75%)*	2 years	Maximum rate of fall – 13% change in flow per day
Large fresh	LF1	Native Fish: NF1–10 – Dispersal/condition (all species); pre-spawning condition of flow pulse specialists; dispersal of floodplain specialists into/from low-lying wetlands Native Vegetation: NV1–3 – In-channel, wetland & fringing Ecosystem Functions: EF2–7 – Lateral connectivity with low-lying wetlands, creeks & anabranches; hydraulic diversity; productivity; transport of nutrients, carbon & sediment.	>10,000	Jul–Sep (or anytime)	5 days minimum	5–10 years in 10 *(75%)*	2 years	Maximum rate of fall – 13% change in flow per day
	LF2	Native Fish: NF1, 3, 4, 6, 7 – Spawning of flow pulse specialists; dispersal of floodplain specialists into/from low-lying wetlands Native Vegetation: NV1–3 – in-channel, wetland & fringing Ecosystem Functions: EF2–7 – as for LF1	>10,000	Oct–Apr	10 days minimum	6–7 years in 10 *(65%)*	2 years	Requirements for spawning of flow pulse specialists: a) Rapid rise in flow (within natural rates of rise); b) water temperature >17^{0}C Maximum rate of fall of 6% during Murray Cod / trout cod nesting season (Sep–Nov) for flows <10,000); 13% at other times & flow rates

[6] See Glossary: Definitions and explanatory text for EWRs.
[7] Long term average frequency (% of years).

Flow Category & EWR code[6]		Ecological objective[6] (Primary objectives in bold)	Flow rate (ML/d)[6] Murray at Doctors Point	Timing[6]	Duration[6]	Frequency[6] *(& LTA[7] Frequency)*	Maximum inter-event period[6]	Additional watering requirements[6]
	LF3 **Relies on relaxed constraints**	Native Fish: NV3,7 – **Spawning (floodplain specialists, especially the critically endangered flathead galaxias^)** Native vegetation: NV1–3 – in-channel, **wetland non-woody**, fringing Functions: EF1–7 **–** as for LF1&2 but more wetlands inundated (14% of total wetland area from Hume to Yarrawonga[8]) Other species: OS2,3b – **Breeding of Sloane's froglet**	>20,000	Aug (or July-Sep)[#]	8 days minimum (for min 3 months wetland inundation)	7–8 years in 10 *(75%)*	2 years	# Required timing is Aug–Sep for flathead galaxias; Jul–Aug for Sloane's froglet (overlap month in Aug) Flathead galaxias are short-lived & need to breed every 1–2 years – in dry periods may need to deliver water to discrete wetlands via infrastructure to protect populations Maximum rate of fall – 13% change in flow per day
Bankfull	BK1 **Relies on relaxed constraints**	Native Fish: NF2–10: **condition/dispersal (all species)**, spawning (flow pulse specialists & floodplain specialists) Native vegetation: NV1, 2, 3, 4a – **in-channel & wetland non-woody; fringing river red gum (RRG), RRG forest** Ecosystem Functions: EF1–7 – **lateral connectivity with low-lying wetlands** (15% of total wetland area Hume to Yarrawonga); productivity; channel maintenance; transfer of nutrients, sediment & carbon transport; groundwater rechargeOther species: OS1–3 – frog breeding	> 25,000	Aug–Nov (or anytime for natural events)	10 days minimum cumulative duration^	6–8 years in 10 *(70%)*	3 years	^Can go below flow threshold for short periods (5 days Maximum) To maintain open marsh areas & avoid hypoxic blackwater events downstream, deliver event in late winter/spring & allow to dry in late spring/early summer Provide exit cue for fish prior to recession Maximum rate of fall – 13% change in flow per day
Small overbank	OB1[9] **Relies on relaxed constraints**	Native Fish: NF2–10 – Spawning (floodplain specialists); dispersal/condition (all species) Native Vegetation: NV2, 3, 4a–b – **Condition of RRG forests** (18% of total area Hume to Yarrawonga); **RRG woodlands** (d/s Yarrawonga) Ecosystem functions: EF1–7: **lateral connectivity with wetlands & low-lying floodplain forests** along Murray River, Barmah–Millewa, Koondrook–Perricoota, Gunbower, Werai & Niemur forests; **productivity**, nutrient & carbon transport; replenish groundwater Other species: OS1–3a – frog breeding	>30,000	Aug–Oct (or anytime for natural events)	21 days minimum cumulative duration^	3–4* years in 10 *(35%)*	5 years	^Can go below flow threshold for short periods (5 days) *more frequent & clustered event [in sequential years] would aid recovery of flood-dependant forests, woodlands & understory) Maximum rate of fall – 14% change in flow per day
	OB2[10] **Relies on relaxed constraints**	Native Fish: NF2–10 – dispersal/condition (all species) Native Vegetation: NV2–3,4a–b – **Condition of RRG forest** (21% of total area Hume to Yarrawonga) & **RRG woodland** (15%) Ecosystem functions: EF1–7: lateral connectivity & productivity (as for OB5) Other species: OS1–4 – frog breeding	>35,000	Aug–Feb (or anytime)	12 days minimum cumulative duration^	3–4 years in 10 *(35%)*	5 years	^Can go below flow threshold for short periods (5 days maximum) Maximum rate of fall – 14% change in flow per day
Medium Overbank	OB3[11] **Natural event only**	Native fish: NF2–10 – dispersal/condition (all species) Native Vegetation: NV4a, b - **Condition of RRG forest** (44%), **RRG woodland** (48%) Ecosystem functions: EF1–7: lateral connectivity (71% of total wetland area) & productivity (as for OB5&6) Other species: OS1–4 – frog breeding	>45,000	Jul–Feb (or anytime)	6 days minimum^	3 years in 10 *(30%)*	5 years	^ Can go below flow threshold for short periods (5 days maximum) Maximum rate of fall – 14% change in flow per day

[8] Percent of wetland area inundated is based on analysis of Murray RIMFIM floodplain inundation model outputs and DPIE-compiled wetland and native vegetation spatial data.

[9] Aligns approximately with OB5 for the Murray River d/s Yarrawonga Weir

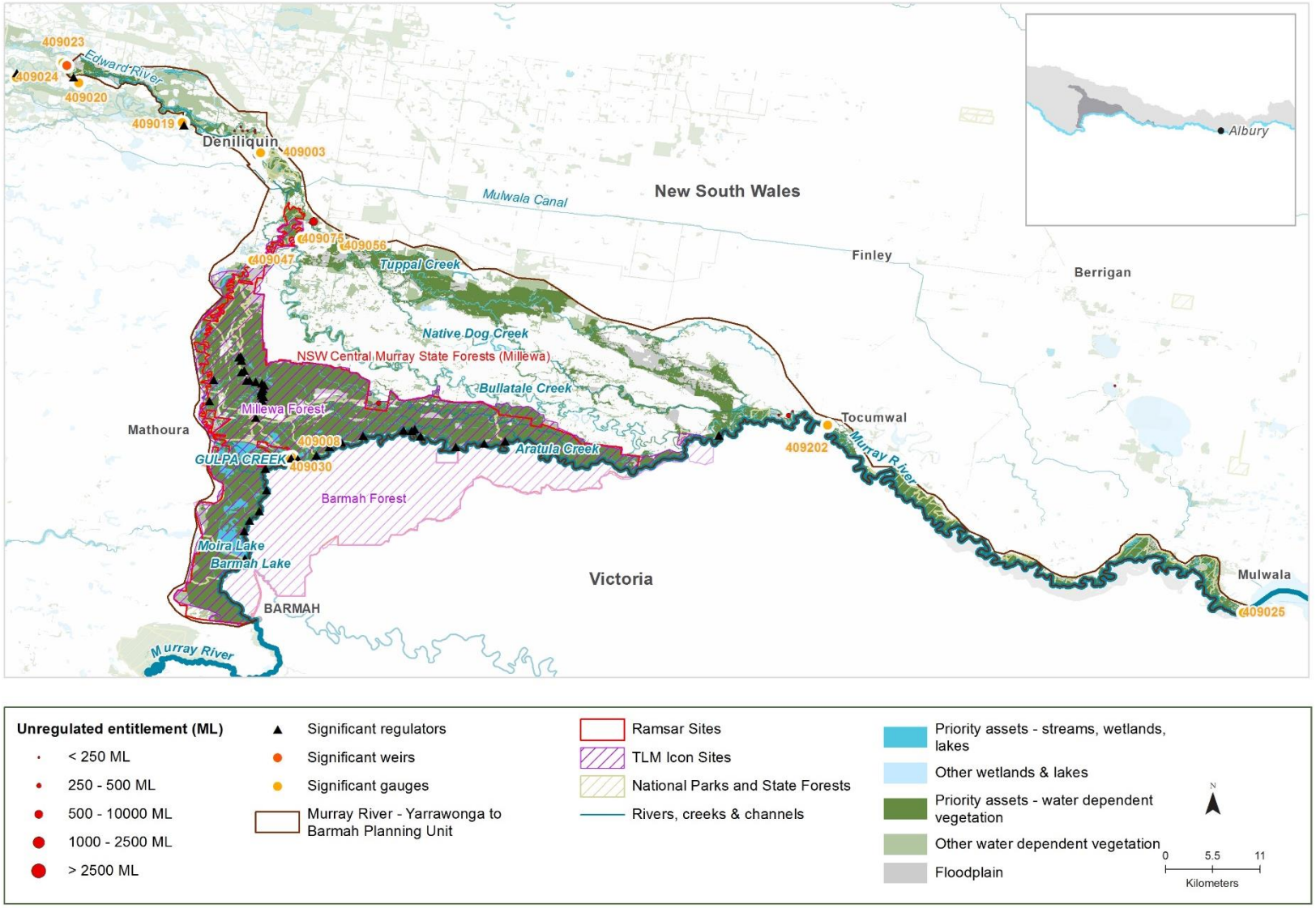
[10] Aligns approximately with OB6 for the Murray River d/s Yarrawonga Weir

[11] Aligns approximately with OB7 for the Murray River d/s Yarrawonga Weir

Flow Category & EWR code[6]		Ecological objective[6] (Primary objectives in bold)	Flow rate (ML/d)[6] Murray at Doctors Point	Timing[6]	Duration[6]	Frequency[6] *(& LTA[7] Frequency)*	Maximum inter-event period[6]	Additional watering requirements[6]
Large overbank	OB4[12] **Natural event only**	Native Vegetation: NV4a,b – **RRG forests** (77%) & **woodlands** (65%); **blackbox woodland condition** (~50% total area Tocumwal to Swan Hill) Waterbirds: WB1–5 – **large scale colonial breeding** (downstream in Barmah–Millewa, Koondrook–Perricoota, Werai & Niemur forests); habitat Ecosystem functions: EF1–7: broad scale connectivity (89% of total wetland area Hume to Yarrawonga), **productivity**, biotic dispersal	>70,000	Anytime	4 days minimum^	2 years in 10 *(20%)*	7 years	^ Can go below flow threshold for short periods (5 days maximum) Maximum rate of fall – 15% change in flow per day

[12] Aligns approximately with OB9 for the Murray River at d/s Yarrawonga Weir

PU2: Murray River – Yarrawonga to Barmah



<table>
<tr><th colspan="6">Priority environmental assets</th></tr>
<tr><td colspan="2">Rivers/creeks & their associated in-stream habitats, fringing vegetation & floodplain wetlands:</td><td colspan="4">Wetlands, lakes & floodplain forests & their associated fringing & floodplain vegetation communities including (but not limited to):</td></tr>
<tr><td rowspan="2">• Murray River
• Edward River
• Gulpa Creek
• Tuppal Creek
• Taylors Creek
• Bullatale Creek
• Native Dog Creek
• Four Post Creek
• Aljoes Creek
• Dahwilly Creek</td><td colspan="2">Millewa forest creeks:</td><td colspan="2">Millewa forest lakes / wetlands:</td><td>Yarrawonga to upstream of Millewa forest wetlands:</td></tr>
<tr><td>• Aratula Creek
• Toupna Creek
• Little Toupna Creek
• Aluminy Creek
• Tootalong Creek
• Pinchgut Creek
• Cornalla Creek
• Middle Creek
• Towrong Creek
• Warrick Creek</td><td>• Wild Dog Creek
• Gerapna Creek
• Campbells Creek
• Stockyard Creek
• Little Edward Creek
• McCartneys Creek
• O’Shanassys Creek
• Swifts Creek
• Coolamon Creek
• Bunnydigger Creek
• Moira Creek</td><td>• Reed Beds Swamp
• Duck Lagoon
• Coppingers Swamp
• Saint Helena Swamp
• Black Swamp
• Moira Lake
• Sheldrakes Lake
• Caldwells Waterhole
• Douglas Swamp
• Deadwood Swamp
• Fishermans Lagoon
• Horseshoe Lagoon</td><td>• Duggans Lagoon
• Little Edward Lagoon
• Whites Swamp
• Duffys Lagoon
• Black Gate Lagoon
• Melvilles Waterhole
• Coonambidgal Lagoon 1&2
• Boomanoomana Wetland
• Nine-Panel LagoonPinchgut Lagoon</td><td>• Horseshoe Lagoon
• The Black Hole
• Bullanginya Lagoon
• Whites Lagoon
• Walkers Lagoon
• Grout Lagoon
• 8-Mile Lagoon</td></tr>
<tr><td>Native fish[13]</td><td colspan="5">• Australian smelt
• bony herring
• dwarf flathead gudgeon
• flat-headed gudgeon
• golden perch
• Murray crayfish
• Murray-Darling rainbowfish
• river blackfish
• short-headed lamprey
• southern pygmy perch
• trout cod
• unspecked hardyhead
• flathead galaxias (P)
• carp gudgeon
• silver perch
• Murray cod</td></tr>
<tr><td>Birds</td><td colspan="5">100 water-dependent bird species recorded, including the following listed[14] waterbird species:</td></tr>
</table>

[13] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

[14] Listed as Commonwealth or NSW threatened (Vulnerable, Endangered or Critically Endangered) or under international migratory bird agreements (JAMBA, CAMBA, ROKAMBA).

Priority environmental assets				
	• Australasian bittern (E) • Australian painted snipe (E) • blue-billed duck (V) • brolga (V)	• Caspian tern (J) • cattle egret (J) • common greenshank (C,J,K) • curlew sandpiper (E,CE,C,J,K)	• eastern great egret (J) • freckled duck (V) • Latham's snipe (J,K) • marsh sandpiper (C,J,K)	• red-necked stint (C,J,K) • sharp-tailed sandpiper (C,J,K) • whimbrel (C,J,K)
Native vegetation	24 water-dependent PCTs including: • non-woody wetland • nitre goosefoot floodplain	• lignum shrubland & wetland	• river red gum forest & woodland	• black box woodland
Other species	• common eastern froglet • eastern banjo frog • eastern sign-bearing froglet • barking marsh frog	• Sloane’s froglet (V) • Peron's tree frog • southern bell frog (E) • spotted marsh frog	• wrinkled toadlet • broad-shelled turtle • eastern snake-necked turtle • Macquarie turtle	• platypus • southern myotis (V) • yellow-bellied sheathtail-bat (V) • superb parrot (V)
Unregulated WALs	There is 2278 ML of unregulated entitlements in the PU, of which 2242 ML are unregulated water access licences (WALs) for production. There are 11 WALs for production of <250 ML, two between 250–500 ML, & one between 500–1000 ML. They are distributed throughout the PU, with a group of six licences located on the Murray River near Deniliquin.			

Table 3 Environmental watering requirements for the Murray River – Yarrawonga to Barmah
Representative gauge: Murray River d/s Yarrawonga Weir (409025)

Flow Category & EWR code[15]		Ecological objective[15] (Primary objectives in bold)	Flow rate[15] (ML/d) (Murray d/s Yarrawonga Weir)	Timing[15]	Duration[15]	Frequency[15] *(& LTA[16] Frequency)*	Maximum inter-event period[15]	Additional watering requirements[15]
Very low flows	VLF	Native Fish NF1 – survival & condition (all species) Ecosystem Functions (EF1, 2) – refuge habitat	>1800	All year	365 days minimum each year	Annual (100%)	89 days	Maximum rate of fall = 9% change in flow
Baseflows	BF1	Native Fish: NF1–9 – condition & movement (all species) Native Vegetation: NV1 – in-channel non-woody Ecosystem Functions: EF1, 2, 3, 4, 8 – longitudinal connectivity along Murray; refuge habitat	>4000	All year	278 days minimum (184 min days in very dry years)	Annual (100%)	130 days	Allow temporal variability in baseflows in response to inflows from upstream. Periods of low-flow (BF3) in the Murray River d/s Yarrawonga Weir are essential to provide a drying phase for river banks, wetlands & riparian areas. Maximum daily rate of fall = 9% change in flow per day
	BF2 *Winter baseflow*	Native Fish: NF1–9 – condition & movement (all species) Native Vegetation: NV1 – in-channel non-woody Ecosystem Functions: EF1, 2, 3 – **longitudinal connectivity along Murray & Edward–Wakool system during irrigation system shutdown period**; refuge habitat	>4000*	Apr–Aug	128 days minimum in timing window (71 days min days in very dry years)	Annual (100%)	1 year	*Do not exceed 5000 ML/d for some of the time to achieve BF3 (drying phase). Maximum daily rate of fall = 9% change in flow per day
	BF3	Ecosystem Functions: EF2 – **Drying phase for Barmah–Millewa forest & Moira/Barmah Lakes**	< 5000 (i.e. do not exceed 5000 ML/d) (<4500 ML/d for Barmah Lake^)	Anytime#	60 days minimum (up to 4 months)	6–10 years in 10 (80%)	2 years	# Ideally in summer but most likely feasible in Apr–Jul outside irrigation season.
Nesting support	NestS1	Native Fish NF5, 6 – **Nesting of riverine specialists – e.g. Murray cod & trout cod** (protect nesting sites by avoiding rapid changes in water levels)	If flows are 4000–12,000 ML/d at 15 Sep, apply EWR requirements	15 Sep – 15 Nov	60 days minimum	5–10 years in 10 (75%)	2 years	If flows are in this range during 15 Sep – 15 Nov, provide variable flows but avoid large sudden decreases in water level & flow to prevent loss of nesting sites. Maximum daily rate of fall = 6% change in flow per day
Small fresh	SF1	Native Fish: NF1–9 – **Dispersal/condition (all species)** Native Vegetation: NV1 – in-channel non-woody Ecosystem Functions: EF1–7 – Variable in-channel habitat; water quality; transport of nutrients, sediment & carbon; small-scale productivity	>7000	Oct–Apr (or anytime)	10 days minimum	Annual (100%) (Ideally 2 events per year)	1 year	Maximum rate of fall of 6% during Murray cod/trout cod nesting season (15Sep–15Nov) – (see Nesting Flow NFF1), 9% at other times.
	SF2	Native Fish: NF1–4 – **Spawning (river specialist, generalist fish); recruitment/dispersal following spring breeding** (flow pulse specialists, riverine specialists & generalists); possible spawning of flow pulse specialists; Native vegetation: NV1 – in-channel non-woody Ecosystem Functions: EF1–7 – as for SF1	>7000	Sep–Dec	90 days minimum	5–10 years in 10 (75%)	2 years	Maximum rate of fall of 6% during Murray cod /trout cod nesting season (15 Sep–15 Nov) – (see Nesting Flow NFF1), 9% at other times
Large fresh	LF1	Native Fish: NF1–10 – **Dispersal/condition (all species); pre-spawning condition of flow pulse specialists**; dispersal of floodplain specialists Native Vegetation: NV1–3 – in-channel, wetland & fringing Ecosystem Functions: EF2–7 – Lateral connectivity with low-lying wetlands (14–21% of total wetland area Yarrawonga to Barmah), creeks & anabranches; hydraulic diversity; productivity & transport of nutrients, carbon & sediment.	>12000	Jul–Sep (or anytime)	5 days minimum	5–10 years in 10 (75%)	2 years	Maximum rate of fall of 6% during Murray cod /trout cod nesting season (15Sep–15Nov) for flows < 12,000 ML/d (see Nesting Flow NFF1), 9% at other times/flows

[15] See Glossary: Definitions and explanatory text for EWRs

[16] Long term average frequency (% of years)

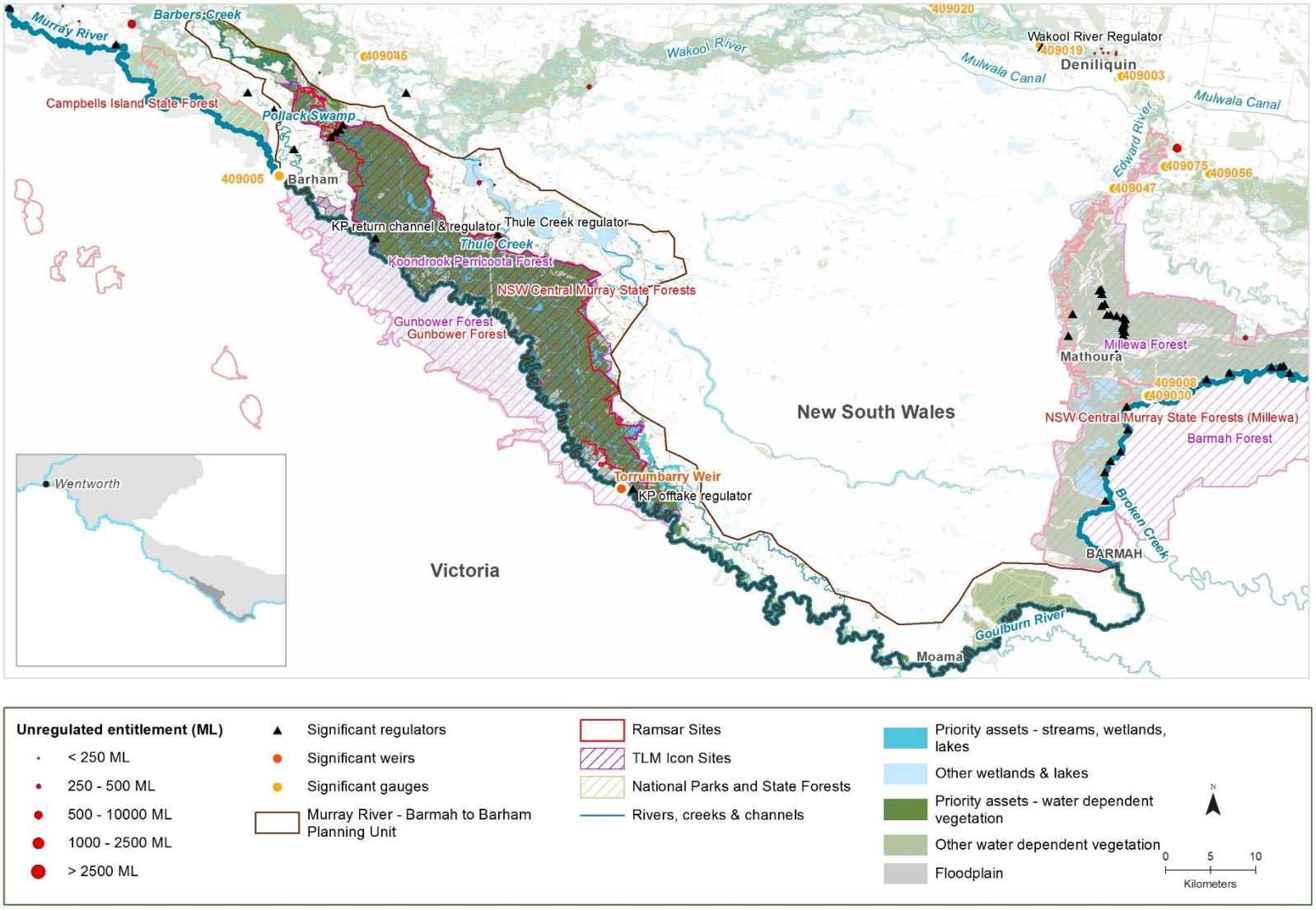
Flow Category & EWR code[15]		Ecological objective[15] (Primary objectives in bold)	Flow rate[15] (ML/d) (Murray d/s Yarrawonga Weir)	Timing[15]	Duration[15]	Frequency[15] *(& LTA[16] Frequency)*	Maximum inter-event period[15]	Additional watering requirements[15]
	LF2	Native Fish: NF1, 3, 4, 6, 7 – **Spawning of flow pulse specialists**; dispersal of floodplain specialists into/from low-lying wetlands Native Vegetation: NV1–3 – in-channel, wetland & fringing vegetation Ecosystem Functions: EF2–6 – as for LF1	>12000	Oct–Apr	10 days minimum	6–7 years in 10 (65%)	2 years	Requirements for spawning of flow pulse specialists: a) Rapid rise in flow (within natural rates of rise); b) water temperature >17^{0}C Maximum rate of fall of 6% during Murray cod /trout cod nesting season (15 Sep–15 Nov) – (see Nesting Support NS1), 9% at other times.
	LF3 **Large fresh for Yarrawonga to Tocumwal reach** **Relies on relaxed constraints**	Native Fish: NV3,7 – **Spawning (floodplain specialists, especially the critically endangered flathead galaxias)** Native vegetation: NV1–3 – in-channel, wetland non-woody, fringing Ecosystem Functions: EF1–7 – as for Large fresh 1&2 (23% wetlands area Yarrawonga to Tocumwal) Other species: OS2,3b – **Breeding of Sloane's froglet**	>18,000 (target 15,000–18,000 under current constraints) For Yarrawonga to Tocumwal reach	Aug[#] (July-Sep)	8 days minimum (for min 3 months wetland inundation)	7–8 in 10 years (75%)	2 years	# Required timing is Aug–Sep for flathead galaxias; Jul–Aug for Sloane's froglet (overlap month in Aug). Flathead galaxias are short-lived & need to breed every 1–2 years. In dry periods may need to deliver water to discrete wetlands via infrastructure to protect populations. Maximum rate of fall of 6% during Murray cod/trout cod nesting season (15 Sep–15 Nov) – (see Nesting Support NS1), 9% at other times
Bankfull	BK1	Native Fish: NF2–10: **condition/dispersal (all species)**, spawning (flow pulse specialists), spawning (floodplain specialists) Native vegetation: NV1,2,3,4a – **in-channel & wetland non-woody vegetation; fringing river red gum (RRG)** Waterbirds: WB1, 2, 5 – foraging habitat (Barmah–Millewa); potential waterbird breeding in St Helena/Black Swamp (Millewa). Ecosystem Functions: EF1–7 – **lateral connectivity with creeks, anabranches & low-lying wetlands/floodplains in Barmah–Millewa**; **productivity**; channel maintenance; transfer of nutrients, sediment & carbon transport; groundwater recharge Other species: OS1–3 – frog breeding	> 10,000 (10,000–12,000) For Tocumwal to Barmah reach	Aug–Nov (or anytime for natural events)	45 days minimum cumulative duration^	5–10 years in 10 (75%)	2 years	^Can go below flow threshold for short periods (7 days maximum at a time). Maximum rate of fall = 6–9% change in flow (6% during Murray Cod/trout cod nesting season (Sep–Nov) for flows <12,000 ML/d (see Nesting Support Flow NSF1), 9% at other times/flows). Keep all Barmah–Millewa regulators open to provide flow & connectivity into creeks. To maintain open marsh areas as waterbird breeding & foraging habitats, deliver event in late winter/spring/early summer & commence drying in early summer to avoid invasion by giant rush, which sets seed in autumn & is encouraged by summer flows. Provide exit cue for fish prior to recession by allowing river flows to fall sharply for a short period of time & then rise to the previous flow rate. If waterbird breeding occurs in Reed Beds/Duck Lagoon, extend inundation duration by another 1–4 months by delivering flows >500 ML/d from the Gulpa Creek Offtake Regulator). St Helena/Black Swamp will likely be inundated with flows from the Millewa creeks which may support waterbird breeding – can top up from Edward River via Opitz & Black Swamp regulators, however unlikely to get significant numbers of waterbirds at these flow rates. May need to support discrete wetlands & creeks (e.g. Toupna Creek, Warrick Creek, Horseshoe Lagoon, Fishermans Lagoon, Nine–Panel Lagoon) for floodplain specialist native fish during dry periods (breeding required every 1–2 years)
	BK2 **Relies on relaxed constraints**		> 29,000 (29,000-37,000) For Yarrawonga to Tocumwal reach		15 days minimum cumulative duration^		3 years	
Small overbank	OB1 **Dry scenario (also an interim EWR under current constraints)** **Only overbank in some areas**	Native fish: NF2–10 – **dispersal**, **pre-spawning condition** & **spawning/recruitment** (all species) Native Vegetation: NV1–3 – **in-channel, wetland & floodplain understory non-woody vegetation (including open plains In Barmah–Millewa); fringing river red gum condition**. Ecosystem functions (NF1–7): **productivity**, **longitudinal connectivity** along Murray & with Edward–Wakool system (freshes), **lateral connectivity** with wetland & low-lying areas of floodplain forests (Barmah–Millewa, Koondrook–Perricoota & Gunbower forests), **nutrient & carbon exchange & transport.** Other species: OS1–3a – frog breeding	>15,000 (ideally 18,000 ML/d)	Aug–Nov (or anytime for natural events)	45 days minimum cumulative duration^ (ideally 90–120 days)	6–10 years in 10 (75%)	2 years	

Flow Category & EWR code[15]		Ecological objective[15] (Primary objectives in bold)	Flow rate[15] (ML/d) (Murray d/s Yarrawonga Weir)	Timing[15]	Duration[15]	Frequency[15] *(& LTA[16] Frequency)*	Maximum inter-event period[15]	Additional watering requirements[15]
	OB2 **Only an overbank in some areas (Barmah–Millewa)**	Native fish: NF2–10 – dispersal, spawning & recruitment (all species) Native Vegetation: NV1–3 – in-channel, **wetland & floodplain understory non-woody vegetation**; fringing RRG condition. Waterbirds: WB1–5: **initiate & support small-scale colonial waterbird breeding events (Barmah–Millewa);** Ecosystem functions (NF1–7): lateral connectivity with wetland & low-lying areas of floodplain forests (Barmah–Millewa, Koondrook–Perricoota & Gunbower forests), **productivity**, nutrient & carbon transport.Other species: OS1–3a – frog breeding	>15,000 for 45 days minimum cumulative duration followed by >9,000 for 105 days minimum cumulative duration	Sep–Nov (or anytime for natural events) *Event can run until March depending on start of waterbird breeding*	45 days minimum >15,000 ML/d followed by 105 days minimum > 9000 ML/d (& 500 ML/d in Gulpa Creek) *for a total 5 months minimum cumulative duration to support waterbird breeding to completion*	4–8 years in 10 (60%)	2 years	^Can go below flow threshold for short periods (7 days maximum at a time). 5 months of habitat inundation is required for successful waterbird breeding to fledging 45 days minimum @ >15000 ML/d, then can drop to 9000 ML/d d/s Yarrawonga Weir & >500 ML/d at the Gulpa Creek Offtake for 3 months minimum (Dec–Feb/Mar) to ensure water levels are maintained in rookeries for 4–5 months in total. Four months of river flows is required as Barmah–Millewa forest is a shedding floodplain & does not retain water for long once river flows recede below commence-to-flow thresholds of inflow points.Critical to deliver larger/longer duration flows (OB3 & higher) to manage river red gum encroachment in open Moira grass plains. Maximum rate of fall of 6% during Murray cod/trout cod nesting season (15 Sep–15 Nov) for flows < 12,000 ML/d (see Nesting Support NS1), 9% at other times/flows.
Small overbank	OB3 **Relies on relaxed constraints** (not overbank Yarrawonga – Tocumwal)	Native fish: NF2–10 – Spawning (floodplain specialists) dispersal & recruitment (all species) Native Vegetation: NV1–3 – **wetland non-woody vegetation (including Moira grass plains in Millewa forest**), **control of river red gum (RRG) encroachment onto Moira Grass plains;** RRG forest condition (50% total extent in Barmah–Millewa). Waterbirds WB1–5: **Support small-scale colonial waterbird breeding in Barmah–Millewa forests & along Niemur River** Ecosystem Functions: EF1–7 – **productivity**, lateral connectivity with wetland & low-lying areas of floodplain forests (Barmah–Millewa, Werai & Niemur forests) Other species: OS1–3a – frog breeding	>25,000 for 21 days minimum cumulative duration^ & (before or after) >15,000 for 90 days minimum cumulative duration^	Aug–Nov (or Aug–Jan for natural events)	21 days minimum (>25,000 ML/d) & (before or after) 90 days minimum cumulative duration^ (>15,000 ML/d) *for a total 3.5 months minimum cumulative duration of flow (for 4–5 months minimum inundation of Moira grass*)	6–10 years in 10 (70%)	3 years (ideally not more than 2 years to maintain vigour & cover of non-woody vegetation)	^Can go below flow threshold for short periods (7 days maximum at a time). Maximum rate of fall of 6% during Murray cod /trout cod nesting season (15 Sep–15 Nov) for flows < 12,000 ML/d (see Nesting Support NS1), 9% at other times/flows. Consider closing Moira Creek regulator to hold water on Moira grass plains surrounding Moira Lake for sufficient duration for Moira grass germination & seeding (the remaining areas of Moira grass plain in Millewa forest occurs around the Sheldrakes Lake, Moira Lake & Algeboia areas). Although Moira grass plains are inundated at >10,000–15,000 ML/d the inundation depth over Moira grass plains at 15,000 ML/d is only ~30–50cm, 25,000 ML/d is required to achieve sufficient depth of inundation to support growth of thick growth of Moira grass (which are more likely to persist) & to control river red gum encroachment by drowning out RRG seedlings). Critical to start overbank events by early Sep to flush organic matter & transport carbon into the rivers during the cooler months to reduce the risk of hypoxic blackwater. An annual dry period of 2–3 months from late summer to early autumn is needed for non-woody wetland vegetation to complete life cycles. Events may trigger waterbird breeding, so need to provide additional watering generally until the end of January.
Small Overbank	OB4 **Relies on relaxed constraints**	Native fish: NF2–10 – Dispersal (all species); Spawning (floodplain specialists) Native vegetation: NV2, 3, 4a,b,c – **non-woody wetland & understorey; recovery of RRG & black box** Ecosystem Functions: EF1–7 – **connectivity with the Edward–Wakool system including meeting large fresh & bankfull flow requirements in the Yallakool/Wakool, Edward River & Colligen/Niemur systems.** Other species: OS1–3a – frog breeding	>35,000	Aug–Nov (or anytime for natural events)	14 days minimum cumulative duration^	5–8 years in 10 (65%)	3 years (ideally not more than 2 years)	^Can go below flow threshold for short periods (7 days maximum). Meets large freshes in Yallakool/upper Wakool & large freshes & bankfull flows in the Edward River, Colligen Creek & Niemur River. Also maintain/improve the condition of RRG forests & RRG/BB woodlands & flood-dependant understorey in low-lying floodplain forests (degraded areas require successive events to support recovery) along the River Murray when

Flow Category & EWR code[15]		Ecological objective[15] (Primary objectives in bold)	Flow rate[15] (ML/d) (Murray d/s Yarrawonga Weir)	Timing[15]	Duration[15]	Frequency[15] *(& LTA[16] Frequency)*	Maximum inter-event period[15]	Additional watering requirements[15]
								delivered in conjunction with longer duration overbank flows (e.g. OB5)
	OB5 **Relies on relaxed constraints**	Native Fish: NF2–10 – Spawning (floodplain specialists); dispersal/condition (all species) Native Vegetation: NV2, 3, 4a,4b – Condition of **river red gum (RRG) forests** (18% of total area Hume to Yarrawonga, 9% Yarrawonga to Tocumwal, 24% Tocumwal to Barmah, 60% in Barmah–Millewa); **RRG woodlands** (10–13% Hume to Barmah) Waterbirds: WB1–5 – colonial waterbird breeding#; habitat Ecosystem functions: EF1–7: **lateral connectivity with wetlands & low-lying floodplain forests** along River Murray, in Barmah–Millewa, Koondrook–Perricoota (KP) & Gunbower forests (Victoria), Campbell Island, Bengallow Creek, & Werai & Niemur forests; productivity, nutrient & carbon transport; replenish groundwater which RRG relies on during dryer times Other species: OS1–3a – frog breeding	>35,000	Aug–Oct (or anytime for natural events)	30 days minimum cumulative duration^	3–4 years in 10* (35%)	5 years	^Can go below flow threshold for short periods (7 days maximum) Preferable to start early Sep to flush organic matter & transport carbon, nutrients & micro–organisms into rivers & wetlands. # May trigger colonial waterbird breeding in key breeding sites in Millewa forest (Reed Beds, St Helena, Coppingers Swamp/Duck Lagoon), so may need to extend duration of flows to optimise breeding & recruitment success. *More frequent & clustered event in sequential years (e.g. together with OB3), would aid recovery of flood-dependant forests, woodlands & understory vegetation. Maximum rate of fall of 6% during Murray cod/trout cod nesting season (15 Sep–15 Nov) for flows < 12,000 ML/d (see Nesting Support Flow NSF1), 9% at other times/flows
	OB6 **Relies on relaxed constraints**	Native Fish: NF2–10 – dispersal/condition (all species), spawning (floodplain specialists) Native Vegetation: NV2, 3, 4a,4b – **Condition of river red gum (RRG) forest** (21% of total area Hume to Yarrawonga, 13% Yarrawonga to Tocumwal, 35% Tocumwal to Barmah) & **RRG woodland** (12–15% Hume to Barmah) Waterbirds: WB1–5 – large scale colonial breeding#; habitat Ecosystem functions: EF1–7: **productivity**, **nutrient & carbon transport**, biotic dispersal, connectivity with Edward–Wakool system (small overbank (OB1) in Werai & Niemur forests). Other species: OS1–4 – frog breeding	>40,000	Aug–Feb (or anytime)	21 days minimum cumulative duration^~ (ideally >30 days)	3–4 years in 10 (35%)	5 years	^Can go below flow threshold for short periods (7 days maximum) ~ If colonial waterbird breeding, maintain water levels in nesting sites where possible to ensure breeding & recruitment success. Maximum rate of fall of 6% during Murray cod/trout cod nesting season (15 Sep–15 Nov) for flows < 12,000 ML/d (see Nesting Support Flow NSF1), 10% at other times/flows.
Medium Overbank	OB7 **Natural event only**	Native fish: NF2–10 – dispersal/condition (all species) Native Vegetation: NV2, 3, 4a,4b **Condition of river red gum (RRG) forest** *(45% Tocumwal to Barmah, 30% Yarrawonga to Tocumwal, 80% Barmah–Millewa)***, RRG woodland** *(13% Yarrawonga to Tocumwal)*; Blackbox *(1% Tocumwal–Barmah)* Waterbirds: WB1–5 – large scale colonial breeding#; habitat Ecosystem functions: EF1–7: **productivity**, biotic dispersal Other species: OS1–4 – frog breeding	>50,000	Jul–Feb (or anytime)	14 days minimum cumulative duration^~ (ideally >21 days)	3 years in 10 (30%)	5 years	^ Can go below flow threshold for short periods (7 days maximum). ~ If colonial waterbird breeding, maintain water levels in breeding sites where possible to ensure nesting & recruitment success. # Assumes duration is extended at lower overbank flow thresholds to support completion of waterbird breeding (with a minimum duration of habitat inundation of 5 months) Maximum rate of fall = 9% change in flow per day.
	OB8 **Natural event only**	Native fish: NF2–10 – dispersal/condition (all species) Native Vegetation: NV2, 3, 4a, 4b, 4c – **River red gum (RRG) woodland** *(48% Hume to Yarrawonga, 21% Tocumwal–Barmah)* & **RRG forest** *(55% Hume – Barmah)*, lignum condition (small area), **blackbox** *(3% Tocumwal to Barmah, 30% Torrumbarry to Swan Hill).* Waterbirds: WB1–5 – large scale colonial breeding#; habitat Ecosystem functions: EF1–7: **productivity**, biotic dispersal, large scale connectivity.	>60,000	Jul–Feb (or anytime)	10 days minimum cumulative duration^~	2–3 years in 10 (25%)	5 years	

Flow Category & EWR code[15]		Ecological objective[15] (Primary objectives in bold)	Flow rate[15] (ML/d) (Murray d/s Yarrawonga Weir)	Timing[15]	Duration[15]	Frequency[15] *(& LTA[16] Frequency)*	Maximum inter-event period[15]	Additional watering requirements[15]
Large overbank	OB9 **Natural event only**	Native Vegetation: Blackbox woodland condition (34–46%) (*34% of total extent Tocumwal to Barmah & 42–46% Torrumbarry to Swan Hill*); River red gum (RRG) forests (70–76%) & RRG woodlands *(47% Tocumwal to Barmah)* Waterbirds: WB1–5 – large scale colonial breeding[#]; habitat Ecosystem functions: EF1–7: productivity, biotic dispersal, large scale connectivity	>80,000	Anytime	8 days minimum cumulative duration	2 years in 10 (20%)	7 years	
	OB10 **Natural event only**	Native Vegetation: Black box woodland condition (62% Tocumwal to Barmah); RRG forests *(79% Hume to Barmah)* & RRG woodlands *(63–70% Hume to Barmah)* Waterbirds: WB1–5 – large scale colonial breeding[#]; habitat Ecosystem functions: EF1–7: productivity, biotic dispersal, large scale connectivity	>100,000	Anytime	3 days minimum cumulative duration	1-2 years in 10 (15%)	10 years	

PU3: Murray River – Barmah to Barham



Priority environmental assets

Rivers, creeks, lakes, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):

- Murray River
- Thule Creek
- Thule Lagoon
- Thule Swamp
- Barbers Creek
- Black box Lagoon
- Eagle Creek (upstream reaches)
- Merangatuk Creek
- Several Private Property Wetland Watering sites in the Murray Irrigation Area

Koondrook–Perricoota state forest (also TLM icon site & Ramsar site)

- Crooked Creek
- Myloc Creek
- Bullock Head Creek
- Burrumbury Creek
- Barbers Creek
- Cow Creek
- Calf Creek
- Little Barbers Creek
- Swan Lagoon
- The Pollack (Pollack Swamp)
- Pollack Lagoon
- Allens Waterhole
- Clarkes lagoon
- Penny Royal Lagoon
- Belbins Waterhole
- Rusty Gate
- Twin Lagoon
- Moses Camp Lagoon
- Moorings Lagoon
- McMahons Creek
- Waterhole Trail
- The Rookery
- Smokehut Lagoon
- IU Rookery
- Long Lagoon
- Sandpit Trail

Native fish[17]

- Australian smelt
- bony herring
- carp gudgeon
- dwarf flathead gudgeon
- flat-headed gudgeon
- golden perch
- Murray crayfish
- Murray–Darling rainbowfish
- short-headed lamprey
- silver perch
- unspecked hardyhead
- freshwater catfish (eel-tailed catfish)
- flathead galaxias (P)
- Murray cod
- trout cod

[17] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

Priority environmental assets				
Birds	87 water-dependent bird species recorded, including the following listed[18] waterbird species:			
	• Australasian bittern (E) • blue-billed duck (V) • Latham's snipe (J,K)	• brolga (V) • Caspian tern (J)	• cattle egret (J) • common sandpiper (C,J) • freckled duck (V)	• eastern great egret (J)
Native vegetation	21 water-dependent PCTs, including:			
	• non-woody wetland • nitre goosefoot floodplain	• lignum shrubland & wetland	• river red gum forest & woodland	• black box woodland
Other species	• Bibron's toadlet • brown-striped frog • eastern banjo frog • common eastern froglet	• eastern sign-bearing froglet • barking marsh frog • Peron's tree frog • Sloane's froglet (V)	• southern bell frog (E) • spotted marsh frog • broad-shelled turtle • eastern snake-necked turtle	• Macquarie turtle • platypus • southern myotis (V) • yellow-bellied sheathtail-bat (V) • superb parrot (V)
Unregulated WALs	There is 533 ML of unregulated water access licences (WALs) for production in the PU. There are two WALs <250 ML and one between 250–500 ML. They are all located in Thule Swamp & Thule Creek.			

[18] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Table 4 **Environmental watering requirements for the Murray River – Barmah to Barham**
Representative gauge: Murray River at Torrumbarry (409207)

Flow Category & EWR code[19]		Ecological objective[19] (Primary objectives in bold)	Flow rate[19] (ML/d) (Murray at Torrumbarry)	Timing[19]	Duration[19]	Frequency[19] *(& LTA[20] Frequency)*	Maximum inter-event period[19]	Additional watering requirements[15]
Very low flows	VLF	Native Fish NF1 – survival & condition (all species) Ecosystem Functions (EF1, 2) – refuge habitat	>2000	All year	365 days minimum each year	Annual *(100%)*	75 days	Maximum rate of fall = 6% change in flow
Baseflows	BF1	Native Fish: NF1–9 – condition & movement (all species) Native Vegetation: NV1 – in-channel non-woody Ecosystem Functions: EF1, 2, 3, 4, 8 – longitudinal connectivity along Murray; refuge habitat	>4500	All year	307 days minimum (208 days min in very dry years)	Annual *(100%)*	113 days	Allow temporal variability in baseflows in response to inflows from upstream. Maximum daily rate of fall = 7% change in flow per day
	BF2 *Winter baseflow*	Native Fish: NF1–9 – condition & movement (all species) Native Vegetation: NV1 – in-channel non-woody Ecosystem Functions: EF1, 2, 3 – **longitudinal connectivity along Murray & Edward–Wakool system during irrigation system shutdown period**; refuge habitat	>4500	Apr–Aug	137 days minimum in timing window (78 days min in very dry years)	Annual *(100%)*	1 year	Maximum daily rate of fall = 7% change in flow per day
Nesting support	NestS1	Native Fish NF5, 6 – **Nesting of riverine specialists – e.g. Murray cod** (protect nesting sites by avoiding rapid changes in water levels)	If flows are 4500–12,000 ML/d at 1 Oct, apply EWR requirements	Oct–Nov	21 days minimum (starting 1 Oct)	5–10 years in 10 *(75%)*	2 years	If flows are in this range at 1 Oct or other observed start date of Murray cod nesting, provide variable flows but avoid large sudden decreases in water level to prevent loss of nesting sites. Maximum daily rate of fall = 4% change in flow per day
Small fresh	SF1	Native Fish: NF1–9 – **Dispersal/condition (all species)** Native Vegetation: NV1 – in-channel non-woody Ecosystem Functions: EF1–7 – Variable in-channel habitat; water quality; transport of nutrients, sediment & carbon; small-scale productivity	>7000	Oct–Apr (or anytime)	10 days minimum	Annual *(100%)* (Ideally 2 events per year)	1 year	Maximum rate of fall of 4% during Murray cod nesting season (Oct–Nov) – (see Nesting Flow NFF1), 6% at other times
	SF2	Native Fish: NF1–4 – **Spawning (river specialist, generalist fish); recruitment/dispersal following spring breeding** (flow pulse specialists, riverine specialists & generalists); possible spawning of flow pulse specialists; Native vegetation: NV1 – in-channel non-woody Ecosystem Functions: EF1–7 – as for SF1	>7000	Sep–Dec	90 days minimum	5–10 years in 10 *(75%)*	2 years	
Large fresh	LF1	Native Fish: NF1–10 – **Dispersal/condition (all species); pre-spawning condition of flow pulse specialists**; dispersal of floodplain specialists Native Vegetation: NV1–3 – in-channel, wetland & fringing Ecosystem Functions: EF2–7 – Lateral connectivity with low-lying wetlands, creeks & anabranches; hydraulic diversity; productivity & transport of nutrients, carbon & sediment.	>12000	Jul–Sep (or anytime)	5 days minimum	5–10 years in 10 (75%)	2 years	Maximum rate of fall = 6% (for flows >12,000 ML/d), 4% during Murray cod nesting season (Oct–Nov) for flows <12,000 ML/d – see Nesting Flow NFF1
	LF2	Native Fish: NF1, 3, 4, 6, 7 – **Spawning of flow pulse specialists**; dispersal of floodplain specialists into/from low-lying wetlands Native Vegetation: NV1–3 – in-channel, wetland & fringing vegetation Ecosystem Functions: EF2–6 – as for LF1	>12000	Oct–Apr	10 days minimum	6–7 years in 10 *(65%)*	2 years	Requirements for spawning of flow pulse specialists: a) Rapid rise (within natural rates of rise); b) water temperature >17^{0}C. Maximum rate of fall of 6% during Murray cod/trout cod nesting season (15 Sep–15 Nov) – (see Nesting Support Flow NSF1), 9% at other times.

[19] See Glossary: Definitions and explanatory text for EWRs.

[20] Long term average frequency (% of years).

Flow Category & EWR code[19]		Ecological objective[19] (Primary objectives in bold)	Flow rate[19] (ML/d) (Murray at Torrumbarry)	Timing[19]	Duration[19]	Frequency[19] *(& LTA[20] Frequency)*	Maximum inter-event period[19]	Additional watering requirements[15]
Bankfull	BK1	Native Fish: NF2–10: **condition/dispersal (all species)**, spawning (flow pulse specialists), spawning (floodplain specialists) Native vegetation: NV1,2,3,4a – **in-channel & wetland non-woody vegetation; fringing river red gum (RRG)** Waterbirds: WB1, 2, 5 – foraging habitat; potential waterbird breeding in Swan Lagoon & other open water/marshland areas in Koondrook–Perricoota forest. Ecosystem Functions: EF1–7 – **lateral connectivity with creeks, anabranches & low-lying wetlands/floodplains in Gunbower forest; Swan Lagoon & core wetlands in Koondrook–Perricoota (wetland refuges for floodplain specialist fish)**; **productivity**; channel maintenance; transfer of nutrients, sediment & carbon transport; groundwater recharge Other species: OS1–3 – frog breeding	>16,000 (16,000–25,000*) (or equivalent infrastructure assisted delivery) **For Gunbower Forest**	Aug–Nov (or anytime for natural events)	45 days minimum cumulative duration^	5–10 years in 10 *(75%)*	2 years	^Can go below flow threshold for short periods (7 days maximum at a time). Maximum rate of fall = 4–6% change in flow (4% during Murray Cod /trout cod nesting season (Sep–Nov) for flows <12,000 ML/d (see Nesting Flow NFF1), 6% at other times/flows). Provide exit cue for fish prior to recession. If waterbird breeding occurs, can extend inundation duration by another 1–4 months with infrastructure assisted delivery. May need to support discrete wetlands for floodplain specialists during dry periods (breeding required every 1–2 years). *For Gunbower Forest – there is a gradual increase in connection between the river & Gunbower Forest flood-runners between ~15,000 ML/d (estimate of lowest commence-to-flow) up to ~25,000 ML/d (considered fully connected).
	BK2 **Relies on relaxed constraints**		> 22,000 (or equivalent infrastructure assisted delivery) **For Koondrook–Perricoota forest**		30 days minimum cumulative duration^			
Small overbank	OB1[21] **Relies on relaxed constraints**	Native fish: NF2–10 – dispersal, spawning & recruitment (all species) Native Vegetation: NV1–3 – in-channel, **wetland & floodplain understory non-woody vegetation**; fringing river red gum condition. Waterbirds: WB1–5: **support waterbird foraging (& support breeding to completion if breeding is triggered by larger overbank events in Koondrook–Perricoota or Swan Lagoon)** Ecosystem functions (NF1–7): lateral connectivity with wetland & low-lying areas of floodplain forests (Koondrook–Perricoota & Gunbower forests), **productivity**, nutrient & carbon transport. Other species: OS1–3a – frog breeding	> 25,000 (or equivalent infrastructure assisted delivery to Koondrook–Perricoota)	Sep–Nov (or anytime for natural events) *Event can run until March depending on start of waterbird breeding*	60 days minimum cumulative duration^ (ideally 2-8 months habitat inundation in Koondrook-Perricoota)	5–8 years in 10 *(65%)*	3 years (ideally not more than 2 years to maintain vigour & cover of non-woody vegetation)	^Can go below flow threshold for short periods (7 days maximum at a time). Maximum rate of fall of 4% during Murray Cod nesting season (Oct–Nov) for flows <12,000 ML/d (see Nesting Flow NFF1); 7% at other times/flows. Water is typically retained for ~18 months in in-stream pools & wetlands in Koondrook–Perricoota. It takes 3 weeks for water to get from Swan Lagoon to the lower end of Koondrook state forest (where historical bird breeding sites are). May need to extend duration of flows if colonial waterbird breeding occurs. Koondrook–Perricoota & Gunbower forest infrastructure can be used to supplement unregulated or managed river flows (e.g. extend duration of inundation).
	OB2[22] **Relies on relaxed constraints**	Native Fish: NF2–10 – Spawning (floodplain specialists); dispersal/condition (all species) Native Vegetation: NV2, 3, 4a, 4b – Condition of **river red gum (RRG) forests** (34% in KP); **RRG woodlands** (32% in KP); **blackbox** (17%) Waterbirds: WB1–5 – colonial waterbird breeding#; habitat Ecosystem functions: EF1–7: **lateral connectivity with wetlands & low-lying floodplain forests** along River Murray, in Koondrook–Perricoota (KP) & Gunbower (Victoria) forests, Campbell Island, Bengallow Creek; **productivity**, nutrient & carbon transport; replenish groundwater which RRG relies on during dryer times Other species: OS1–3a – frog breeding	> 33,000 (or equivalent infrastructure assisted delivery to Koondrook–Perricoota)	Aug–Oct (or anytime for natural events)	60 days minimum cumulative duration^ (ideally 3-8 months habitat inundation in Koondrook-Perricoota)	3–4 years in 10* *(35%)*	6 years (ideally not more than 5 years)	^Can go below flow threshold for short periods (7 days maximum) Preferable to start by Sep to flush organic matter & transport carbon, nutrients & micro-organisms into rivers & wetlands. # May trigger colonial waterbird breeding in key breeding sites so may need to extend duration at lower flows or support with infrastructure. *More frequent & clustered event [in sequential years e.g. together with OB2), would aid recovery of flood-dependant forests, woodlands & understory vegetation). Maximum rate of fall of 4% during Murray cod nesting season (Oct–Nov) for flows < 12,000 ML/d (see Nesting Flow NFF1), 7% at other times/flows

[21] Aligns approximately with OB3/4 for the Murray River d/s Yarrawonga Weir depending on the magnitude and duration of inflows from the Goulburn River.

[22] Aligns approximately with OB5/6 for the Murray River d/s Yarrawonga Weir depending on the magnitude and duration of inflows from the Goulburn River.

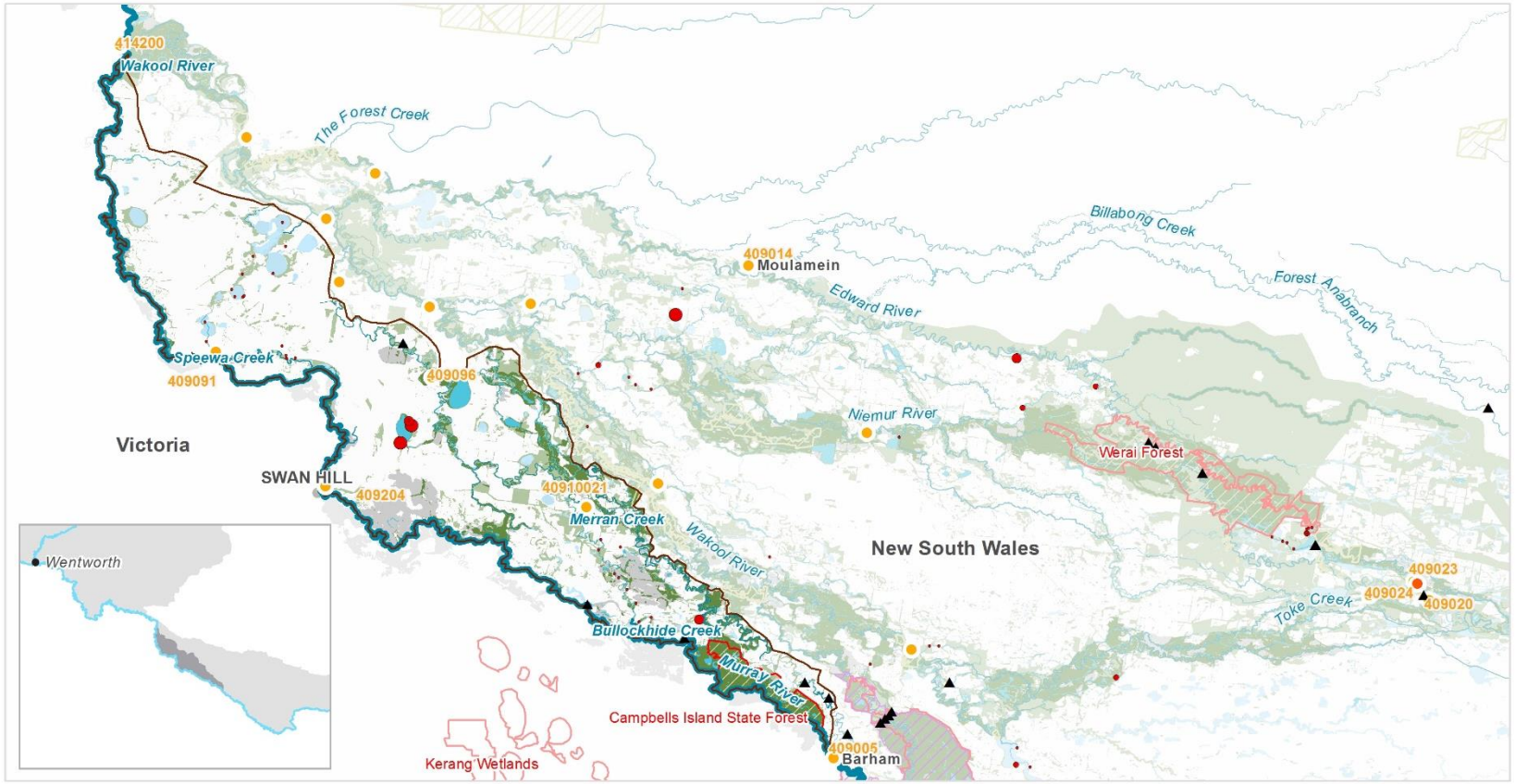
Flow Category & EWR code[19]		Ecological objective[19] (Primary objectives in bold)	Flow rate[19] (ML/d) (Murray at Torrumbarry)	Timing[19]	Duration[19]	Frequency[19] *(& LTA[20] Frequency)*	Maximum inter-event period[19]	Additional watering requirements[15]
Medium Overbank	OB3[23] **Natural event only**	Native fish: NF2–10 – dispersal/condition (all species) Native Vegetation: NV2,3,4a,4b **Condition of river red gum (RRG) forest, RRG woodland**; Blackbox (10–15% Torrumbarry to Swan Hill) Waterbirds: WB1–5 – large scale colonial breeding#; habitat Ecosystem functions: EF1–7: **productivity**, biotic dispersal Other species: OS1–4 – frog breeding	>40,000	Jul–Feb (or anytime)	21 days minimum cumulative duration^~	3 years in 10 (30%)	5 years	^ Can go below flow threshold for short periods (7 days maximum). ~ If colonial waterbird breeding, maintain water levels in breeding sites where possible to ensure breeding success. # Assumes duration is extended at lower overbank flow thresholds to support completion of waterbird breeding if required (with a minimum duration of habitat inundation of 5 months).
	OB4[24] **Natural event only**	Native fish: NF2–10 – dispersal/condition (all species) Native Vegetation: NV2, 3, 4a, 4b, 4c – **River red gum (RRG) woodland** & **RRG forest** (45–50% Torrumbarry – Swan Hill), lignum condition (limited area), **blackbox** (*30% Torrumbarry to Swan Hill)* Waterbirds: WB1–5 – large scale colonial breeding#; habitat Ecosystem functions: EF1–7: **productivity**, biotic dispersal, large scale connectivity.	>45,000	Jul–Feb (or anytime)	14 days minimum cumulative duration^~	2–4 years in 10 (30%)	5 years	
Large overbank	OB5[25] **Natural event only**	Native Vegetation: **Blackbox woodland condition** (*42–46% Torrumbarry to Swan Hill*); **River red gum (RRG) forests** (70–76%) & **RRG woodlands** Waterbirds: WB1–5 – **large scale colonial breeding#**; habitat Ecosystem functions: EF1–7: **productivity**, biotic dispersal, large scale connectivity	>55,000	Anytime	8 days minimum cumulative duration^~	2 years in 10 (20%)	7 years	Maximum rate of fall = 9% change in flow per day

[23] Aligns approximately with OB7/8 for the Murray River d/s Yarrawonga Weir depending on the magnitude and duration of inflows from the Goulburn River.

[24] Aligns approximately with OB8/9 for the Murray River d/s Yarrawonga Weir depending on the magnitude and duration of inflows from the Goulburn River.

[25] Aligns approximately with OB9/10 for the Murray River d/s Yarrawonga Weir depending on the magnitude and duration of inflows from the Goulburn River.

PU4: Murray River – Barham to Wakool Junction



Priority environmental assets				
Rivers, creeks, lakes, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):				
• Murray River • Speewa Creek • Merran Creek • Little Murray River • Campbells Island State Forest	• Bullockhide Creek • Eagle Creek • Coobool Creek • St Helen Creek • Larrys Creek	• Mulligans Creek • Tallys Lake • Tallys Swamp • Poon Boon Lakes (Lake Wollare, Talpile, Poomah, Poon Boon, Woromur, Genoe & Geer)	• Lake Coomaroon • Bingera Creek • Woodleigh Wetland • Gynong Wetlands • Brechin Wetlands	
Native fish[26]	• Australian smelt • bony herring • dwarf flathead gudgeon	• flat-headed gudgeon • freshwater catfish (eel-tailed catfish) • Murray cod	• Murray–Darling rainbowfish • silver perch • southern pygmy perch • unspecked hardyhead	• flathead galaxias (P) • carp gudgeon • golden perch • trout cod
Birds	96 water-dependent bird species recorded, including the following listed[27] waterbird species:			
	• Australian painted snipe (E) • black-tailed godwit (V,C,J,K) • blue-billed duck (V) • Caspian tern (J)	• cattle egret (J) • common greenshank (C,J,K) • curlew sandpiper (CE,C,J,K) • eastern great egret (J)	• Latham's snipe (J,K) • magpie goose (V) • marsh sandpiper (C,J,K)	• red-necked stint (C,J,K) • sharp-tailed sandpiper (C,J,K) • white-winged black tern (C,J)
Native vegetation	21 water-dependent PCTs, including:			
	• non-woody wetland	• lignum shrubland & wetland	• river red gum forest & woodland	• black box woodland
Other species	• Bibron's toadlet • barking marsh frog • common eastern froglet • eastern banjo frog	• eastern sign-bearing froglet • Peron's tree frog • southern bell frog (E)	• spotted marsh frog • broad-shelled turtle • eastern snake-necked turtle	• Macquarie turtle • platypus • southern myotis (V) • little pied bat (V) • regent parrot (E)
Unregulated WALs	There is 18,741 ML of unregulated entitlements in the PU, of which 18,446 ML are unregulated water access licences (WALs) for production. There are 25 production WALs <250 ML, one between 500–1000 ML, three between 1000–2500 ML, & one >2500 ML			

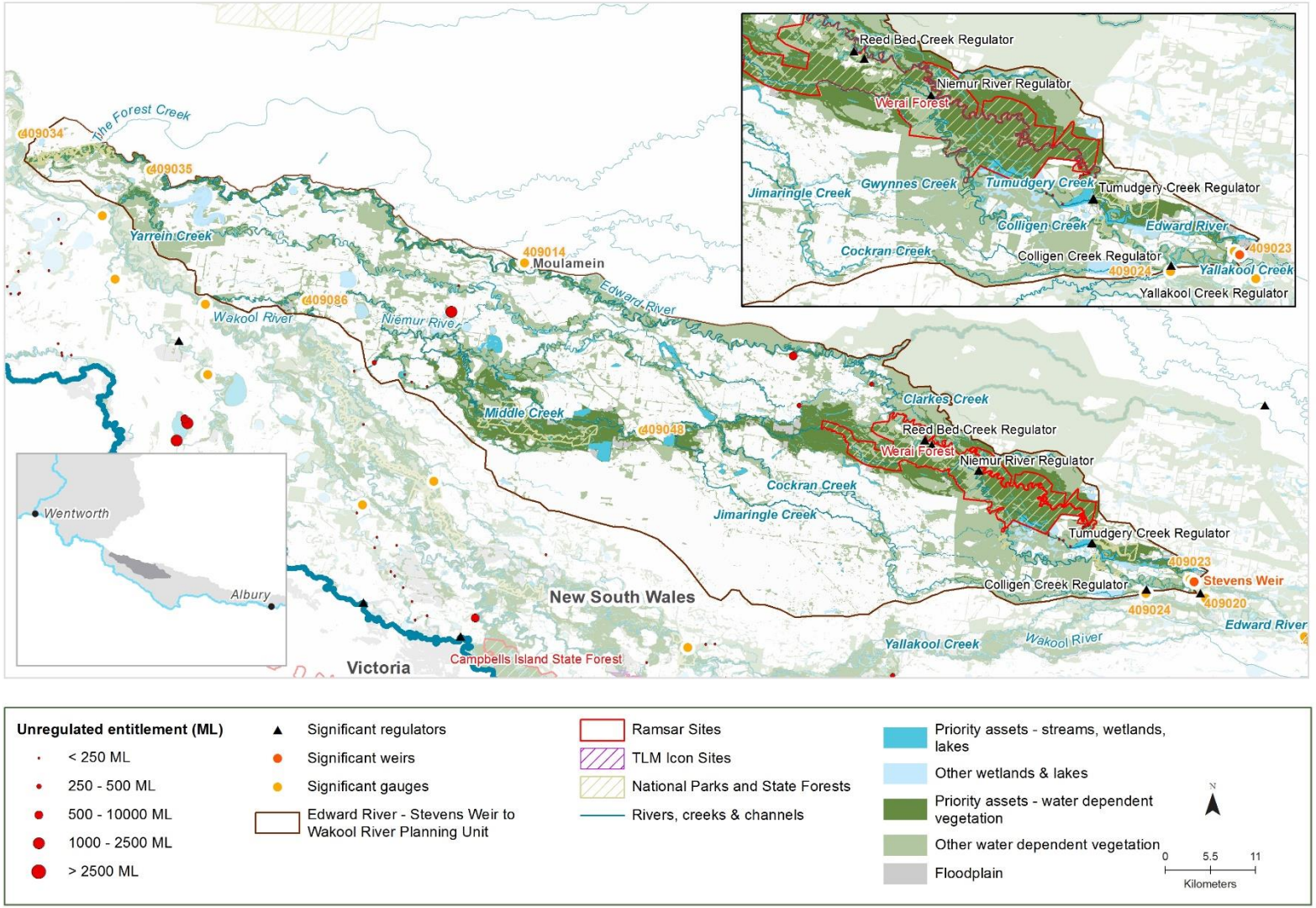
[26] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

[27] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Priority environmental assets	
	(12,965 ML). They are distributed along Bullockhide Creek, Murray Downs Lake, Speewa Creek & in multiple lakes in the bottom half of the PU that fill from the Murray River.
Environmental Water Requirements	See EWRs for Murray River at Torrumbarry in Table 4 (PU 3).

2.4 Edward–Wakool water management area

PU5: Edward River – Stevens Weir to Wakool River



Priority environmental assets				
Rivers, creeks, lakes, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):				
• Edward River (Stevens Weir to Wakool River junction) • Colligen Creek • Jimaringle Creek • Cockrans Creek • Gwynnes Creek • Niemur River • Yarrein Creek • Murrain-Yarrein Creek • Little Yarrein Creek	• Werai Forest • Niemur Forest • Reed Beds Creek • Tumudgery Creek • Mary Kelly Creek • Barratta Creek • Mutton Gut Lagoon • Moonya Lagoon • Reed Beds Lagoon • Yadaballa Lagoon	• Water Rat Lagoon • Clarkes Creek • Cooyeo Creek • Jawbone Creek • Ooronong Creek • Niemur Anabranch Elimdale Wetland • Middle Creek • Papanue Creek • Gum Creek	• Mallen Mallen Creek • Horseshoe Lagoon • Murgha Lagoon • Sheepwash Lagoon • Agnes Swamp • Mores Lagoon • Several private property wetlands (MIL)	
Native fish[28]	• Australian smelt • bony herring • dwarf flathead gudgeon • freshwater catfish (eel-tailed catfish)	• flat-headed gudgeon • golden perch • Murray–Darling rainbowfish • Southern pygmy perch	• silver perch • trout cod • unspecked hardyhead	• flathead galaxias (P) • carp gudgeon • Murray cod
Birds	106 water-dependent bird species recorded, including the following listed[29] waterbird species:			
	• Australasian bittern (E) • bar-tailed godwit (V,C,J,K) • black-tailed godwit (V,C,J,K) • blue-billed duck (V) • brolga (V) • common greenshank (C,J,K) • common sandpiper (C,J)	• curlew sandpiper (E,CE,C,J,K) • eastern great egret (J) • freckled duck (V) • great knot (V,CE,C,J,K) • grey plover (C,J,K) • little stint (K)	• long-toed stint (C,J,K) • marsh sandpiper (C,J,K) • Pacific golden plover (C,J,K) • pectoral sandpiper (J,K) • red-necked stint (C,J,K) • red knot (C,J,K) • ruddy turnstone (C,J,K)	• ruff (C,J,K) • sharp-tailed sandpiper (C,J,K) • white-winged black tern (C,J) • wood sandpiper (C,J,K)

[28] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

[29] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Native vegetation	23 water-dependent PCTs, including: • non-woody wetland • nitre goosefoot floodplain	• lignum shrubland & wetland	• river red gum forest & woodland	• black box woodland
Other species	• common eastern froglet • spotted grass frog • eastern sign-bearing froglet	• eastern banjo frog • barking marsh frog • Peron's tree frog	• smooth toadlet • southern bell frog (E) • wrinkled toadlet	• Sudell's frog • eastern snake-necked turtle • southern myotis (V) • superb parrot (V)
Unregulated WALs	There is 4674 ML of unregulated entitlements in the PU, of which 4638 ML are unregulated water access licences (WALs) for production. There are 14 production WALs <250 ML, four between 250–500 ML, one between 500–1000 ML, & one between 1000–2500 ML. They are distributed throughout the PU.			

Aboriginal Cultural Values for Werai Forest (Wemba Wemba and Barapa Barapa Nations)[30]	
Culturally significant sites	Werai Forest, Edward (Kolety) River and other smaller streams (Tumudgery Creek, Reed Beds Creek) in the forest. • lagoons, waterbird rookeries, shallow depressions that fill during higher flows/floods and support wetland plants • burials, oven mounds, scarred trees, story sites and stone artefacts
Values	Water-dependant native vegetation • grasses and herbs (river mint, old man weed, flax lily etc) - traditional medicine and food resources • sedges – weaving baskets and bags • cumbungi and other reeds – food and weaving baskets and bags – (reeds are best green for ease of weaving) • river red gum – multiple uses All native fish species – food resource Other species – yabbies, turtles, frogs (used as fish bait), black swans, native bees Spring flows to allow traditional welcome dances for native fish, native bees & nesting species (emus, swans, turtles, ducks and brolgas)
Cultural watering objectives	• Maintain a healthy floodplain ecosystem • Increase species abundance and biodiversity • Improve abundance of cultural resources

[30] Based on DPIE-BC consultation with traditional owners of Werai Forest (Wemba Wemba and Barapa Barapa nations), from the Werai Land and Water Board of Management; and the Werai Water Management Plan (Webster and Nias 2018)

	• Develop business opportunities • Improve forest health through environmental water delivery • Mimic historical, natural flooding patterns and cycles • Maintain spiritual connections • Maintain spiritual and physical connection to country • Grow medicinal /cultural plants • Maintain and improve the ecology • Increase in native fish populations • Getting elders back on country • Enhance habitat • Maintain the ecological character (Ramsar) • Traditional Owners are involved in planning and managing watering events • Traditional Owner knowledge and science is considered in planning of watering events • Traditional Owners are involved operational monitoring of watering events: “to see where the water goes and go back to see where the pools are and know how much water is needed for next watering to push it further” (reference the quote) • Traditional Owners are involved in monitoring of plants and animals in Werai Forest following watering events Cultural heritage is protected during all works (e.g. erosion control works, upgrade/maintenance of regulators etc). Cultural heritage monitors are present during all such works. Cultural heritage monitors should be endorsed by the Wemba Wemba and Barapa Barapa nation traditional owners.
Priority actions for meeting Aboriginal cultural objectives[31]	• Develop a pathway for Aboriginal peoples’ involvement in watering event planning and monitoring • Improve capacity for Aboriginal peoples to engage in environmental water planning • Resolve constraints to high flows in the Murray and Edward-Wakool system to enable watering of Werai Forest • Resolve water accounting issues to allow water delivery into Werai forest • Remove block banks, log accumulations and levees that block flow through runners and into wetlands (e.g. Moonyah Lagoon) • Upgrade Werai Forest regulators to be fish and turtle friendly • Construct water control infrastructure to reinstate more appropriate drying regimes in three key wetlands (Mutton Gut complex and two wetlands in the Stevens Weir portion of Werai forest) • Agreements with other landholders that prevent pumping of environmental water from Tumudgery Creek

[31] See Werai Water Management Plan (Webster and Nias 2018) for more details.

Table 5 **Environmental watering requirements for the Edward River (Stevens Weir to Wakool River), Colligen Creek & Niemur River**
Representative gauges: Edward River d/s Stevens Weir (409023)[32], Edward River at Deniliquin (409003)[32], Colligen Creek below regulator (409024) and Niemur River at Barham–Moulamein Bridge (409048)

Flow Category & EWR code[33]		Ecological objective[33] (Primary objectives in bold)	Gauge	Flow rate[33] (ML/d)	Timing[33]	Duration[33]	Frequency3 3 *(& LTA[34] Frequency)*	Maximum inter-event period[33]	Additional watering requirements[33]
Cease-to-flow	CTF	Native Fish: NF1 – survival (all species) Ecosystem Functions (EF1, 2) – refuge habitat, drying regime ***CTF events not desired due to the highly modified nature of system & the presence of native fish populations***	Edward d/s Stevens Weir	N/A	Cease-to-flow not desired (occurred in less than 1% of years modelled without-development flow record)				When restarting flows from CTF or very low flows, avoid harmful water quality impacts such as de-oxygenated refuge pools.
			Colligen Creek	0	In line with historical low flow season: Dec–June	Events should not persist longer than 63 days	Should occur in no more than 9 years in 10	N/A	
			Niemur River	0		Events should not persist longer than 77 days			
Very low flow	VLF	Native Fish: NF1 – survival & condition (all species Ecosystem Functions (EF1, 2) – refuge habitat, drying regime	Edward d/s Stevens Weir	> 170	All year^	365 days each year	Annual *(100%)*	0	
			Colligen Creek	> 50		226 days minimum		107 days	^Currently can't be achieved for approx. 4–6 weeks during winter maintenance of Stevens Weir because weir pool is drawn down below offtake regulator CTFs. Meeting this flow rate during this time will rely on high flows in the Murray (approx. >18,000 ML/d)
Baseflows	BF1	Native Fish: NF1–9 – **condition & movement** Native Vegetation: NV1 – **in-channel non-woody** Ecosystem Functions: EF1, 2, 3, 4, 8 – longitudinal connectivity, refuge habitat	Edward d/s Stevens Weir	>300	All year^	321 days minimum (210 days min in very dry years)	Annual (100%)	48 days	
			Colligen Creek	>170		196 days minimum (76 days min in very dry years)		125 days	^ see note for VLF
			Niemur River	> 50		210 days minimum (100 days in very dry years)		121 days	
	BF2 Winter baseflow	Native Fish: NF1–9 – **condition & movement** Native Vegetation: NV1 – in-channel non-woody Ecosystem Functions: EF1, 2, 3, 4, 8 – longitudinal connectivity; **refuge habitat during irrigation shut-down period**	Edward d/s Stevens Weir	>600	May–Aug^	113 days minimum (59 days min in very dry years)	Annual (100%)	71 days	^Currently can't be achieved for approx. 4–6 weeks during winter maintenance of Stevens Weir because weir pool is drawn down below offtake regulator CTF. Meeting this flow rate during this time will rely on high flows in the Murray (> approx. 18,000 ML/d) For Niemur River – BF2 achievable with flows from Colligen Creek & via the Niemur offtake regulator on the Edward River, but during Stevens Weir winter maintenance, only via the Niemur offtake regulator. Current commence-to-flow threshold of the regulator is ~800 ML/d at Stevens, but this could be lowered to 600 ML/d by lowering the sill on the Niemur regulator – investment priority.
			Colligen Creek	>50		86 days minimum (22 days min in very dry years)		107 days	
			Niemur River	>50		75 days minimum (14 days in very dry years)		121 days	
	BF3	Native vegetation: NV1: in-channel non-woody	Edward d/s Stevens Weir	170 – 1000 (do not exceed)	Apr–Jul (although	60 days minimum	6–10 years in 10 (80%)	2 years	

[32] EWRs for the Edward River are described at the Edward River d/s Stevens Weir gauge for low to moderate flows (VLF-OB1), and at the Edward River at Deniliquin gauge for higher flows (>15,000 ML/d i.e. OB2 and higher). The Deniliquin gauge is unreliable at flows below ~15,000 ML/d due to backwater effects from Stevens Weir, and the d/s Stevens Weir gauge is unreliable at flows greater than 15,000 ML/d due to overbank flows at the gauge site.

[33] See Glossary: Definitions and explanatory text for EWRs

[34] Long term average frequency (% of years)

Flow Category & EWR code[33]		Ecological objective[33] (Primary objectives in bold)	Gauge	Flow rate[33] (ML/d)	Timing[33]	Duration[33]	Frequency33 *(& LTA[34] Frequency)*	Maximum inter-event period[33]	Additional watering requirements[33]
	Drying phase	Ecosystem Functions: EF2: **Drying phase for in-channel habitats (for vegetation outcomes)**	Colligen Creek	30 – 200 (do not exceed)	ideally in summer)				
Small freshes	SF1	Native Fish: NF1–9 – **Dispersal/condition (all species)** Native Vegetation: NV1 – in-channel & fringing Ecosystem Functions: EF1–7 – **Variable in-channel habitat;** improve WQ in pools, transport of nutrients, sediment & carbon	Edward d/s Stevens Weir	>1600	Oct–Apr (or anytime)	10 days minimum	Annual (100%) (Ideally 2 events per year*)	1 year	Coordinate with wider river Murray actions where possible to maximise benefit for native fish & ecosystem functions. *Delivery of summer pulse will support dispersal of native fish larvae & juveniles; autumn pulse is especially important if spawning detected in previous 6–8 months to support juvenile fish to survive first winter. # Suggested flow range to target
			Colligen Creek	>500					
			Niemur River	>800 (800–1500#)					
	SF2	Native Fish: NF1–6, 8–10 – **Spawning (river specialist, generalist fish),** possible spawning of flow pulse specialists Native vegetation: NV1,3 – **in-channel non-woody & fringing vegetation** Ecosystem Functions: EF1–7 – Variable in-channel habitat; transport of nutrients, sediment & carbon, productivity	Edward d/s Stevens Weir	> 1600	Sep–Dec	90 days minimum	5–10 years in 10 (75%)	2 years (3 years for Colligen Creek, but ideally 2 years maximum to promote native fish recovery)	Apply a slow recession to maximise in-channel non-woody vegetation outcomes. Coordinate with wider river Murray actions where possible to maximise benefit for native fish & ecosystem functions.
			Colligen Creek	>500					
			Niemur River	>800					
Large freshes	LF1	Native Fish: NF1–8 – **Dispersal/condition (all species); pre-spawning condition of flow pulse specialists**; dispersal of floodplain specialists into/from low-lying wetlands) Native Vegetation: NV1–3 – in-channel, wetland & fringing vegetation Ecosystem Functions: EF2–6 – hydrodynamic diversity; lateral connectivity with low-lying wetlands & creeks in Werai & Neimur forests; dispersal of biota; exchange of nutrients/carbon/sediment; groundwater recharge	Edward d/s Stevens Weir	>2600	Jul–Sep (or anytime)	5 days minimum	5–10 years in 10 (75%)	2 years	Consider opening Tumudgery & Reed Beds Creek regulators if connectivity of Werai forest creeks is desired e.g. for native vegetation in Werai & floodplain specialist fish dispersal/condition (e-water would need to pay use in creeks/forest but currently no metering). Note, regulators must be open at >2700 ML/d to avoid erosion issues around regulators.Coordinate with wider river Murray actions where possible to maximise benefit for native fish & ecosystem functions.
			Colligen Creek	>600					
			Niemur River	>1000					
	LF2	Native Fish: NF1, 3, 4, 6, 7 – **Spawning (flow pulse specialists)**; dispersal of floodplain specialists into/from low-lying wetlands, creeks & anabranches Native Vegetation: NV1–3 – in-channel/wetland (amphibious/herbaceous non-woody), & fringing vegetation Ecosystem Functions: EF2–6 – lateral connectivity with low-lying wetlands & possible connection with creeks in Werai & Neimur forests*; dispersal of biota; exchange of nutrients/carbon/sediment, GW recharge Other species: OS1,3a – frog refuge habitat	Edward d/s Stevens Weir	>2600	Oct–Apr	10 days minimum	6–10 years in 10 (80%)	2 years	
			Colligen Creek	>600					
			Niemur River	>1000					
Large freshes	LF3	Native Fish: NF2–9 – dispersal & condition (all species); spawning (floodplain specialists) Native vegetation: NV1–3: **in-channel & wetland vegetation** (including Werai forest creeks, wetlands & low-lying floodplain)	Edward d/s Stevens Weir	>3400	Aug–Mar (or anytime for natural events)	60 days minimum cumulative duration^	6–8 years in 10 (70%)	2 years	Open regulators on Tumudgery & Reed Bed creeks to allow flows into Werai forest. Provide exit cue for fish to return to main channels (small sharp drop in WL, raise, then slow recession) Slow recession to support non-woody vegetation colonisation & succession on river banks.

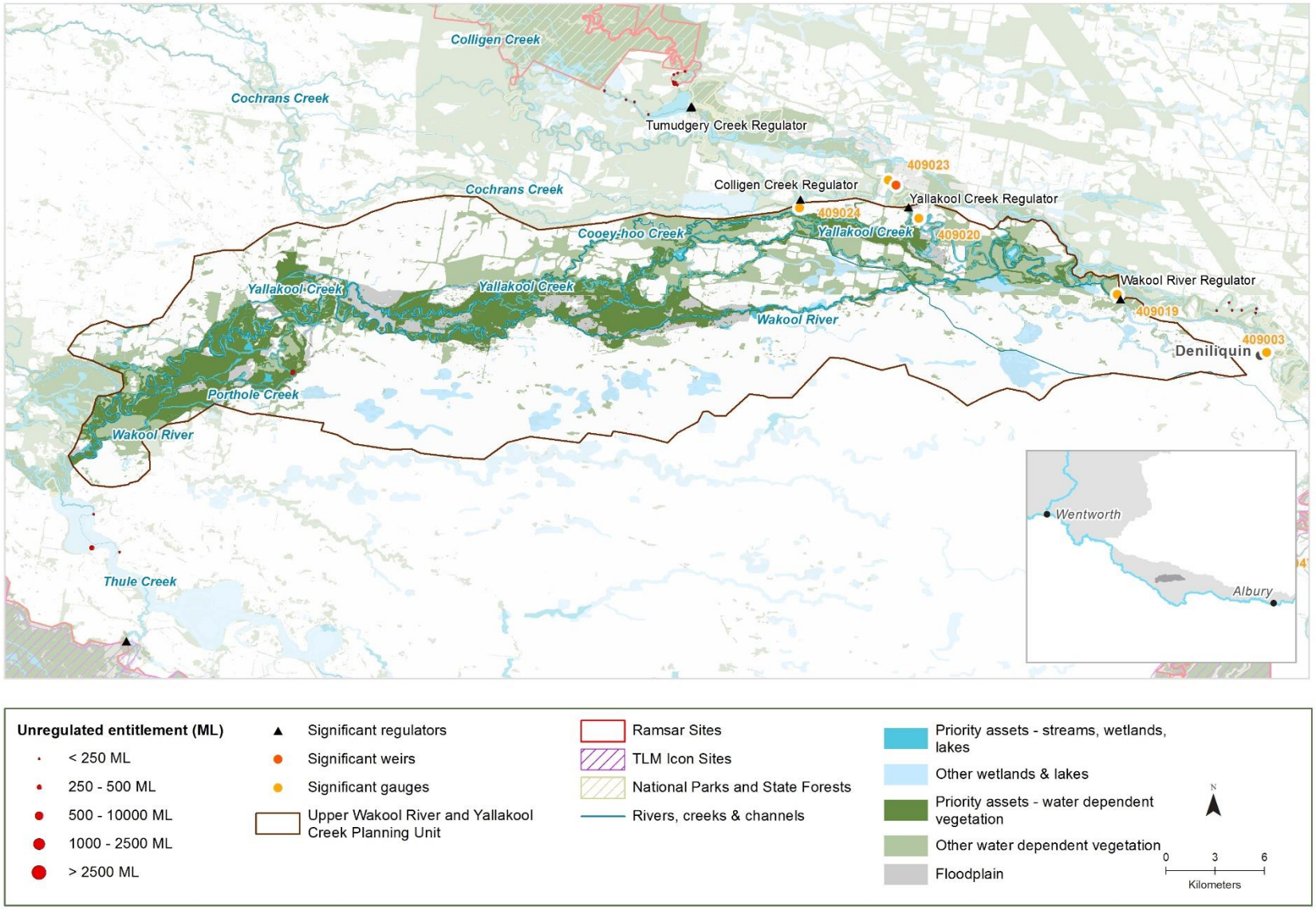
Flow Category & EWR code[33]		Ecological objective[33] (Primary objectives in bold)	Gauge	Flow rate[33] (ML/d)	Timing[33]	Duration[33]	Frequency33 *(& LTA[34] Frequency)*	Maximum inter-event period[33]	Additional watering requirements[33]
		Waterbirds: WB1–5 – maintain breeding & foraging habitat; **support naturally triggered colonial breeding events along Niemur River to completion** Ecosystem functions: EF1–6 – **lateral connectivity with eastern part of Werai Forest** including floodplain adjacent to Tumudgery & Reed Bed creeks; productivity; nutrient/carbon/sediment transfer Other species: OS1–3a – frog habitat & breeding, including SBF	Colligen Creek	>600					^ Can go below flow threshold for short periods (5 days maximum) 3400 ML/d at Stevens weir should meet 600 ML/d target in Colligen Creek & 1100 ML/d in Niemur River. All met by ~25,000 ML/d at d/s Yarrawonga Weir or delivery via Mulwala canal (see comment below). This EWR could be met fully by supplementing Edward River operational flows with delivery of ~1000-2000 ML/d to the Edward River via Edward escape. But noting this should only be done if 25,000 ML/day cannot be achieved in the Murray River d/s Yarrawonga Weir. Meeting this EWR should not replace Millewa forest watering, especially in Sep–Nov. Ideally the EWR would be met as part of a Murray multi-site event which includes overbank flows through Barmah–Millewa forest (>25,000 ML/d at d/s Yarrawonga Weir [OB3].
			Niemur River	>1100					
	LF4	Native Fish: NF2–9 – dispersal & condition (all species); spawning (floodplain specialists) Native vegetation: NV1–3 – **in-channel, wetland & floodplain vegetation** (including Werai forest creeks, wetlands & low-lying floodplain) Waterbirds: WB1–5 – maintain breeding & foraging habitat; **support naturally triggered colonial breeding events along Niemur River to completion** Ecosystem functions: **lateral connectivity with eastern part of Werai Forest** including floodplain adjacent to Tumudgery & Reed Bed creeks; productivity; nutrient/carbon/sediment transfer Other species: OS1–3a – frog habitat & breeding, including SBF	Edward d/s Stevens Weir	>3400	Aug–Mar (or anytime for natural events)	120 days minimum cumulative duration^	3–6 years in 10 (45%)	3 years	
			Colligen Creek	>600					
			Niemur River	>1100					
Bankfull flows	BKF Relies on relaxed constraints or natural events	Native fish: NF2–9 – Spawning (Floodplain specialists*); Dispersal & condition (all species) Native Vegetation: **in-channel & wetland non-woody vegetation, lignum, fringing RRG, low-lying RRG forest** Waterbirds: WB5 – maintain habitat Ecosystem functions: EF 2–7: **Lateral connectivity with creeks in Werai & Neimur forests & very small scale inundation of low-lying forests in Werai forest** Other species: OS1–3a – frog habitat & breeding, including SBF	Edward d/s Stevens Weir	>6000 (6000–8000)*	Aug–Nov (or anytime for natural events) (*Jul–Aug for flathead galaxias)	30 days minimum cumulative duration^ (ideally 60 days cumulative duration)	5–8 years in 10 (65%)	3 years	^ can go below flow threshold for short periods (5 days maximum) 6000–8000 ML/d should be achievable with Murray flows of 35,000–40,000 ML/d at d/s Yarrawonga Weir. **Approx. equivalent flows: Deniliquin: 9,000 – 14,000; Colligen Ck: 1100 – 1400 (LF); Niemur R: 2000 – 3000 (LF3/4,BKF)*
			Colligen Creek	>1600 *(1600–2500)**					1600 ML/d should be achieved with approximately 8000–9000 ML/d in Edward River at d/s Stevens Weir (approx. 40,000 ML/d d/s Yarrawonga Weir). **contributes to bankfull downstream but bankfull capacity of Colligen Creek itself is 3500–4000 ML/d)*
			Niemur River	>1600 *(1600-2500)** (ideally >2000 ML/d)					1600 ML/d should be achieved with approximately 5000–6000 ML/d in Edward d/s Stevens Weir (approx. 35,000 ML/d at Yarrawonga) **contributes to bankfull flows in some parts of the Niemur River & in anabranch creeks but bankfull capacity for most of the Niemur River is ~3000 ML/d)*

Flow Category & EWR code[33]		Ecological objective[33] (Primary objectives in bold)	Gauge	Flow rate[33] (ML/d)	Timing[33]	Duration[33]	Frequency33 *(& LTA[34] Frequency)*	Maximum inter-event period[33]	Additional watering requirements[33]
Small Overbank	OB1 Relies on relaxed constraints or natural events (only overbank in some areas)	Native fish: NF2–9 – Dispersal & condition (all species) Vegetation: NV2, 3, 4a,b – in-channel & wetland non-woody; fringing RRG; low-lying RRG & black box woodlands Waterbirds: WB1–5: Support colonial waterbird breeding in Niemur River colonies Ecosystem functions: EF 2–7 – **Small scale inundation of low-lying forests in Werai & Niemur forests, extensive lateral connectivity with creeks in Werai & Niemur forests** Other species: OS1–3a – frog habitat & breeding, including SBF	Edward d/s Stevens Weir	> 8000*	Aug–Nov (or anytime for natural events)	30 days minimum cumulative duration^ (ideally 60 days minimum cumulative duration)	3–4 years in 10 (35%)	3 years	^ can go below flow threshold for short periods (5 days maximum) 8000–9000 ML/d at Stevens Weir requires approx. 40,000 ML/d d/s Yarrawonga Weir. ^extend duration at lower flows >3400 ML/d (LF3) at D/S Stevens Weir to support colonial waterbird breeding if triggered by this or larger flows. **Approx. equivalent flows: Deniliquin >14,000; Colligen Ck > 1400 (Large fresh); Niemur R >3000 (OB1)*
			Colligen Creek	> 4000					4000 ML/d requires approx. 100,000ML/d d/s Yarrawonga Weir (OB10) and 32,000 ML/d at Deniliquin.
			Niemur River	>3000					3000 ML/d requires approx. 40,000 ML/d d/s Yarrawonga Weir and 8000–9000 ML/d d/s Stevens Weir. Also possible to supplement Murray flows with input from Edward Escape if Barmah–Millewa forest watering is not desired (but see comments under LF3). May inundate small areas of cropping land along the Niemur River.
Small Overbank	OB2 Natural events only (only overbank in some areas)	Native fish: NF2–9 **–** dispersal and condition (all species) Native vegetation: NV2, 3, 4a, b, c – **condition of low-lying RRG forests** (9–25% total area), **RRG woodlands** (4–19%) **and black box** (2–17%) Waterbirds: WB1–5 – habitat, colonial waterbird breeding Ecosystem functions: EF 2–7 **– small-medium scale lateral connectivity with wetlands and creeks (11–42%) and low-lying areas in Werai and Niemur forests.** Other species: OS1–3a – frog habitat and breeding, including SBF	Edward d/s Stevens Weir	>11,000*	Aug–Nov (or anytime for natural events)	28 days minimum cumulative duration^	3–4 years in 10 (35%)	5 years	^ can go below flow threshold for short periods (5 days maximum) ~extend duration at lower flows >3400 ML/d (LF3) at d/s Stevens Weir to support colonial waterbird breeding along Niemur River if triggered 11,000 ML/d d/s Stevens Weir requires approx. 50,000 ML/d d/s Yarrawonga Weir (OB6) & will result in approx. 4500 ML/d in the Niemur River at Barham/Moulamein Rd **Approx. equivalent flows: Edward R @ Deniliquin >18,000; Colligen Ck > 2300 (LF/BKF); Niemur R > 4500 (OB1)*
			Colligen Creek	> 5100					5100 ML/d requires approx. 115,000 ML/d d/s Yarrawonga Weir (25,000 ML/d at d/s Stevens Weir (40,000 ML/d @ Deniliquin & 115,000 ML/d d/s Yarrawonga Weir).
			Niemur River	> 7000					7000 ML/d requires approx. 80,000 ML/d at Yarrawonga (OB7), 28,000 ML/d at Deniliquin
Medium overbank	OB3 Natural events only	Native vegetation: NV4a, b, c – **Condition of RRG forests** (37-63% total area), **RRG woodland** (10-28%) **condition; low-lying black box** (10–29%) & lignum (4–18%) Waterbirds: OB1–5 – colonial waterbird breeding Ecosystem functions: EF2–7 – **lateral connectivity with wetlands & creeks** (17–63%), & **low-lying floodplain in Werai & Niemur forests**, & more broadly along the Edward	Edward River at Deniliquin[35]	> 28,000*	Anytime	10 days minimum cumulative duration^	3–4 years in 10 (35%)	5 years	^ can go below flow threshold for short periods (5 days maximum) 28,000 ML/d at Deniliquin met by ~70,000 ML/d d/s Yarrawonga Weir; & provides approx. 7000-17,000 ML/d in the Niemur River ^ extend duration at lower flows >3400 ML/d (LF3) at d/s Stevens Weir to support colonial waterbird breeding along Niemur River if triggered by natural event

[35] The Edward River at Deniliquin (409003) gauge is used as the representative gauge for the Edward River instead of the d/s Stevens Weir gauge (409023) for high flows of >15,000 ML/d (at Deniliquin) as the rating curve for d/s Stevens Weir gauge ends at ~15,000 ML/d due to overbank flows at the gauge site. Note, the Deniliquin gauge is not suitable at low to moderate flows due to a backwater effect from Stevens Weir.

Flow Category & EWR code[33]		Ecological objective[33] (Primary objectives in bold)	Gauge	Flow rate[33] (ML/d)	Timing[33]	Duration[33]	Frequency33 *(& LTA[34] Frequency)*	Maximum inter-event period[33]	Additional watering requirements[33]
		River, Colligen Creek & ephemeral streams; biotic dispersal; nutrient & carbon transport: productivity Other species: OS1–3a – frog habitat & breeding, including SBF							* *Approx. equivalent flows: Edward d/s Stevens Weir > 17,000; Colligen Ck > 3500 (OB1)* *Niemur R > 7000 (OB2)*
			Niemur River	>15,000					15,000 ML/d in Niemur River requires 28,000 - 53,000 ML/d in Edward River @ Deniliquin (OB3/4)
Large overbank	OB4 Natural events only	Native vegetation: NV4a, b, c **– Condition of black box woodlands** (29–93%), **lignum shrublands** (48–93%), & higher elevation RRG forests (37–97%) & RRG woodlands (26–96%) Waterbirds: OB1–5 – colonial waterbird breeding Ecosystem functions: EF2–7 – **broad scale lateral connectivity with wetlands & creeks** (65–97%), **low-lying floodplain in Werai & Niemur forests,** & more broadly along the Edward River, Colligen Creek & ephemeral streams; biotic dispersal; nutrient & carbon transport: productivity Other species: OS1–3a – frog habitat & breeding, including SBF	Edward River at Deniliquin[35]	>53,000*	Anytime	7 days minimum cumulative duration^#	1–2 years in 10 (15%)	10 years	53,000 ML/d requires approx. 150,000 ML/d d/s Yarrawonga Weir & will provide flows of approx. 15,000 - 25,000 ML/d in the Niemur River at Barham–Deniliquin Road. ^ can go below flow threshold for short periods (5 days maximum) # extend duration at lower flows >3400 ML/d (LF3) d/s Stevens Weir to support colonial waterbird breeding along Niemur River if triggered by natural event* * *Approx. equivalent flows: Niemur R >15,000 (OB3)*
			Niemur River	>21,000					21,000 ML/d in Niemur River requires approx. 60,000 - 70,000 ML/d at Deniliquin and 140,000 - 210,000 ML/d d/s Yarrawonga Weir.

PU6: Upper Wakool River and Yallakool Creek



Priority environmental assets				
Rivers, creeks, lakes, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):				
• Wakool River (Edward River near Stevens Weir to Thule Creek) • Yallakool Creek • Cooee Creek • Cooey-Hoo Creek • Toke Creek • Porthole Creek		• Black Dog Creek • Back Creek • Box Creek • Shaws Creek • Several Private Property Wetland Watering sites in the Murray Irrigation area		
Native fish[36]	• Australian smelt • carp gudgeon • dwarf flathead gudgeon • freshwater catfish (eel-tailed catfish)	• flat-headed gudgeon • golden perch • silver perch • Murray cod	• Murray–Darling rainbowfish • unspecked hardyhead • southern pygmy perch	• flathead galaxias (P) • bony herring
Birds	70 water-dependent bird species recorded, including the following listed[37] waterbird species:			
	• blue-billed duck (V)	• eastern great egret (J)	• sharp-tailed sandpiper (C,J,K)	• freckled duck (V)
Native vegetation	15 water-dependent PCTs, including:			
	• non-woody wetland • nitre goosefoot floodplain	• lignum shrubland & wetland	• river red gum forest & woodland	• black box woodlands
Other species	• barking marsh frog • eastern banjo frog	• eastern sign-bearing froglet • spotted marsh frog	• Peron's tree frog • southern bell frog (E)	• Sudell's frog • platypus • superb parrot (V)
Unregulated WALs	There is 267 ML of unregulated entitlements in the PU, which includes one unregulated water access licence (WAL) for production of 262 ML located on Porthole Creek.			

[36] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

[37] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Table 6 Environmental watering requirements for the Upper Wakool River and Yallakool Creek.
Representative gauges: Yallakool Creek offtake (409020), Wakool River offtake (409019) & Wakool at Deni/Wakool Rd (409072)[38]

Flow Category & EWR code[39]		Ecological objective[39] (Primary objectives in bold)	Gauge	Flow rate[39] (ML/d)	Timing[39]	Duration[39]	Frequency[39] *(& LTA[40] Frequency)*	Maximum inter-event period[39]	Additional requirements[39]
Cease to flow	CTF	Native Fish NF1 – survival (all species) Ecosystem Functions (EF1, 2) – refuge habitat ***CTF events not desired due to highly modified nature of system & the presence of native fish populations***	Yallakool (409020)	0	In line with historical low flow season: Dec–June	No longer than 47 days	Annual but ideally should not occur	N/A	When restarting flows from a cease–to-flow or very low flows, avoid harmful water quality impacts such as de-oxygenated refuge pools.
			Wakool (409019)	0		No longer than 18 days			
Very Low Flow	VLF	Native Fish NF1 – **survival** & condition (all species) Ecosystem Functions (EF1, 2) – **refuge habitat**, drying regime	Yallakool (409020)	> 30	All year^	297 days minimum	Annual (100%)	53 days	When restarting flows from a cease-to-flow or very low flows, avoid harmful water quality impacts such as de-oxygenated refuge pools. ^ During annual 4–6 week period of maintenance on Stevens Weir when weir pool level is lowered, meeting very low flows & baseflows will rely on high flows in the Murray (> approx. 18,000 ML/d) *no minimum in very dry years
			Wakool (409019)	> 20		262 days minimum		52 days	
Baseflows	BF1	Native Fish: NF1–9 – **condition & movement** Native Vegetation: NV1 – in-channel Ecosystem Functions: EF1, 2, 3, 4, 8 – **longitudinal connectivity; refuge habitat**	Yallakool (409020)	> 80	All year^	166 days minimum	Annual (100%)	112 days	
			Wakool (409019)	> 50		116 days minimum		145 days	
	BF2 Winter baseflow	Native Fish: NF1–9 – condition & movement Native Vegetation: NV1 – in-channel Ecosystem Functions: EF1, 2, 3, 4, 8 – **longitudinal connectivity; refuge habitat during irrigation shut-down period**	Yallakool (409020)	> 80	May–Aug^	54 days minimum*	Annual (100%)	1 year	
			Wakool (409019)	> 50		31 days minimum*			
	BF3 Drying phase	Vegetation: EF1: non-woody in-channel Ecosystem Functions: EF2: **Drying phase for in-channel habitats (for vegetation outcomes)**	Yallakool (409020)	30–170 (do not exceed)	Anytime (ideally in summer but practically Apr–Jul)	60 days minimum	6–10 years in 10 (80%)	2 years	
			Wakool (409019)	20–100 (do not exceed)					
Small fresh	SF1	Native Fish: NF1–9 – **Dispersal/condition (all species)** Native Vegetation: NV1 – in-channel & fringing Ecosystem Functions: EF1–7 – **Variable in-channel habitat;** improve WQ in pools; nutrients, sediment & carbon transport	Yallakool (409020)	>500^	Oct–Apr (or anytime)	10 days minimum	Annual (100%) (Ideally 2 events per year)	1 year	Coordinate with wider Murray River actions where possible to maximise benefit for native fish & ecosystem functions. Apply a slow recession to maximise in-channel non-woody vegetation outcomes SF1 – Delivery of summer pulse will support dispersal of native fish larvae & juveniles; autumn pulse is especially important if spawning detected in previous 6–8 months to support juvenile fish to survive first winter. ^ 500 ML/d may be difficult to achieve under current operational arrangements. Current operational limit of Yallakool regulator is 720 ML/d but in practice, may only be 470 ML/d (based on observations in Sep 2018). Wakool
			Wakool (409019)	>100~					

[38] Discontinued gauge. Used here to represent combined flows in Yallakool Creek and the upper Wakool River.

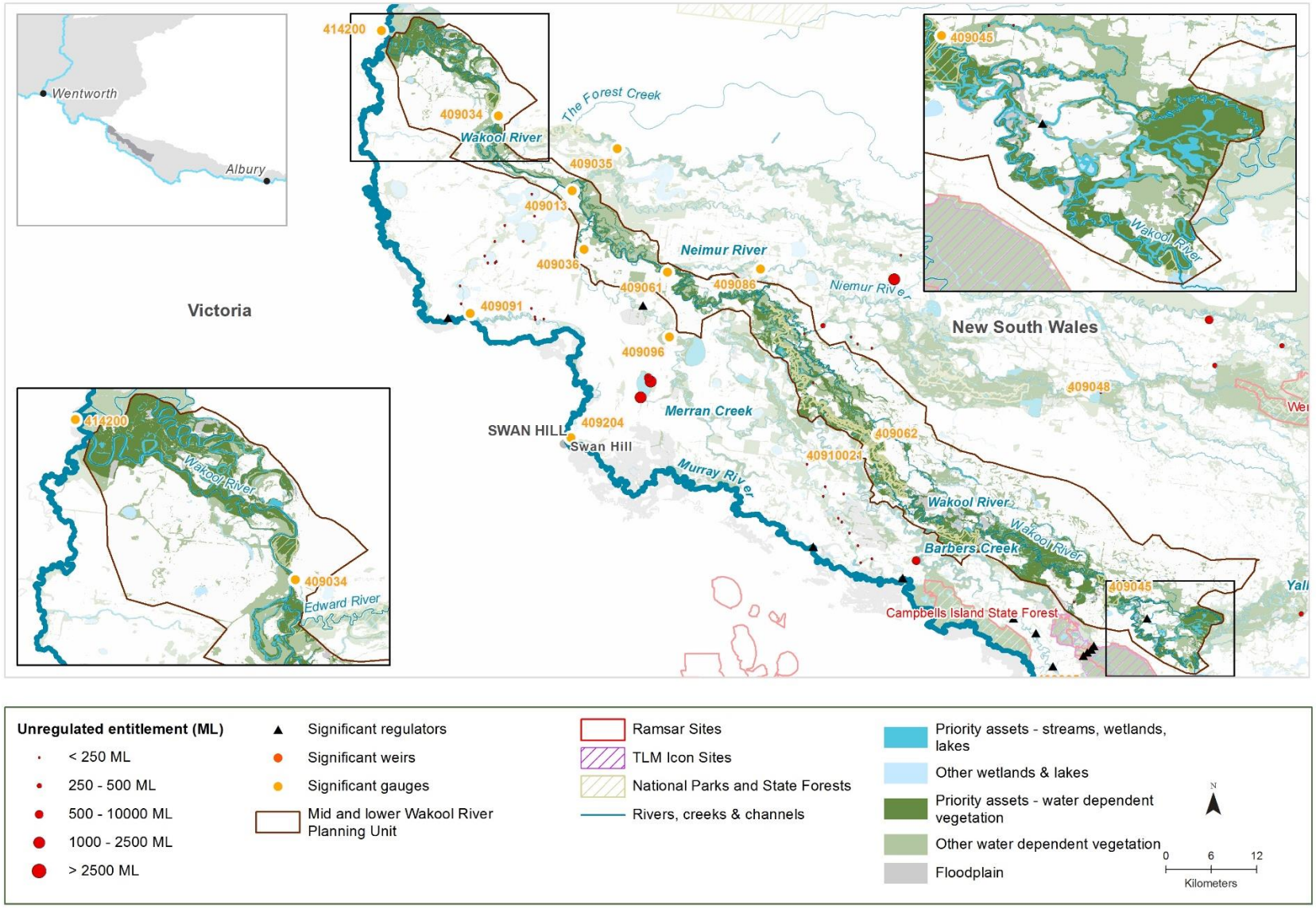
[39] See Glossary: Definitions and explanatory text for EWRs

[40] Long term average frequency (% of years)

Flow Category & EWR code[39]		Ecological objective[39] (Primary objectives in bold)	Gauge	Flow rate[39] (ML/d)	Timing[39]	Duration[39]	Frequency[39] *(& LTA[40] Frequency)*	Maximum inter-event period[39]	Additional requirements[39]
	SF2	Native Fish: NF1–4 – **Spawning (river specialist, generalist fish),** possible spawning of flow pulse specialists Native vegetation: NV1,3 – **in-channel non-woody & fringing vegetation** Ecosystem Functions: EF1–7 – Variable in-channel habitat; transport of nutrients, sediment & carbon	Yallakool (409020)	>500	Sep–Dec	90 days minimum	5–10 years in 10 (75%)	2 years	offtake regulator operational limit during regulated conditions is 120 ML/d in normal years & 70–80 ML/d in dry years. These operational limits relate to avoidance of local break outs from Stevens Weir pool. Higher flow rates would require Stevens Weir pool to be raised higher. Strategy – e-water could cover losses due to any break outs from Stevens Weir pool. Also a 600 ML/d operational constraint downstream of the Yallakool/Wakool junction.
			Wakool (409019)	>100					
Large freshes	LF1	Native Fish: NF1–8 – **Dispersal/condition (all species); pre-spawning condition of flow pulse specialists**; potential spawning (flathead galaxias) Native Vegetation: NV1, 2, 3 – in-channel, wetland & fringing vegetation Ecosystem Functions: EF2–6 – **hydrodynamic diversity**; lateral connectivity with low-lying wetlands & creeks; dispersal of biota; small-scale productivity; transport of nutrients/carbon/sediment, GW recharge	Yallakool (409020)	>900	Jul–Sep (or anytime) (*Aug–Sep if targeting flathead galaxias spawning)	5 days minimum	5–10 years in 10 (75%)	2 years	Deliver Yallakool & upper Wakool flows together to maximise ecological benefits & connectivity downstream of Yallakool/Wakool junction. Ideally this EWR is met with a Murray multi-site event rather than flows regulated from Stevens Weir. For Murray multi-site event, requires approximately 35,000 ML/d at d/s Yarrawonga Weir (OB4 in mid–Murray EWRs) Slow recession to baseflow over 3–6 weeks is recommended to benefit native vegetation growth & succession on river banks. Delivery considerations & constraints: Yallakool Creek – 900 ML/d not possible under current (2018) operational arrangements due to insufficient hydraulic head from Stevens Weir to push sufficient water through Yallakool Ck offtake regulator. Would require raising Stevens Weir pool above FSL. This is likely to result in some small lateral spills (no known 3rd party impacts) so accounting arrangement to cover losses would be required). Upper Wakool River – It's possible to supplement delivery from Stevens Weir pool with top-up flows from Wakool escape on Mulwala canal (escape capacity is currently 500 ML/d) – but multi-site event is preferred for maximising ecological outcomes. 600 ML/d operational constraint downstream of the Yallakool/Wakool junction
			Wakool (409019)	>500					
	LF2	Native Fish: NF1, 3, 4, 6, 7 – **Spawning (flow pulse specialists)**; dispersal (floodplain specialists) Native Vegetation: NV1, 2, 3 – **in-channel/wetland (amphibious/herbaceous non-woody)**, & fringing vegetation Ecosystem Functions: EF2–6 – as for LF1 Other species: OS1,2,3 – frog habitat & breeding	Yallakool (409020)	>900	Oct–Apr	10 days minimum	4–6 years in 10 (50%)	4 years	
			Wakool (409019)	>500					
Bankfull flows	BK1 Constraints relaxed or natural event Only overbank in some areas	Native fish: NF2–9 – Spawning (floodplain specialists*); Dispersal & condition (all species) Native vegetation: NV1,2,3,4e – **in-channel non-woody, fringing RRG, lignum** Waterbirds: WB5 – habitat Ecosystem functions: EF 2–7: Lateral connectivity with wetlands, creeks & anabranches; productivity; geomorphic maintenance; hydraulic diversity Other species: OS1,2,3 – habitat & breeding including southern bell frogs	Yallakool (409020)	>1600^ (1600–3500)	Aug–Nov (or anytime for natural events) *Aug–Sep if targeting flathead galaxias	10 days minimum cumulative duration#	4–5 years in 10 (45%)	3 years	* To support NF7 (expand population of flathead galaxias into the area – a critically endangered species) – wetland inundating flows are required in Aug–Sep. ^ 1600 ML/d at Yallakool Creek offtake remains in-channel but contributes to bankfull flows d/s of the Yallakool–Wakool Junction. Yallakool Creek bankfull is ~3500 ML/d. # 1300 ML/d at Wakool offtake contributes to bankfull flows downstream of Yallakool–Wakool junction & some local scale overbank flows in Black Dog Creek in the Upper Wakool system. Met by approximately 45,000 ML/d at d/s Yarrawonga Weir (OB7 in mid–Murray EWRs)
			Wakool (409019)	>1300# (1300–2000)					
			Wakool @ Deni/Wakool Rd (409072)	>2000 (2000–3000)					

Flow Category & EWR code[39]		Ecological objective[39] (Primary objectives in bold)	Gauge	Flow rate[39] (ML/d)	Timing[39]	Duration[39]	Frequency[39] *(& LTA[40] Frequency)*	Maximum inter-event period[39]	Additional requirements[39]
Small Overbank	OB1 Natural event only Only overbank in some areas	Native fish: NF2–9: **dispersal (all species)**, potential spawning (floodplain specialists*); Native vegetation: NV1, 2, 3, 4a, 4c, 4e: **wetland non-woody, fringing RRG; low-lying RRG forest, black box & lignum** Waterbirds: WB5 – habitat Ecosystem functions: EF 2–7 – lateral connectivity with wetlands, creeks & small areas of low-lying floodplain^; **productivity;** nutrient & carbon transport; biotic dispersal Other species: OS1–4 – frog habitat & breeding	Yallakool (409020)	>2100^	Aug–Nov (or anytime for natural events)	10 day minimum cumulative duration[#] (ideally > 14 days)	3–4 years in 10 (35%)	4 years	^ Remains in-channel in Yallakool Creek & the upper Wakool River but when delivered together, these flows contributes to small-scale inundation of low-lying areas near the Yallakool/Wakool junction including along Black Dog Creek & d/s junction near Shaws Ck & Merribit–Bookit creeks. * To support NF7 (expand population of flathead galaxias into the area – a critically endangered species) – wetland inundating flows are required in July–Aug # Can go below flow threshold for short periods (5 days maximum)
			Wakool (409019)	>1800^					
			Wakool @ Deni/Wakool Rd (409072)	>3000					
	OB2 Natural event only Only overbank in some areas	Native fish: NF2–9: dispersal (all species), potential spawning (floodplain specialists*); Native vegetation: NV1, 2, 3, 4a, c, e: in-channel & **wetland non-woody, fringing RRG; low-lying RRG forest, black box & lignum** Waterbirds: WB1,2,5 – habitat Ecosystem functions: EF 2–7 – lateral connectivity with wetlands, creeks & low-lying floodplain~; **productivity**; nutrient & carbon transport; biotic dispersal Other species: OS1–4 – frog habitat & breeding	Yallakool (409020)	>2700~	Anytime	10 day minimum cumulative duration[#] (ideally >14 days)	3–4 years in 10 (35%)	5 years	~ Remains in-channel in Yallakool Creek (& most of upper Wakool River) but when delivered together, these flows contribute to inundation of low-lying areas near the Yallakool/Wakool junction (immediately upstream of junction near Black Dog Creek), & downstream of the junction near Shaws Ck, Porthole Creek & Merribit–Bookit creeks. # Can go below flow threshold for short periods (5 days maximum) Met by (approximately): 28,000 ML/d at Deniliquin (OB3 for Edward River PU); & 80,000 ML/d d/s Yarrawonga Weir (OB9 in Mid–Murray EWRs)
			Wakool (409019)	>2300~					
			Wakool @ Deni/Wakool Rd (409072)	>4000					
Medium overbank	OB3 Natural events only	Native fish: NF2–9: dispersal (all species), potential spawning (floodplain specialists*); Native vegetation: NV1, 2, 3, 4a, c, e: wetland non-woody, fringing RRG; **RRG forest (27%), RRG woodland (42%); black box (19%) & lignum (62%)** Waterbirds: WB1,2,5 – habitat Ecosystem functions: EF 2–7 – lateral connectivity with wetlands & creeks (43%) & floodplains; **productivity**; nutrient & carbon transport; biotic dispersal Other species: OS1–4 – frog habitat & breeding	Yallakool offtake (409020)	>3500	Anytime	7 days minimum cumulative duration[#]	3–4 years in 10 (35%)	5 years	Met by (approximately): 35,000 ML/d at Deniliquin & 100,000 ML/d d/s Yarrawonga Weir (OB10 in mid–Murray EWRs)
			Wakool (409019)	>2900					
			Wakool @ Deni/Wakool Rd (409072)	>5000					
Large overbank	OB4 Natural events only	Native fish: NF2–9: dispersal (all species) Native vegetation: NV1, 2, 3, 4a, c, e: Condition of **RRG woodland (42%), black box (50%), lignum (75%)** & RRG forest (61%) Waterbirds: WB1,2,5 – habitat Ecosystem functions: EF 2–7 – broad scale lateral connectivity with wetlands & creeks (64%) & floodplains; **productivity**; nutrient & carbon transport; biotic dispersal Other species: OS1–4 – frog habitat & breeding	Yallakool (409020)	>4700	Anytime	7 days minimum cumulative duration[#]	1–2 years in 10 (15%)	7 years	Met by (approximately): 47,000 ML/d at Deniliquin (OB4 in Edward River PU) & 135,000 ML/d d/s Yarrawonga Weir (larger than OB10 in mid–Murray EWRs)
			Wakool (409019)	>3900					
			Wakool @ Deni/Wakool Rd (409072)	>7000					

PU7: Mid and lower Wakool River



Priority environmental assets				
Rivers, creeks, lakes, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):				
• Wakool River (downstream of Thule Creek junction) • Merribit Creek • Merran Creek (downstream reaches) • Christies Creek • Bookit Creek • Back Creek Lagoon	• Bunna Creek • Armstrong Creek • Whymoul Creek • Merangatuk Creek • Barbers Creek (downstream reaches) • Armstrong Creek • Wyam Creek	• Noorong Creek • Lanker Creek • Cunninyeuk Creek • Mackenzie Creek • Pissen Creek • Bucky creek • Wee Wee Creek (upstream reaches)	• Eagle Creek • Mortons Lagoon • Teare Creek • Horseshoe Lagoon • Yarrein Creek • Several Private Property Wetland Watering sites in the Murray Irrigation area	
Native fish[41]	• Australian smelt • carp gudgeon • dwarf flathead gudgeon	• flat-headed gudgeon • Murray cod • Murray-Darling rainbowfish	• silver perch • unspecked hardyhead • freshwater catfish (eel-tailed catfish)	• flathead galaxias (P) • bony herring • golden perch • short-headed lamprey
Birds	93 water-dependent bird species recorded, including the following listed[42] waterbird species:			
	• Australasian bittern (E) • Australian painted snipe (E) • black-tailed godwit (V,C,J,K) • blue-billed duck (V)	• Caspian tern (J) • cattle egret (J) • common greenshank (C,J,K) • curlew sandpiper (E,CE,C,J,K)	• eastern great egret (J) • Latham's snipe (J,K) • freckled duck (V)	• marsh sandpiper (C,J,K) • red-necked stint (C,J,K) • sharp-tailed sandpiper (C,J,K)
Native vegetation	22 water-dependent PCTs, including:			
	• non-woody wetland • nitre goosefoot floodplain	• lignum shrubland & wetland	• river red gum forest & woodland	• black box woodland

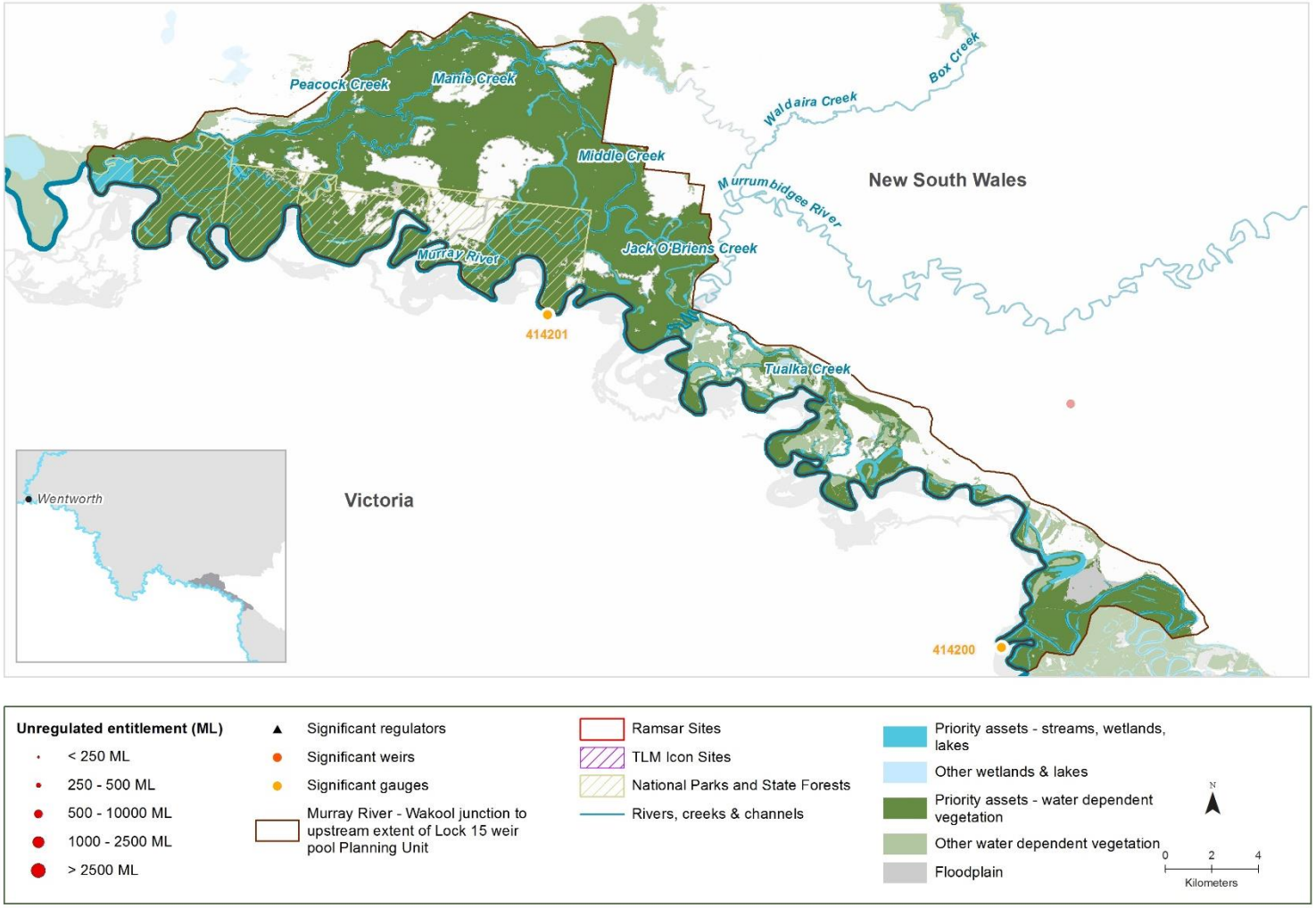
[41] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

[42] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Priority environmental assets				
Other species	• Bibron's toadlet • common eastern froglet • eastern banjo frog	• eastern sign-bearing froglet • barking marsh frog • Peron's tree frog	• southern bell frog (E) • spotted grass frog • eastern snake-necked turtle	• Macquarie turtle • platypus • regent parrot (E)
Unregulated WALs	There is 696 ML of unregulated entitlements in the PU, of which 682 ML are unregulated water access licences (WALs) for production. There are six unregulated WALs for production of <250 ML. These are distributed throughout the upstream half of the PU.			
Environmental Watering Requirements	The mid & lower Wakool River receive flows from multiple sources including the upper Wakool River, Yallakool River, return flows from Koondrook–Perricoota, Merran Creek & other minor creeks. Indicative flow thresholds for baseflows, freshes, bankfull and overbank flows are provided in Table 9 in Part A. There is insufficient information at this time to describe complete EWRs (including frequency, timing and duration).			

2.5 Lower Murray water management area

PU8: Murray River – Wakool junction to upstream extent of Lock 15

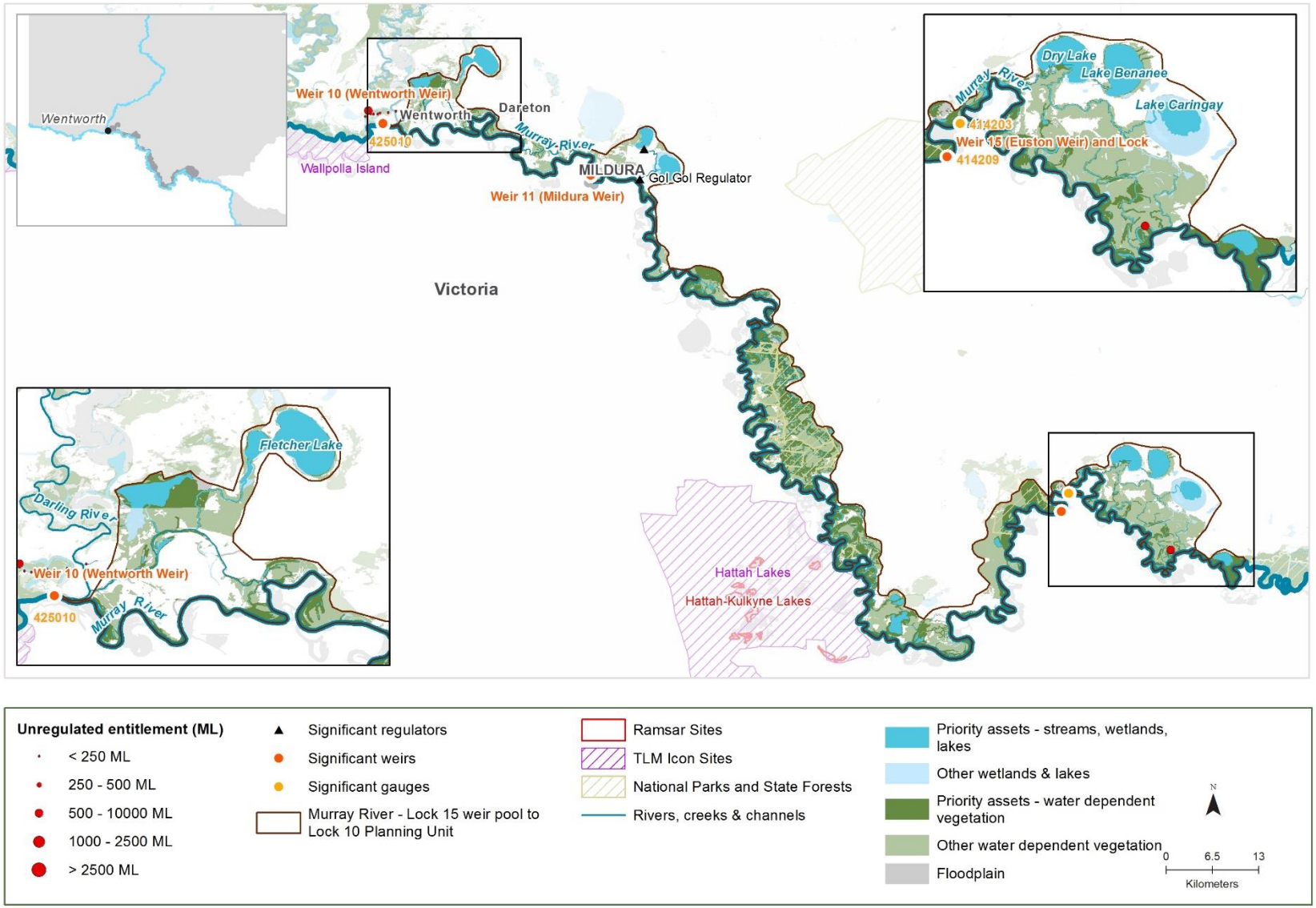


Priority environmental assets				
Rivers, creeks, lakes, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):				
• Murray River • Wee Wee Creek (upstream reaches only)	• Peacock Creek • Middle Creek • Manie Creek	• Tualka Creek • Jack O'Briens Creek	• Junction Wetlands (Murrumbidgee-Murray river junction)	
Native fish[43]	• Australian smelt • carp gudgeon • dwarf flathead gudgeon	• flat-headed gudgeon • golden perch • Murray cod	• Murray–Darling rainbowfish • silver perch • unspecked hardyhead	• flathead galaxias (P) • bony herring
Birds	57 water-dependent bird species recorded, including the following listed[44] waterbird species:			
	• Australian painted snipe (E)	• eastern great egret (J)	• freckled duck (V)	• magpie goose (V)
Native vegetation	16 water-dependent PCTs, including non-woody wetland, lignum shrubland & wetland, nitre goosefoot floodplain, river red gum forest & woodland, & black box woodland			
Other species	• common eastern froglet • southern bell frog (E)	• eastern sign-bearing froglet • barking marsh frog	• Peron's tree frog • spotted marsh frog • eastern banjo frog	• eastern snake-necked turtle • regent parrot (E)
Unregulated WALs	There is one 240 ML general security water access licence (WAL) located on Peacock Creek at the very bottom of the PU.			

[43] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

[44] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

PU9: Murray River – upstream extent of Lock 15 weir pool to Lock 10 (Wentworth)



Priority environmental assets				
Rivers, creeks, lakes, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):				
• Murray River (including Lock 15 weir pool & downstream to Lock 10 near Wentworth) • Euston Lakes (Dry Lake, Lake Benanee, Lake Caringay) • Washpen Creek • Taila Creek			• Fletchers Creek & Little Fletchers Lake • Bengallow Creek • Bottle Bend Floodplain • Gol Gol Swamp • Lake Gol Gol • Tuckers Creek	
Native fish	• Australian smelt • bony herring • carp gudgeon • dwarf flathead gudgeon	• flat-headed gudgeon • freshwater catfish (eel-tailed catfish) • golden perch	• Murray cod • Murray–Darling rainbowfish • southern pygmy perch	• unspecked hardyhead • silver perch • Murray hardyhead • short-headed lamprey
Birds	95 water-dependent bird species recorded, including the following listed[45] waterbird species:			
	• Australian painted snipe (E) • black-tailed godwit (V,C,J,K) • blue-billed duck (V) • Caspian tern (J)	• common greenshank (C,J,K) • curlew sandpiper (E,CE,C,J,K) • eastern great egret (J) • freckled duck (V)	• little curlew (C,J,K) • long-toed stint (C,J,K) • marsh sandpiper (C,J,K) • Pacific golden plover (C,J,K) • pectoral sandpiper (J,K)	• red-necked stint (C,J,K) • ruddy turnstone (C,J,K) • sharp-tailed sandpiper (C,J,K) • white-winged black tern (C,J) • wood sandpiper (C,J,K)
Native vegetation	17 water-dependent PCTs, including non-woody wetland, lignum & nitre goosefoot shrubland & wetland, river red gum forest, & black box woodland			
Other species	• common eastern froglet • eastern banjo frog • eastern sign-bearing froglet • barking marsh frog	• trilling frog • Peron's tree frog • southern bell frog (E) • spotted grass frog	• Sudell's frog • yellow-bellied sheathtail-bat (V) • southern myotis (V)	• platypus • regent parrot (E) • superb parrot (V)
Unregulated WALs	There is 1063 ML of unregulated entitlements in the PU, of which 1056 ML are unregulated water access licences (WALs) for production. There is one unregulated WALs for production of <250 ML & one between 500–1000 ML. One is located on an unnamed lagoon in the upper part of the PU & the second is located on Boeill Lagoon near Buronga.			

[45] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Table 7 Environmental watering requirements for the Murray River – Lock 15 (Euston) weir pool to Lock 10 (Wentworth)
Representative gauge: Murray River downstream Euston (414203)

Flow Category & EWR code[46]		Ecological objectives[46] Primary objectives in bold	Flow rate (ML/d)[47]	Weir pool level[48]	Timing[46]	Duration[46]	Frequency[46] *(& LTA frequency[49])*	Maximum inter-event period[46]	Additional watering requirements[46]
Very low flow	VLF	Native Fish: NF1 – survival (all species) Vegetation: NV1 – non-woody in-channel Ecosystem functions: EF1 – refuge habitat	>2500	Ideally a drawdown (see WP1,3)^	All year	Continuous	Annual *(100%)*	NA	^ Ideally drawdown weir pools (see WP1,3 at end of table) to improve hydraulic diversity to reduce the risk of stratification & promote native fish movement in the Murray
Baseflow	BF1	Native Fish: NF1 – survival (all species), dispersal (all species), recruitment (riverine specialists, generalists) Native vegetation: NV1, 2, 3 – in-channel non-woody; fringing & wetland Ecosystem Functions: EF1, 2, 3 – longitudinal connectivity, hydraulic diversity	>6000	Any (see WP1–3) but ideally a drawdown^	Jul–Dec	180 days minimum (135 days minimum in very dry years)	Annual *(100%)*	1 year	Flow rate should reflect contributions from upstream. Ideally would be a translucent flow from mid–Murray &/or lower Darling rivers. ^Ideally, drawdown weir pools during low flows for part of the year to enhance hydraulic diversity & native fish movement in the Murray
Nesting support	Nest S1	Native Fish: NF5, 6 – **Nesting of riverine specialists (especially Murray cod)** (protect nesting sites by avoiding rapid changes in water levels) *Minimum requirements for Murray cod breeding during low flows, but ideally SF2*	>5000 ideally >10,000 ML/d	Maintain natural rates of change in water level	Oct–Nov	21 days minimum starting 1 Oct#	5–10 years in 10 *(75%)*	4 years	# or 14 days minimum from the detection of Murray cod spawning Rates of fall (weir pool level): ideally 1–2 cm/day (or 10–15 cm/week if small incremental daily drawdowns are not operationally feasible). Maximum: 3–4 cm/day (or 20–30 cm/wk).
Small fresh	SF1	Native Fish: NF2–10 – **condition & dispersal** (all species, including **diadromous species**) Vegetation: NV1, 2 – in-channel non-woody, fringing RRG Functions: EF2, 3, 4, 5, 7 – **hydraulic diversity, longitudinal connectivity, biotic dispersal & movement, nutrient & carbon transport**	>14,000	Any (see WP1–4)^	Jun–Sep	14 days minimum	Annual *(100%)*	1 year	Rates of fall (weir pool level): ideally 1–2 cm/day (or 10–15 cm/week if small incremental daily drawdowns are not operationally feasible). Maximum: 3–4 cm/day (or 20–30 cm/week). SF2 is particularly important in dry years to support fish condition/dispersal & potential spawning. ^ Consider drawing down weir pools to FSL or below if flows are less than 20,000 ML/d to improve hydraulic variability (flow velocities and mixing of water column), especially: a) if small fresh occurs between Oct and Dec to improve hydraulic diversity to support native fish dispersal, spawning & recruitment, and transport of nutrients, carbon and sediment. b) during late winter–spring in very dry years if small freshes (SF1&2) cannot be met for more than 1 year. This will improve flow velocities in weir pools & support native fish movement, migration & possible spawning. See WP3 at end of table for details.
	SF2	Native Fish: NF1–6, 8–10 – **Spawning (river specialist, generalist fish); recruitment/dispersal following spring breeding (flow pulse specialists, riverine specialists & generalists)** Vegetation: NV1–3, 4e – in-channel non-woody, fringing RRG, & (if weir pool raising) lignum & wetland non-woody Functions: EF2, 3, 4, 5, 7 – **hydraulic diversity, longitudinal connectivity, biotic dispersal & movement**, nutrient & carbon transport, productivity	>14,000	Any (see WP1–4) but ideally a drawdown if fresh occurs in Sep – Dec^	Sep–Dec (ideally Oct–Nov for spawning)	45 days minimum (ideally 90 days)	5–10 years in 10 *(75%)*	2 year	

[46] See Glossary: See Glossary: Definitions and explanatory text for EWRs.

[47] At gauge: Murray River downstream Euston (414203).

[48] At gauge: Murray River upstream Euston (414209). Refer to Table 8 for specific levels.

[49] Long term average frequency (% of years).

Flow Category & EWR code[46]		Ecological objectives[46] Primary objectives in bold	Flow rate (ML/d)[47]	Weir pool level[48]	Timing[46]	Duration[46]	Frequency[46] *(& LTA frequency[49])*	Maximum inter-event period[46]	Additional watering requirements[46]
Large fresh	LF1	Native Fish: NF2–10 – **dispersal (all species)**, pre-spawning condition of flow pulse specialists Native vegetation: NV1–4, 4e – in-channel & wetland non-woody; lignum; fringing RRG (& black box, lignum & understory non-woody vegetation in Hattah Lakes TLM site[50]) Functions: EF2, 3, 4, 5, 7 – lateral **connectivity with anabranches & wetlands (including Hattah Lakes^),** hydraulic diversity (fast flowing habitat); biotic dispersal & movement, nutrient & carbon transport Waterbirds: WB1, 2, 5 – habitat	>20,000	Any (see WP1–4)	Jun–Oct	14 days minimum	6–8 years in 10 *(70%)*	3 years	^Ideally >23,000 ML/d to allow natural inflows to Hattah Lakes. Avoid holding flows at 20,000-23,000 ML/d when Hattah infrastructure is in operation as these flows can compromise pumping operations.
Large fresh	LF2	Native Fish: NF2–10 – **spawning (flow pulse specialists); dispersal (all species)** Native vegetation: NV1–4, 4e – **in-channel & wetland non-woody; fringing RRG** (black box, lignum/nitre goosefoot shrublands & understorey non-woody vegetation in Hattah Lakes TLM site[50]) Functions: EF2, 3, 4, 5, 7 – hydraulic **diversity (fast flowing habitat in Murray & anabranches); productivity transfer from upstream**, **biotic dispersal & movement,** lateral connectivity with anabranches & wetlands (including Hattah Lakes[50] and Murrumbidgee junction wetlands), nutrient & carbon transport Waterbirds: WB1, 2, 5 – habitat	>20,000	Any	Sep–Apr	25 days minimum (ideally 60 days)	6–10 years in 10 *(80%)*	2 years	Water temp. > 17^{0}C for spawning of flow pulse specialists and zooplankton growth Rapid increase in velocity (by managing WL &/or flow) to stimulate spawning. 25 days duration to support native vegetation and completion of zooplankton life cycles to boost in-channel productivity. Greater outcomes are expected at longer durations (ideally 60 days). Very important to maintain the integrity (shape & magnitude) of flow pulses from upstream when native fish spawning detected upstream (to aid dispersal of larvae & juvenile fish to the lower Murray. Rates of fall (weir pool level): ideally 1–2 cm/day (or 10–15 cm/week if small incremental daily drawdowns are not operationally feasible). Maximum: 3–4 cm/day (or 20–30 cm/wk).
Bankfull[51]	BK1	Native Fish: NF2–10 – spawning & recruitment (flow pulse specialists, generalists); dispersal (all species) (freshwater catfish population in Washpen Creek – improved wetland & anabranch habitat opportunities) Vegetation: NV1–3 – in-channel & **wetland non-woody**; **fringing RRG** (6% of total area Euston–Wentworth[52]), lignum/nitre goosefoot shrublands Waterbirds: WB1, 2, 5: habitat Functions: EF1–7 – **hydraulic diversity, channel maintenance; connectivity with low–lying wetlands** (5% of wetland area Euston to Wentworth, including some Hattah Lakes temporary wetlands); nutrient & carbon transfer, **productivity**, GW recharge, **biotic dispersal** Other species: OS1, 2 – frog breeding & dispersal	>38,000^	Any (ideally a raising to maximise native vegetation, productivity & waterbird outcomes)	Aug–Mar (or anytime)	30 days minimum (ideally > 60 days)	5–8 years in 10 (*65%*)	3 years	^Bankfull flow ranges by reach: Lock 15 weir pool: 38,000–46,000 ML/d *Based on multiple info sources; weir pool full supply levels, flows at which weirs are removed & reinstated; & RIMFIM floodplain inundation models.*

[50] Subject to operation of Hattah Lakes TLM infrastructure on the Victorian side of the Murray River. Ideally >23,000 ML/d to allow natural inflows to Hattah Lakes.

[51] Relies on relaxed constraints, natural events, or infrastructure assisted delivery to wetlands (e.g. pumping to discrete wetlands).

[52] Percent of wetland area inundated is based on DPIE-BC analysis of Murray RIMFIM floodplain inundation model outputs and wetland and native vegetation spatial data.

Flow Category & EWR code[46]		Ecological objectives[46] Primary objectives in bold	Flow rate (ML/d)[47]	Weir pool level[48]	Timing[46]	Duration[46]	Frequency[46] *(& LTA frequency[49])*	Maximum inter-event period[46]	Additional watering requirements[46]
Small overbank[53]	OB1	Native Fish: NF2–10 – **spawning & recruitment (flow pulse specialists, floodplain specialists, generalists);** dispersal (all) Vegetation: NV1–3,4a,b,c,e – in-channel & **wetland non-woody; fringing RRG** (10–20%[54]) **& low-lying blackbox** (1–4%[54]); lignum/nitre goosefoot shrublands Waterbirds: WB1–5: **habitat & non-colonial breeding & support small-scale colonial waterbird breeding in Euston Lakes** Functions: EF1–7 – **hydraulic diversity, channel maintenance; lateral connectivity with wetlands & lakes** (10–38% of total area; including Lake Caringay & Hattah Lakes temporary wetlands[54]), **nutrient & carbon transfer, productivity**, GW recharge, **biotic dispersal** Other species: OS1,2 – frog breeding & dispersal	> 50,000^	N/A – Weirs are out	Aug–Mar (or anytime)	30 days minimum (ideally > 60 days)	3–7 years in 10 *(50%)*	4 years	Rates of fall (weir pool level): ideally 1–2 cm/day (or 10–15 cm/week if small incremental daily drawdowns are not operationally feasible). Maximum: 3–4 cm/day (or 20–30 cm/wk). ^ for flows above 50,000 ML/d, Lake Caringay will also start to fill via Caringay Creek *(Murray upstream)
Medium overbank[53]	OB2	Native Fish: NF2–10 – as for OB2 Vegetation: NV1, 2, 3, 4a,b,c,e – **wetland non-woody; RRG** (36–43%[54]) & **black box** (5–8%[54]); lignum/nitre goosefoot shrublands Waterbirds: WB1–5: **habitat & non-colonial breeding & support small-scale colonial waterbird breeding in Euston Lakes** Functions: EF1–7 – **lateral connectivity with wetlands** (15–46% of wetland area) **& floodplains**; **nutrient & carbon transfer, productivity**, groundwater recharge, biotic dispersal Other species: OS1,2 – frog breeding & dispersal	>60,000	N/A – Weirs are out	Anytime	25 days minimum (ideally > 40 days)	3–5 years in 10 *(40%)* (ideally clustered events^)	5 years	^ Ideally clustered as groups of 2–3 sequential events 12–18 months apart to promote RRG, lignum & black box recruitment/recovery; & recovery of saline areas (flushing of salt from soils & shallow groundwater). *note Minor Flood Level at Boundary Bend at 68,900 ML/d
Large overbank[55]	OB3	Vegetation: NV3,4a,b,c,e – **wetland non-woody; RRG (49%)** & **black box** (19–29%[54]) maintenance; lignum/nitre goosefoot Waterbirds: WB1–5: **habitat & non-colonial breeding & support large-scale colonial waterbird breeding in Euston Lakes** Functions: EF1–7 – **lateral connectivity with wetlands** (40–81% of wetland area[54]) **& floodplains** (including Hattah Lakes RRG woodlands & understorey); **nutrient & carbon transfer**, productivity, groundwater recharge, biotic dispersal Other species: OS1,2 – frog breeding & dispersal	>80,000	N/A – Weirs are out	Anytime	25 days minimum (ideally > 30 days)	2–4 years in 10 (30%) (ideally clustered events^)	7 years	^ Ideally clustered as groups of 2–3 sequential events 12–18 months apart to promote RRG, lignum & black box recruitment/recovery; & recovery of saline areas (flushing of salt from soils & shallow groundwater).
	OB4	Vegetation: NV3, 4a,b,c,e – **RRG** (64–68%[54]), **black box** (32–37%) maintenance, lignum/nitre goosefoot shrublands Waterbirds: WB1–5: **habitat & non-colonial breeding & support large-scale colonial waterbird breeding in Euston Lakes** Functions: EF1–7 – broad **scale lateral connectivity with floodplain, lakes & wetlands** (72–82% of wetland area), **biotic dispersal & movement, productivity**	>100,000	N/A – Weirs are out	Anytime	20 days minimum (ideally > 30 days)	1–2 years in 10 (15%) (ideally clustered events^)	10 years	^ Ideally clustered events in sequential years to promote black box recovery & recovery of saline areas.

[53] Relies on relaxed constraints in the Murray downstream of Yarrawonga Weir (but only if there are simultaneous natural large flow events in the Murrumbidgee and Goulburn Rivers), natural events alone or infrastructure assisted delivery to wetlands (e.g. pumping to discrete wetlands)

[54] Percent of total area of wetlands or native vegetation communities inundated at specific flow rate along the Murray River floodplain between the upstream extent of the Lock 15 (Euston) weir pool and Wentworth. Based on DPIE-BC analysis of Murray RIMFIM floodplain inundation model outputs and wetland and native vegetation spatial data.

[55] Relies on natural events or infrastructure assisted delivery to wetlands (e.g. pumping to discrete wetlands)

Flow Category & EWR code[46]		Ecological objectives[46] Primary objectives in bold	Flow rate (ML/d)[47]	Weir pool level[48]	Timing[46]	Duration[46]	Frequency[46] *(& LTA frequency[49])*	Maximum inter-event period[46]	Additional watering requirements[46]
	OB5	Vegetation: NV3,4a,b,c,e – **RRG** (65–77%[54]), **black box** (36–56%) maintenance, lignum/nitre goosefoot shrublands Waterbirds: WB1–5: **habitat & non-colonial breeding & support large-scale colonial waterbird breeding in Euston Lakes** Functions: EF1–7 – **broad scale lateral connectivity with floodplain, lakes & wetlands** (77–78% of wetland area), **biotic dispersal & movement, productivity**	>120,000	N/A –Weirs are out	Anytime	15 days minimum (ideally >25 days)	1 year in 10 *(10%)* (ideally clustered events^)	11 years	^ Ideally clustered events in sequential years to promote black box recovery & recovery of saline areas.

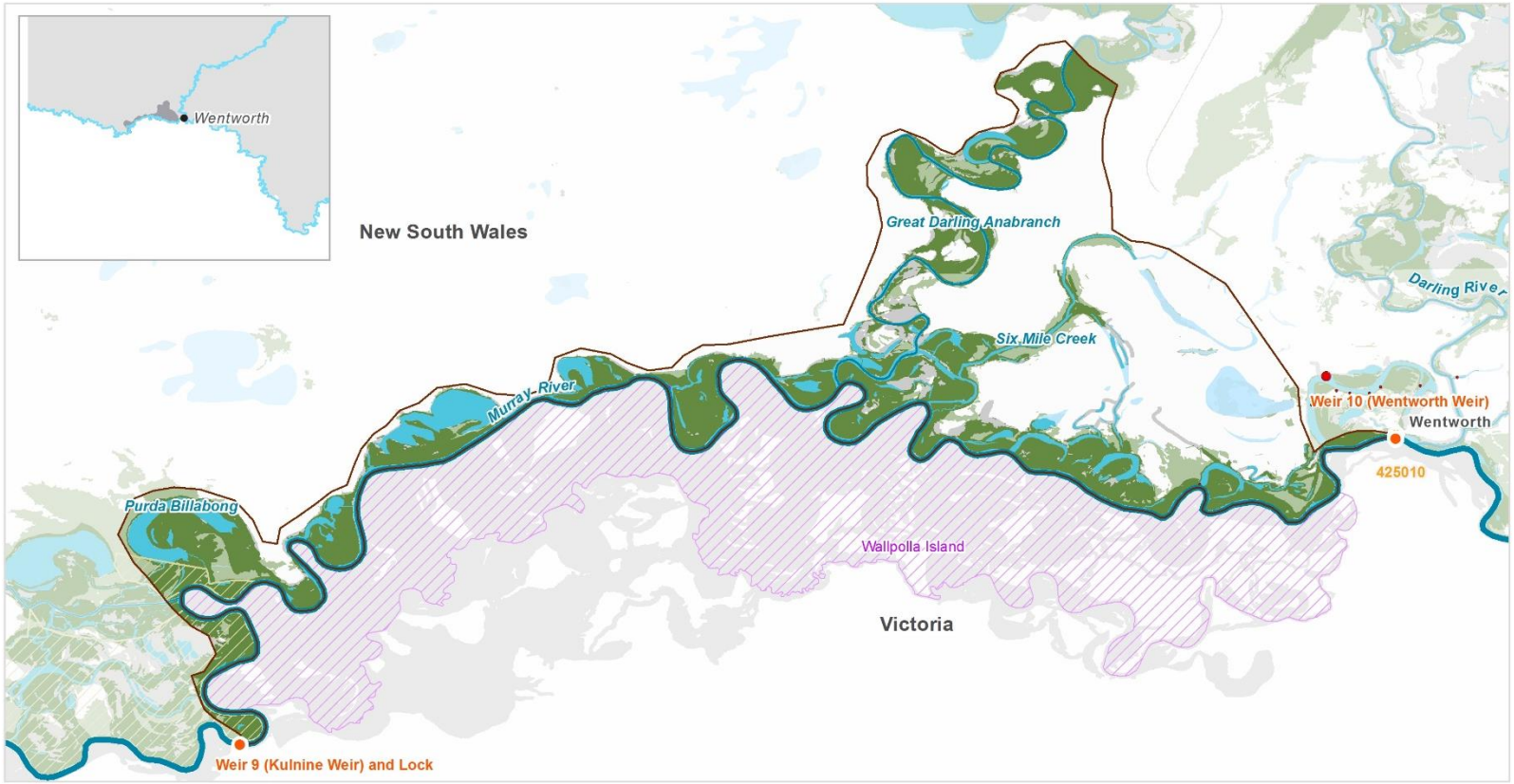
Table 8 Environmental Watering requirements for Lock 15 (Euston) weir pool
Representative gauge: Murray River upstream Euston (414209)

Flow Category & EWR code[46]	Ecological objective[46] Primary objectives in bold	Flow rate (ML/d)[56]	Weir pool level[57] (m above/below full supply level) L15: FSL = 47.6 m AHD	Timing[46]	Duration[46]	Frequency[46] *(& LTA frequency[49])*	Maximum inter-event period[46]	Additional watering requirements[46]
WP1 Weir pool drawdown (summer–autumn) *Similar to a natural baseflow i.e. without weirs*	Native Fish: NF2–10 – movement cues (all species) Native Vegetation: NV1, 2, 3 – **drying regime for in-channel, fringing & wetland veg** Ecosystem functions: EF1–4 – **hydraulic diversity, water quality (prevent weir pool stratification), longitudinal connectivity**, biotic dispersal & movement; **drying regime** for weir pool margins & wetlands (including Lake Benanee & Dry Lake), **productivity**, lower groundwater table	River flows under which summer–autumn drawdown should/can be considered: Lock 15: 2500–46,000 ideally >5000 ML/d	L15: 0.3 m below FSL^	Jan–May	90 days minimum#	7–10 years in 10 *(85%)*	3 years	Drawdown is especially important if flows are below 14,000 ML/d during summer–autumn to provide hydraulic diversity in the Murray channel. #variable durations (90–180 days) between years will benefit native vegetation diversity **Rates of fall (weir pool drawdown):** ideally 1–2 cm/day (or 10–15 cm/week if small incremental daily drawdowns are not operationally feasible). Maximum: 3–4 cm/day (or 20–30 cm/week). Conservative rates of fall should be considered to minimise the risk of bank slumping, especially when drawing down weir pools following prolonged periods of high weir pool levels or when reinstating weirs following large unregulated events. Slower drawdown rates of 1–2 cm/day should support increased cover & diversity of non-woody vegetation on river banks & channel margins. ^ current operational constraints are that L15 can only be drawn down to**:** – FSL (between Jul–Mar), – 20 cm below FSL (April) – 30 cm below FSL (between May–June) changes to these operational constraints would require stakeholder consultation

[56] Flow rates are for Murray at downstream Euston (414203)
[57] At gauge: Murray River upstream Euston (414209) for PU11: Note: recommended levels assume 2018 operational limits. Larger raising or drawdowns would provide greater ecological benefits.

Flow Category & EWR code[46]	Ecological objective[46] Primary objectives in bold	Flow rate (ML/d)[56]	Weir pool level[57] (m above/below full supply level) L15: FSL = 47.6 m AHD	Timing[46]	Duration[46]	Frequency[46] *(& LTA frequency[49])*	Maximum inter-event period[46]	Additional watering requirements[46]
WP2 Weir pool raising (winter–spring–early summer) *Similar to a small overbank – OB1*	Native fish: NV1–9 – dispersal (all species), spawning (floodplain specialists – from Oct only) (*freshwater (eel-tailed) catfish population in Washpen Creek – improved connectivity with Euston Lakes system) Native vegetation: NV1–3, 4a,b,c,e – in-channel & **wetland non-woody; fringing RRG;** low lying blackbox (limited extent) Waterbirds: WB1,2,5: habitat condition, feeding Ecosystem Functions: EF1–7 – **lateral connectivity with lakes & wetlands** (including partial fill of Lake Caringay & inundation of threatened swamp she-oak communities around Lake Benanee); nutrient & carbon transfer, **productivity**, groundwater recharge, biotic dispersal Other species: OS1, 2, 4 – frog breeding & dispersal	Ideal river flow ranges for undertaking weir pool raising: Lock 15: 14,000^–46,000*	L15: 0.6 m above FSL	Jul–Dec	60 days minimum (up to 5 months to support colonial water bird breeding , if desired)	6–10 years in 10 *(80%)*	3 years	^Weir pool raising also possible at 2,500–14,000 ML/d but this would compromise hydraulic diversity in Murray channel, which is important for native fish movement & breeding, especially in Sep–Dec, and downstream transport of nutrients, carbon and biota. Weir pool raising at flows of 14,000-20,000 ML/d may results in reduced hydraulic variability in the main channel. Consider a temporary drawdown to FSL or below FSL during flow freshes/pulses <20,000 ML/d in Sep-Dec (see WP4). *Upper flow limit for weir pool raising may be lower as weirs may need to be pulled out at lower flows for work health & safety reasons. Rates of fall: see above for WP1
WP3 Weir pool drawdown (winter–spring) *Only required under extended dry periods as a partial surrogate for small freshes (SF1,2)*	Native Fish: NF2–10 – **movement (all species)**, pre-spawning condition (all species), **spawning (riverine specialists,** flow pulse specialists) Ecosystem functions: EF2,3 – **hydraulic diversity**, water quality, longitudinal connectivity, biotic dispersal & movement	Draw down weir pools in winter–spring only during extended (multi-year) dry periods &/or low water availability i.e. if flows in the Murray River have been less than 14,000 ML/d for extended periods (>80% of the time during Aug–Dec) for more than 1–2 years.	L15: 0.3 m below FSL^ *Ideally maximum drawdowns (0.5 m below FSL)*	Aug–Dec (critical period Oct–Nov when Murray cod are breeding	60 day minimum	Only required every 2–3 years during extended dry periods. No specific LTA target. Likely to be required 0–2 years in 10, depending on the occurrence of extended dry periods.	Not more than 2 consecutive years without a winter–spring drawdown or small flow freshes of at least 14,000 ML/d for at least 14 days during Sep–Dec.	^ current operational constraints are that L15 can only be drawn down to**:** – FSL (between Jul – Mar), – 20 cm below FSL (April) – 30 cm below FSL (between May–June) changes to these operational constraints would require stakeholder consultation Note that a spring drawdown provides only a partial surrogate for higher flows (small freshes) with respect to velocity in the Murray River & should not replace higher flows (small & large freshes & higher). Flow velocities in weir pools would likely remain slower under the low flow (<14,000 ML/d) & drawdown scenario compared with a small fresh (>14,000 ML/d) under most weir pool level scenarios – *based on analysis of MDBA unpublished hydraulic model data* for Locks 7 and 8. Rates of fall: see above for WP1
WP4 Weir pool drawdown (spring-early summer)	Native Fish: NF1–6, 8–10 – **Spawning (river specialist, generalist fish);** recruitment/dispersal following spring breeding (flow pulse specialists, riverine specialists & generalists) Functions: EF2, 3, 4, 5, 7 – **hydraulic diversity**, longitudinal connectivity, **biotic dispersal & movement, nutrient & carbon transport**	Any, but especially important during small freshes <20,000 ML/d^	FSL or drawdown Ideally: L15: 0.3 m below FSL^ *Ideally maximum drawdowns (0.5 m below FSL)*	Sep-Dec	14 days minimum (ideally 60 days)	5-10 years in 10 *(75%)*	3 years	^ While it is also desirable to raise weir pools in spring to support native vegetation and fish outcomes on floodplains and in anabranches (see WP2), temporary lowering of weir pools to FSL or below FSL during small freshes/pulses in Sep-Dec, especially if freshes are below 20,000 ML/d, would improve flow velocities in weir pools and therefore likely support native fish spawning and movement in the Murray channel and functional connectivity along the River i.e. promoting downstream transport of carbon, nutrients and biota. For flows above 20,000 ML/d, lowering of weir pools is less important as these higher flows provide good hydraulic diversity at a range of weir pool levels.

PU10: Murray River – Lock 10 to Lock 9



Priority environmental assets				
Rivers, creeks, lakes, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to): • Murray River (Lock 10 to Lock 9, including Lock 9 weir pool) • Darling Anabranch (the lower reach that is influenced by Lock 9 weir pool i.e. from the Murray River) • Tincha Creek • Tuckers Creek • Six Mile Creek • Purda Billabong (also called Pink Lake) • Grand Junction wetland • numerous unnamed wetlands along the Murray River and Darling Anabranch				
Native fish	• Australian smelt • bony herring • carp gudgeon • dwarf flathead gudgeon	• freshwater catfish (eel-tailed catfish) • flat-headed gudgeon • golden perch	• silver perch • Murray cod • Murray–Darling rainbowfish • unspecked hardyhead	• Murray hardyhead • southern pygmy perch • short-headed lamprey
Birds	67 water-dependent bird species recorded, including the following listed[58] waterbird species: • blue-billed duck (V)	• Caspian tern (J)	• eastern great egret (J)	• freckled duck (V)
Native vegetation	13 water-dependent PCTs, including non-woody wetland, lignum & nitre goosefoot shrubland & wetland, river red gum forest, & black box woodland			
Other species	• eastern banjo frog • barking marsh frog • broad-shelled turtle	• eastern sign-bearing froglet • eastern snake-necked turtle	• southern bell frog (E) • Peron's tree frog • Macquarie turtle	• spotted grass frog • Corben's long-eared bat (V)
Unregulated WALs	There is 96 ML of unregulated entitlements in the PU, of which 87 ML are water access licences (WALs) for production. There is one production WALs <250 ML & one between 500–1,000 ML, which is located on an unnamed lagoon near the Murray River in the upper part of the PU.			

[58] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Table 9 **Environmental watering requirements for the Lower Murray River (SA Border to Lock 10 Wentworth): Planning units 10, 11 & 12**
Representative gauges (see footnotes 60 & 61)

Flow Category & EWR code[59]		Ecological objective[59] Primary objectives in bold	Flow rate (ML/d)[60]	Weir pool level[61]	Timing[59]	Duration[59]	Frequency[59] *(& LTA frequency[62])*	Maximum inter-event period[59]	Additional watering requirements[59]
Very low flow	VLF	Native Fish: NF1 – survival (all species) Vegetation: NV1 – non-woody in-channel Ecosystem functions: EF1 – refuge habitat	>3500	Ideally a drawdown (see WP1,3)^	All year	Continuous	Annual	NA	^ Ideally drawdown weir pools (see WP1–3 at end of table) to improve hydraulic diversity to reduce the risk of stratification & promote native fish movement in the Murray
Baseflow	BF1	Native Fish: NF1 – survival (all species), dispersal (all species), recruitment (riverine specialists, generalists) Native vegetation: NV1, 2, 3 – in-channel non-woody; fringing & wetland Ecosystem Functions: EF1, 2, 3 – longitudinal connectivity, hydraulic diversity	>10,000	Any (see WP1–4) but ideally a drawdown^	Jul–Dec	180 days minimum (135 days minimum in very dry years)	Annual	1 year	Flow rate should reflect contributions from upstream. Ideally would be a translucent flow from mid–Murray &/or lower Darling rivers. ^Ideally, drawdown weir pools during low flows for part of the year to enhance hydraulic diversity & native fish movement in the Murray
Nesting flow	Nest S1	Native Fish: NF5, 6 – **Nesting of riverine specialists (especially Murray cod)** (protect nesting sites by avoiding rapid changes in water levels)	>5000 ideally >10,000 ML/d	Maintain natural rates of change in water level	Oct–Nov	21 days minimum starting 1 Oct#	5–10 years in 10 *(75%)*	4 years	# or 14 days minimum from the detection of Murray cod spawning Rates of fall (weir pool level): ideally 1–2 cm/day (or 10–15 cm/week if small incremental daily drawdowns are not operationally feasible). Maximum: 3–4 cm/day (or 20–30 cm/wk).
Small fresh	SF1	Native Fish: NF2–10 – **condition & dispersal** (all species, including **diadromous species**) Vegetation: NV1, 2 – in-channel non-woody, fringing RRG Functions: EF2,3,4,5,7 – **hydraulic diversity, longitudinal connectivity, biotic dispersal & movement, nutrient & carbon transport**	>14,000	Any (see WP1–4)^	Jun–Sep	14 days minimum	Annual *(100%)*	1 year	Rates of fall (weir pool level): ideally 1–2 cm/day (or 10–15 cm/week if small incremental daily drawdowns are not operationally feasible). Maximum: 3–4 cm/day (or 20–30 cm/week). SF2 is particularly important in dry years to support fish condition/dispersal & potential spawning. ^ Consider drawing down weir pools to FSL or below if flows are less than 20,000 ML/d to improve hydraulic variability (flow velocities and mixing of water column), especially: a) if small fresh occurs between Oct and Dec to improve hydraulic diversity to support native fish dispersal, spawning & recruitment, and transport of nutrients, carbon and sediment. b) during late winter–spring in very dry years if small freshes (SF1&2) cannot be met for more than 1 year. This will improve flow velocities in weir pools & support native fish movement, migration & possible spawning. See WP3 at end of table for details.
	SF2	Native Fish: NF1–6, 8–10 – **Spawning (river specialist, generalist fish); recruitment/dispersal following spring breeding (flow pulse specialists, riverine specialists & generalists)** Vegetation: NV1–3, 4e – in-channel non-woody, fringing RRG, lignum & wetland non-woody (if weir pool raising) Functions: EF2, 3, 4, 5, 7 – **hydraulic diversity, longitudinal connectivity, biotic dispersal & movement**, nutrient & carbon transport, productivity	>14,000	Any (see WP1–4) but ideally a drawdown if fresh occurs in Sep – Dec^	Oct–Apr	14 days minimum (ideally >25 days for productivity outcomes)	8–10 years in 10 *(90%)*	2 year	

[59] See Glossary: Definitions and explanatory text for EWRs.

[60] Flow rates are for representative gauges in three lower Murray planning units: 1) Murray at Wentworth (425010) for PU10: Murray – Lock 10 to Lock 9**; 2)** Murray d/s Lock 9 (4260505) and Murray d/s Lock 8 (4260507) for PU11 Murray Lock 7 to 9; 3) Murray d/s Lock 7 (4260509) PU12: Murray – Lock 7 to SA border.

[61] Weir pool levels are for representative gauges: **1)** Murray u/s Lock 9 (4260501) for PU10: Murray – Lock 10 to Lock 9; 2) Murray u/s Lock 8 (4260506) and Murray u/s Lock 7 (4260508) for PU11 Murray – Lock 7 to 9. Note: recommended levels assume 2018 operational limits. Larger raising or drawdowns would provide greater ecological benefits.

[62] Long-term average frequency (% of years).

Flow Category & EWR code[59]		Ecological objective[59] Primary objectives in bold	Flow rate (ML/d)[60]	Weir pool level[61]	Timing[59]	Duration[59]	Frequency[59] *(& LTA frequency[62])*	Maximum inter-event period[59]	Additional watering requirements[59]
Large fresh	LF1	Native Fish: NF2–10 – **spawning (flow pulse specialists); dispersal (all species)** Native vegetation: NV1–4, 4e – in-channel & wetland non-woody; lignum; fringing RRG Functions: EF2, 3, 4, 5, 7 – **hydraulic diversity (fast flowing habitat in Murray & anabranches); productivity transfer from upstream**, **biotic dispersal & movement,** lateral connectivity with anabranches & wetlands; nutrient & carbon transport Waterbirds: WB1, 2, 5 – habitat	>20,000	Any	Sep–Feb	14 days minimum	8–10 years in 10 *(90%)*	2 years	Water temp. > 17^{0}C for spawning of flow pulse specialists Rapid increase in velocity (by managing WL &/or flow) to stimulate spawning. Very important to maintain the integrity (shape & magnitude) of flow pulses from upstream when native fish spawning detected upstream in Murray, lower Darling & other tributaries (to aid dispersal of larvae & juvenile fish to the lower Murray. Rates of fall (weir pool level): ideally 1–2 cm/day (or 10–15 cm/week if small incremental daily drawdowns are not operationally feasible). Maximum: 3–4 cm/day (or 20–30 cm/wk).
	LF2	Native Fish: NF2–10 – **recruitment (all species); spawning (flow pulse specialists)**; dispersal (all species); Native vegetation: NV1–4, 4e – in-channel & wetland non-woody; lignum; fringing RRG Functions: EF2, 3, 4, 5, 7 – **in-channel productivity^, hydraulic diversity (fast flowing habitat in Murray & anabranches);** productivity transfer from upstream, biotic dispersal & movement, lateral connectivity with anabranches & wetlands; nutrient & carbon transport Waterbirds: WB1, 2, 5 – habitat	>20,000	Any	Sep-Mar	25 days minimum (ideally 60 days)	3-7 years in 10 *(50%)*	3 years	Water temp. > 17^{0}C for spawning of flow pulse specialists and zooplankton growth. ^Minimum 25 days duration to support completion of zooplankton life cycles to boost in-channel productivity. Greater productivity outcomes are expected at longer durations (ideally 60 days).
Bankfull[63]	BK1	Native Fish: NF2–10 – spawning & recruitment (flow pulse specialists, generalists); dispersal (all species) Vegetation: NV1–3 – in-channel & **wetland non-woody**; **fringing RRG (6–23%),** lignum/nitre goosefoot shrublands Waterbirds: WB1, 2, 5: habitat Functions: EF1–7 – **hydraulic diversity, channel maintenance; connectivity with anabranches & wetlands (25–96% of wetland area)**; nutrient & carbon transfer, **productivity**, GW recharge, **biotic dispersal** Other species: OS1, 2 – frog breeding and dispersal	>40,000^	N/A – Weirs are out	Aug–Mar (or anytime)	30 days minimum (ideally > 60 days)	6–8 years in 10 *(70%)*	3 years	^Bankfull flow ranges by reach: Lock 9 weir pool: 49,000–50,000 ML/d Lock 8 weir pool: 40,000–50,000 ML/d Lock 7 weir pool: 35,000–40,000 ML/d Lock 6 weir pool: 40,000–45,000 ML/d *Based on multiple info sources; weir pool full supply levels, flows at which weirs are removed and reinstated; and RIMFIM floodplain inundation models.*
Small overbank[63]	OB1	Native Fish: NF2–10 – **spawning and recruitment (flow pulse specialists, floodplain specialists, generalists);** dispersal (all) Vegetation: NV1–3,4a,b,c,e – in-channel and **wetland non-woody; fringing RRG** (17–43%) **and low-lying blackbox** (4–11%); lignum/nitre goosefoot shrublands Waterbirds: WB1,2,5: habitat and breeding Functions: EF1–7 – as for BK1 but greater **connectivity with anabranches and wetlands** (48–96% of total area) Other species: OS1,2 – frog breeding and dispersal	> 55,000	N/A – Weirs are out	Aug–Mar (or anytime)	30 days minimum (ideally > 60 days)	3–7 years in 10 *(50%)*	4 years	Rates of fall (weir pool level): ideally 1–2 cm/day (or 10–15 cm/week if small incremental daily drawdowns are not operationally feasible). Maximum: 3–4 cm/day (or 20–30 cm/wk).

[63] Relies on natural events, relaxed constraints or infrastructure assisted delivery to wetlands (e.g. pumping to discrete wetlands).

Flow Category & EWR code[59]		Ecological objective[59] Primary objectives in bold	Flow rate (ML/d)[60]	Weir pool level[61]	Timing[59]	Duration[59]	Frequency[59] *(& LTA frequency[62])*	Maximum inter-event period[59]	Additional watering requirements[59]
Medium overbank[63]	OB2	Native Fish: NF2–10 – as for OB2 Vegetation: NV1, 2, 3, 4a,b,c,e – **wetland non-woody; RRG** (38–68%) and **blackbox** (5–29%); lignum/nitre goosefoot shrublands Waterbirds: WB1, 2, 3, 5: habitat and non-colonial breeding Functions: EF1–7 – **lateral connectivity with wetlands** (55–96% of wetland area) **and floodplains**; nutrient and carbon transfer, **productivity**, groundwater recharge, biotic dispersal Other species: OS1, 2 – frog breeding and dispersal	>70,000	N/A – Weirs are out	Anytime	20 days minimum (ideally > 40 days)	3–5 years in 10 *(40%)* (ideally clustered events^)	5 years	^ Ideally clustered as groups of 2–3 sequential events 12–18 months apart to promote RRG, lignum & black box recruitment/recovery; & recovery of saline areas (flushing of salt from soils & shallow groundwater).
Large overbank[64]	OB3	Vegetation: NV3,4a,b,c,e – **wetland non-woody; RRG** (54–89%) **& blackbox** (22–57%) maintenance**;** lignum/nitre goosefoot Waterbirds: WB1, 2, 3, 5: habitat & non-colonial waterbird breeding Functions: EF1–7 – **lateral connectivity with wetlands** (63–94% of wetland area) **& floodplains**; nutrient & carbon transfer, **productivity**, groundwater recharge, biotic dispersal Other species: OS1, 2 – frog breeding & dispersal	>80,000	N/A – Weirs are out	Anytime	20 days minimum (ideally > 30 days)	2–4 years in 10 *(30%)* (ideally clustered events^)	7 years	^ Ideally clustered as groups of 2–3 sequential events 12–18 months apart to promote RRG, lignum & black box recruitment/recovery; & recovery of saline areas (flushing of salt from soils & shallow groundwater).
	OB4	Vegetation: NV3, 4a,b,c,e – **RRG** (75–92%)**, black box** (56–72%) **maintenance,** lignum/nitre goosefoot shrublands Waterbirds: WB1, 2, 3, 5: habitat & non-colonial waterbird breeding Functions: EF1–7 – **broad scale lateral connectivity with floodplain, anabranches & wetlands** (65–97% of wetland area), biotic dispersal & movement, **productivity**	>100,000	N/A – Weirs are out	Anytime	20 days minimum (ideally > 30 days)	1–2 years in 10 *(15%)* (ideally clustered events^)	10 years	^ Ideally clustered events in sequential years to promote black box recovery & recovery of saline areas.

[64] Relies on natural events or infrastructure assisted delivery to wetlands (e.g. pumping to discrete wetlands).

Table 10 Environmental water requirements for Locks 7, 8 and 9 – Weir Pool Levels (to be used in conjunction with EWRs for flows as described above in Table 9)

Flow Category & EWR code[65]	Ecological objective[65] Primary objectives in bold	Flow rate (ML/d)[66]	Weir pool level[67] (m above/below full supply level)	Timing[65]	Duration[65]	Frequency[65] *(& LTA frequency[68])*	Maximum inter-event period[65]	Additional watering requirements[65]
WP1 Weir pool drawdown (summer–autumn) *Similar to a natural baseflow i.e. without weirs*	Native Fish: NF2–10 – movement cues (all species) Native Vegetation: NV1, 2, 3 – **drying regime for in-channel, fringing & wetland veg** Ecosystem functions: EF1–4 – **hydraulic diversity, water quality (prevent weir pool stratification), longitudinal connectivity**, biotic dispersal & movement; **drying regime** for weir pool margins & wetlands, productivity, lower groundwater table	River flows under which summer–autumn drawdown should/can be considered: Lock 9: 3500–48,000 Lock 8: 3500–40,000 Lock 7: 3500–24,000 ideally >5000 ML/d	L9: 0.1 m below FSL L8: 0.5–1.0 m below FSL L7: 0.5–1.0 m below FSL	Jan–May	90 days minimum#	7–10 years in 10 *(85%)*	3 years	Ideally lower all weir pools (Locks 7–9) at the same time to maximise longitudinal connectivity & availability of flowing habitat along the entire lower Murray River channel. Drawdown is especially important if flows are below 14,000 ML/d during summer–autumn to provide hydraulic diversity in the Murray channel. #variable durations (90–180 days) between years will benefit native vegetation diversity Rates of fall (weir pool drawdown): ideally 1–2 cm/day (or 10–15 cm/week if small incremental daily drawdowns are not operationally feasible). Maximum: 3–4 cm/day (or 20–30 cm/week). Conservative rates of fall should be considered to minimise the risk of bank slumping, especially when drawing down weir pools following prolonged periods of high weir pool levels or when reinstating weirs following large unregulated events. Slower drawdown rates of 1–2 cm/day should support increased cover & diversity of non-woody vegetation on river banks & channel margins.
WP2 Weir pool raising (winter–spring–early summer) *Similar to a small overbank – OB1*	Native fish: NV1–9 – dispersal (all species), spawning (floodplain specialists – from Oct only) Native vegetation: NV1–3, 4a,b,c,e – in-channel & **wetland non-woody; fringing RRG**; low lying blackbox (limited extent) Waterbirds: WB1,2,5: habitat condition, feeding Ecosystem Functions: EF1–7 – **lateral connectivity with anabranches & wetlands**; nutrient & carbon transfer, **productivity**, groundwater recharge, biotic dispersal Other species: OS1, 2 – frog breeding & dispersal	Ideal river flow ranges for undertaking weir pool raising: Lock 9: 14,000^–48,000* Lock 8: 14,000^–40,000* Lock 7: 14,000^–24,000*	L9: 0.24 m above FSL L8: 0.6–0.8 m above FSL L7: 0.6–0.8 m above FSL	Jul–Dec	60 days minimum	6–10 years in 10 *(80%)*	3 years	^Weir pool raising is also possible at 3500–14,000 ML/d but this would compromise hydraulic diversity in Murray channel, which is important for native fish movement & breeding, especially in Sep–Nov, and downstream transport of nutrients, carbon and biota. Weir pool raising at flows of 14,000-20,000 ML/d also results in reduced hydraulic variability in the main channel. Consider a temporary drawdown to FSL or below FSL during flow freshes/pulses <20,000 ML/d in Sep-Dec (see WP4). *Upper flow limit for weir pool raising may be lower as weirs may need to be pulled out at lower flows for work health & safety reasons Lock 8: >0.2 m above FSL is required to connect the upper Potterwalkergee Creek, an intermittent anabranch of the Murray River, located in Victoria. Rates of fall: see above for WP1

[65] See Glossary: Definitions and explanatory text for EWRs.

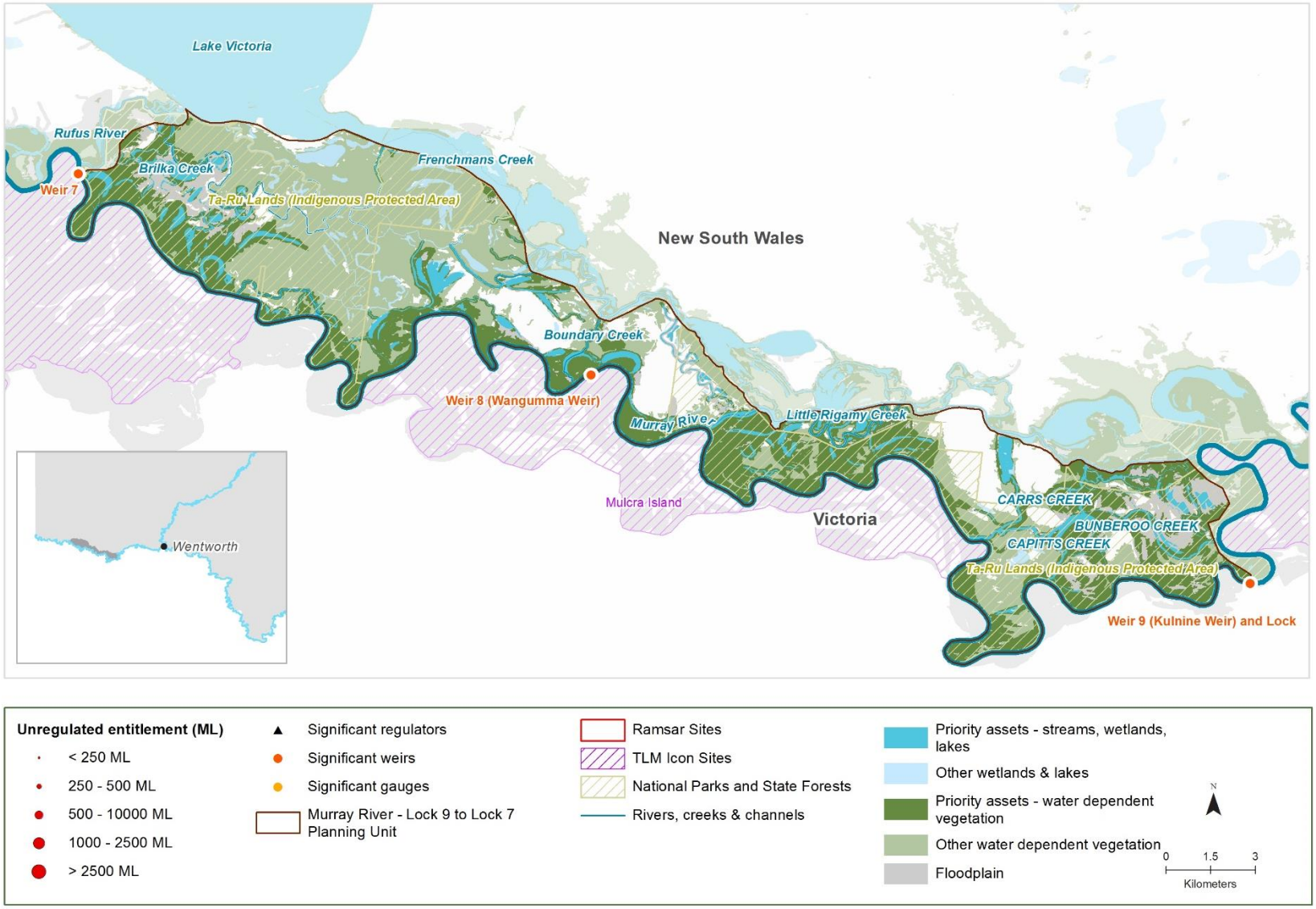
[66] Flow rates are for representative gauges in three lower Murray planning units: 1) Murray at Wentworth (425010) for PU10: Murray – Lock 10 to Lock 9**; 2)** Murray d/s Lock 9 (4260505) and Murray d/s Lock 8 (4260507) for PU11 Murray – Lock 9 to 7; 3) Murray d/s Lock 7 (4260509) PU12: Murray – Lock 7 to SA border.

[67] Weir pool levels are for representative gauges: 1) Murray u/s Lock 9 (4260501) for PU10: Murray – Lock 10 to Lock 9; 2) Murray u/s Lock 8 (4260506) and Murray u/s Lock 7 (4260508) for PU11 Murray – Lock 9 to 7. Note: recommended levels assume 2018 operational limits. Larger raising or drawdowns would provide greater ecological benefits.

[68] Long term average frequency (% of years).

Flow Category & EWR code[65]	Ecological objective[65] Primary objectives in bold	Flow rate (ML/d)[66]	Weir pool level[67] (m above/below full supply level)	Timing[65]	Duration[65]	Frequency[65] *(& LTA frequency[68])*	Maximum inter-event period[65]	Additional watering requirements[65]
WP3 Weir pool drawdown (winter–spring-early summer) *Only required under extended dry periods as a partial surrogate for small freshes (SF1,2)*	Native Fish: NF2–10 – **movement (all species)**, pre-spawning condition (all species), spawning (riverine specialists, flow pulse specialists) Ecosystem functions: EF2,3 – **hydraulic diversity**, water quality, longitudinal connectivity, biotic dispersal & movement	Draw down weir pools in winter–spring only during extended (multi-year) dry periods &/or low water availability i.e. if flows in the Murray River have been less than 14,000 ML/d for extended periods (>80% of the time during Aug–Dec) for more than 1–2 years.	L9: 0.1 m below FSL L8: 0.5–1.0 m below FSL L7: 0.5–1.0 m below FSL *Ideally maximum drawdowns*	Aug–Dec	60 day minimum	Only required every 2–3 years during extended dry periods. No specific LTA target. Likely to be required 0–2 years in 10, depending on the occurrence of extended dry periods.	Not more than 2 consecutive years without a winter–spring drawdown or small flow freshes of at least 14,000 ML/d for at least 14 days during Sep–Dec.	Ideally lower all weir pools (Locks 7–9) at the same time to maximise longitudinal connectivity & availability of flowing habitat along the entire lower Murray River channel. Note that a spring drawdown provides only a partial surrogate for higher flows (small freshes) with respect to velocity in the Murray River & should not replace higher flows (small & large freshes & higher). Flow velocities in weir pools would likely remain slower under the low flow (<14,000 ML/d) & drawdown scenario compared with a small fresh (>14,000 ML/d) under most weir pool level scenarios – *based on analysis of MDBA unpublished hydraulic model data*. Rates of fall: see above for WP1
WP4 Weir pool drawdown (spring-early summer)	Native Fish: NF1–6, 8–10 – **spawning (river specialist, generalist fish)**; recruitment/dispersal following spring breeding (flow pulse specialists, riverine specialists & generalists) Functions: EF2, 3, 4, 5, 7 – **hydraulic diversity**, longitudinal connectivity, **biotic dispersal & movement, nutrient & carbon transport**	Any, but especially important during small freshes <20,000 ML/d^	FSL or drawdown Ideally: L9: 0.1 m below FSL L8: 0.5–1.0 m below FSL L7: 0.5–1.0 m below FSL	Sep-Dec	14 days minimum (ideally 60 days)	5-10 years in 10 *(75%)*	3 years	^ While it is also desirable to raise weir pools in spring to support native vegetation and fish outcomes on floodplains and in anabranches (see WP2), temporary lowering of weir pools to FSL or below FSL during small freshes/pulses in Sep-Dec, especially if freshes are below 20,000 ML/d, would improve flow velocities in weir pools and therefore likely support native fish spawning and movement in the Murray channel and functional connectivity along the River i.e. promoting downstream transport of carbon, nutrients and biota. For flows above 20,000 ML/d, lowering of weir pools is less important as these higher flows provide good hydraulic diversity at a range of weir pool levels.

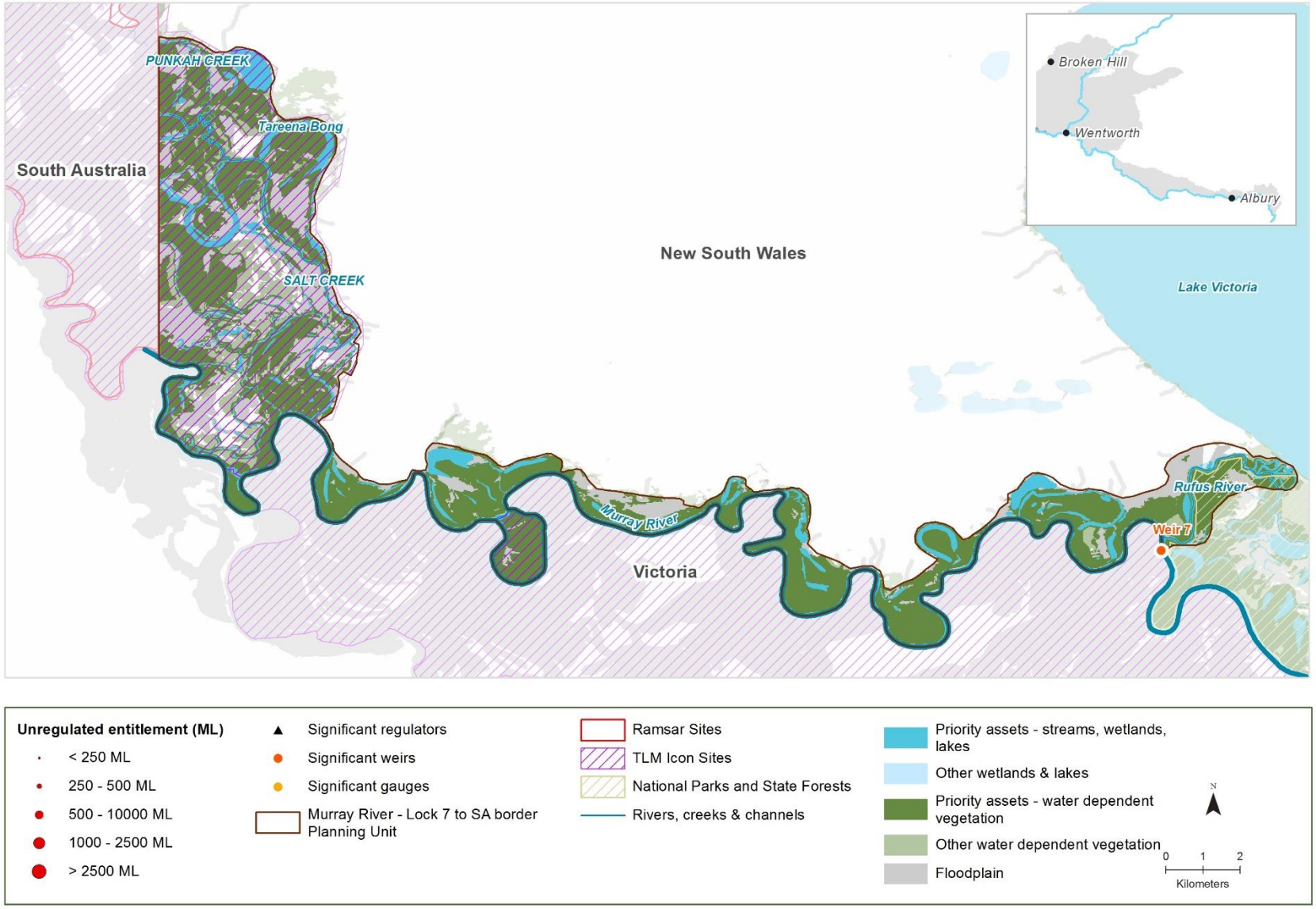
PU11: Murray River – Lock 9 to Lock 7 (Lock 7 and 8 weir pools)



Priority environmental assets				
Rivers, creeks, lakes, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):				
• Murray River (Lock 9 to Lock 7), including Lock 7 & 8 weir pools: • Carrs, Cappits & Bunberoo creek system (Tar-Ru Lands management on behalf of the Barkandji Traditional Owners) • Little Rigamy Creek • Big Rigamy Creek • Wingillie Station • Backwater Lagoon		• Little Frenchmans Creek • Mungo Creek • Brilka Creek • Horseshoe Billabong • Coonpoor Creek • Lucerne Day wetland • Also influences Victorian environmental assets: Lindsay-Mulcra-Wallpolla (TLM Icon site)	
Native fish	• Australian smelt • bony herring • dwarf flathead gudgeon • flat-headed gudgeon	• freshwater catfish (eel-tailed catfish) • golden perch • silver perch	• Murray cod • Murray hardyhead • Murray-Darling rainbowfish	• southern pygmy perch • unspecked hardyhead • carp gudgeon • short-headed lamprey
Birds	63 water-dependent bird species recorded, including the following listed[69] waterbird species:			
	• blue-billed duck (V)	• Caspian tern (J)	• eastern great egret (J)	
Native vegetation	8 water-dependent PCTs, including non-woody wetland, lignum & nitre goosefoot shrubland & wetland, river red gum forest, & black box woodland			
Other species	• eastern banjo frog • barking marsh frog • eastern snake-necked turtle	• eastern sign-bearing froglet • Macquarie turtle	• Peron's tree frog • southern bell frog (E)	• spotted grass frog • regent parrot (V)
Environmental Watering Requirements	EWRs for the Lock 7 -9 reach of the Murray River are presented in Table 9 (for flows) & Table 10 (for weir pool levels) (see previous pages for Planning Units #10 for Murray - Lock 10 to Lock 9).			

[69] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

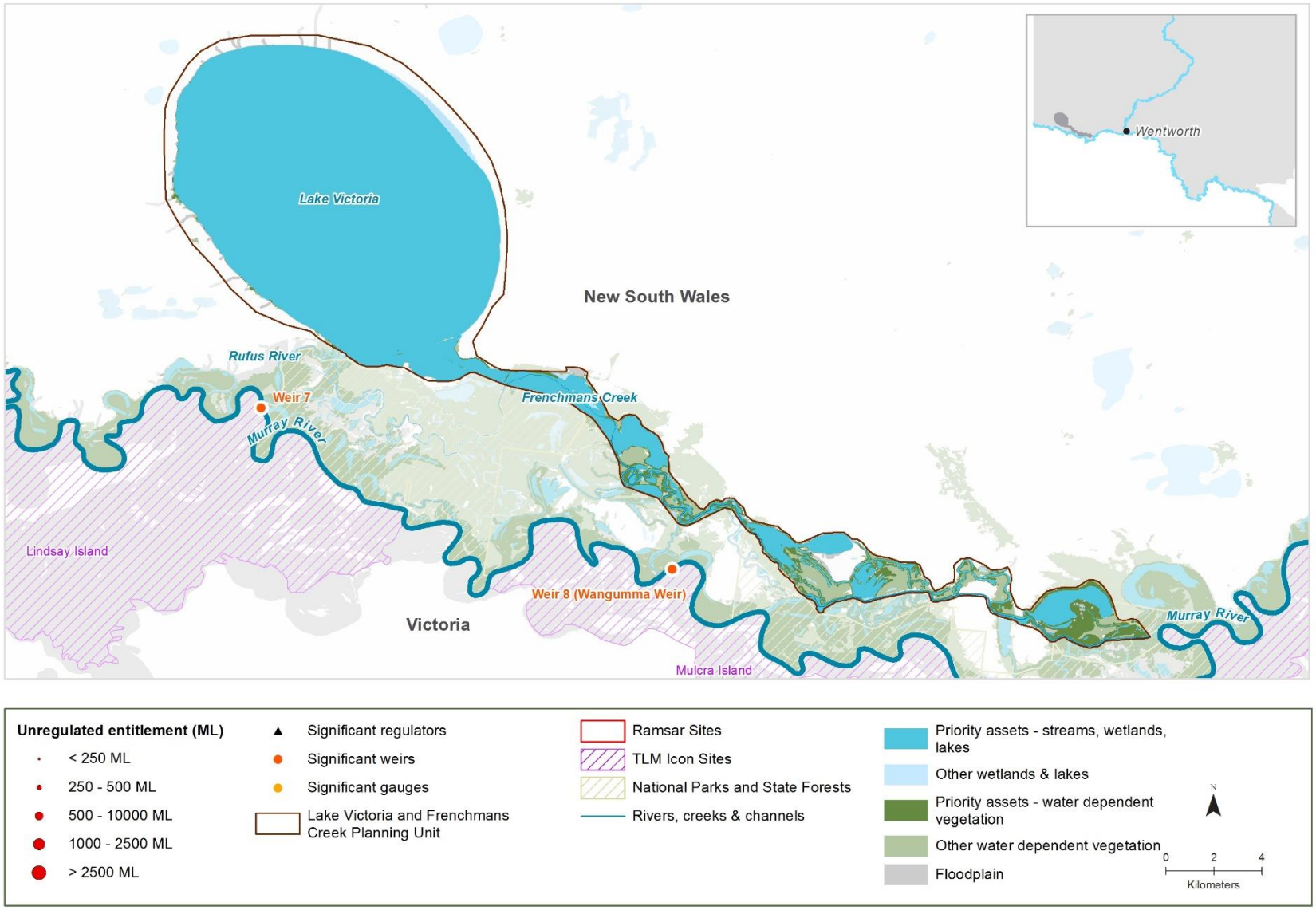
PU12: Murray River – Lock 7 to South Australian border



Priority environmental assets				
Rivers, creeks, lakes, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):				
	• Murray River (Lock 7 to South Australian border) • Rufus River	• NSW Chowilla floodplain including: - Punkah Creek (upper portion in NSW) - Salt Creek - Hypurna Creek	• The Murray River & Lock 7 also influences Victorian environmental assets: Lindsay-Mulcra-Wallpolla (TLM Icon site) • Nampoo • Cliffhouse • Lake Victoria Station	
Native fish	• Australian smelt • bony herring • dwarf flathead gudgeon	• flat-headed gudgeon • freshwater catfish (eel-tailed catfish) • golden perch	• Murray cod • Murray–Darling rainbowfish • silver perch	• spangled perch • unspecked hardyhead • carp gudgeon
Birds	59 water-dependent bird species recorded, including the following listed[70] waterbird species:			
	• Caspian tern (J)	• eastern great egret (J)	• sharp-tailed sandpiper (C,J,K)	
Native vegetation	9 water-dependent PCTs, including non-woody wetland, lignum & nitre goosefoot shrubland & wetland, river red gum forest, & black box woodland			
Other species	• eastern banjo frog • eastern sign-bearing froglet • regent parrot (V)	• giant banjo frog • barking marsh frog • eastern snake-necked turtle	• Peron's tree frog • southern bell frog (E)	• spotted grass frog • Sudell's frog
Environmental Watering Requirements	EWRs for the Murray River from Lock 7 downstream to the South Australian border are presented in Table 9 (for flows) & Table 10 (for weir pool levels) (see previous pages for PU10: Murray River – Lock 10 to Lock 9).			

[70] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

PU13: Frenchmans Creek and Lake Victoria



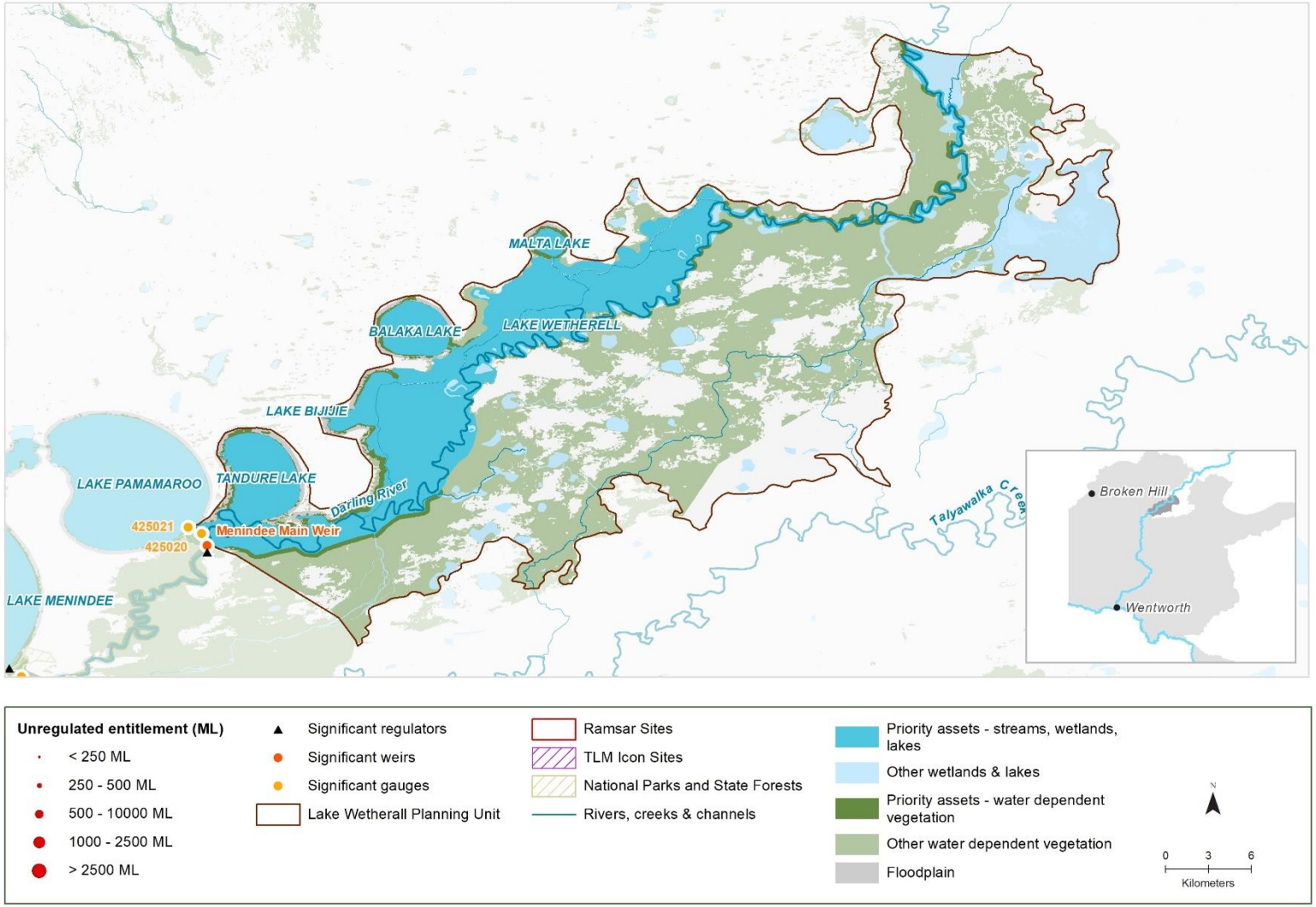
Priority environmental assets				
Rivers, creeks, lakes, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):				
• Lake Victoria • Frenchmans Creek			• Frenchmans Floodplain • Carrs Billabong	
Native fish	• Australian smelt • bony herring • dwarf flathead gudgeon	• flat-headed gudgeon • golden perch • silver perch • Murray cod	• Murray-Darling rainbowfish • unspecked hardyhead • southern pygmy perch	• Murray hardyhead reintroduction site[71] • carp gudgeon • short-headed lamprey
Birds	43 water-dependent bird species recorded, including the following listed[72] waterbird species:			
	• Caspian tern (J)	• common sandpiper (C,J)	• eastern great egret (J)	• freckled duck (V)
Native vegetation	11 water-dependent PCTs, including non-woody wetland, lignum & nitre goosefoot shrubland & wetland, river red gum forest, & black box woodland			
Other species	• eastern banjo frog • eastern sign-bearing froglet	• giant banjo frog • barking marsh frog • Peron's tree frog	• southern bell frog (E) • spotted grass frog • eastern snake-necked turtle	
Environmental Water Requirements	Operation of Lake Victoria is currently guided by the Lake Victoria Operating Strategy (LVOS) (MDBC 2002), which takes into account native vegetation outcomes, protection of Aboriginal cultural heritage in accordance with the Lake Victoria Aboriginal Heritage Impact Permit No. 2471, and reliability of water supply to the lower Murray River in South Australia. Environmental water requirements will be refined and developed for these and other environmental values (native fish, waterbirds and ecosystem functions) in the future in consultation with the Lake Victoria Scientific Panel, ecologists, environmental water managers, River Murray Operations and Aboriginal Traditional Owners.			

[71] Expected (pers. comm. NSW DPIF)

[72] Listed as Commonwealth or NSW threatened (Vulnerable, Endangered or Critically Endangered) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K])

2.6 Lower Darling water management area

PU14: Lake Wetherell and Menindee top lakes (Tandure, Bijijie, Balaka and Malta)



Priority environmental assets				
Lakes, wetlands, rivers, creeks and associated fringing vegetation communities, including (but not limited to): • Darling River • Lake Wetherell • Tandure Lake • Bijiji Lake and Bijiji Creek • Balaka Lake • Malta Lake and Malta creek	• Four Mile Lake • Wintlow Lake • Whistlers Lake • Rodgers Lakes • Yepley Waterhole • Milkingerry Waterhole	• Surbinton Waterhole • Three Mile Waterhole • Alma Creek • Mundy Creek • Two Mile Creek	
Native fish[73]	• Australian smelt • carp gudgeon • dwarf flat-headed gudgeon • flat-headed gudgeon	• golden perch • silver perch • Murray cod	• Murray-Darling rainbowfish • spangled perch	• olive perchlet (P) • bony herring • unspecked hardyhead
Birds	76 water-dependent bird species recorded, including the following listed[74] waterbird species: • Caspian tern (J) • common greenshank (C,J,K)	• common sandpiper (C,J) • eastern great egret (J) • freckled duck (V)	• marsh sandpiper (C,J,K) • pectoral sandpiper (J,K) • red-necked stint (C,J,K)	• sharp-tailed sandpiper (C,J,K)
Native vegetation	16 water-dependent PCTs, including non-woody wetland, lignum & nitre goosefoot shrubland & wetland, river red gum forest & woodland, & black box woodland			
Other species	• spotted grass frog • green tree frog • Macquarie turtle	• Peron's tree frog • inland forest bat (V)	• eastern sign-bearing froglet • little pied bat (V)	• trilling frog • broad-shelled turtle

[73] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

[74] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

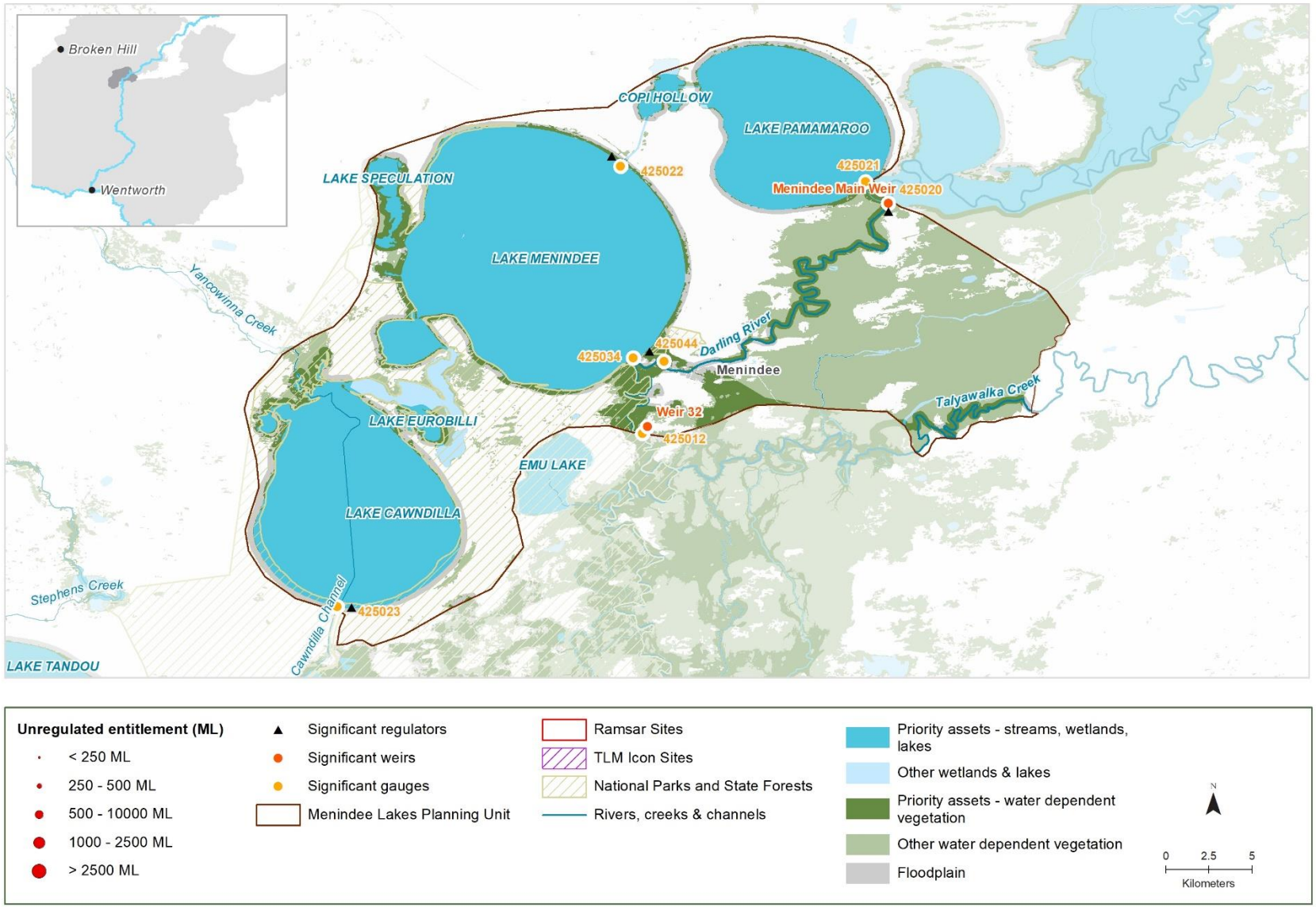
Table 11 Environmental watering requirements for Lake Wetherell, Tandure, Bijijie, Balaka and Malta.
Representative gauge: Darling River at Lakes Wetherell and Tandure Storage Gauge (425020)

Flow category & EWR code[75]		Ecological objectives[75] Primary objectives indicated in bold	Gauge	Lake level (mAHD)	Timing[75]	Duration[75]	Frequency[75] (& LTA[76] frequency)	Maximum inter-event period[75]	Additional watering requirements[75]
Low-level lake fill Lake Wetherell minimum fill	LLLF	Native Fish: NF1 – survival (all species) Ecosystem Functions: EF1 – **drought refuge**	Lake Wetherell & Tandure (425020)	> 57.8	All year	Continuous	9-10 years in 10 *(90%)*	145 days	
Mid-level lake fill Partial connection of Menindee Top Lakes – connecting Lakes Tandure, Bijijie & Balaka	MLLF	Native fish: NF4,6,9 – **Recruitment & dispersal of flow pulse specialists** Native vegetation: non-woody, fringing RRG, black box, lignum Waterbirds: WB1–5 – habitat & potential breeding Ecosystem functions: EF1–6 refuge; **productivity**; transfer of carbon and nutrients	Lake Wetherell & Tandure (425020)	>61.1 m	Anytime	30 days minimum	5-10 years in 10 *(75%)* (clustered events ideally 3–18 months apart to allow dispersal of golden/silver perch)	4 years	Filling followed by drawdown & disconnection of top lakes for <1 year For re-connection events to aid golden/silver perch dispersal, provide a fish exist cue: a short rapid drop, hold, then gradual drawdown. It's important for Lake Malta to be reconnected within 18 months of initial filling to allow dispersal of native fish recruits
High-level lake fill **Full connection of Menindee Top Lakes –** connecting Lakes Tandure, Bijijie, Balaka <u>& Malta</u>	HLLF			>61.8 m			3–5 years in 10 *(40%)* (clustered events ideally 3–18 months apart to allow dispersal of golden/silver perch)	4 years	

[75] See Glossary: Definitions and explanatory text for EWRs.

[76] Long term average frequency (% of years).

PU15: Menindee Lakes system



Priority environmental assets				
Lakes, wetlands, rivers, creeks and associated fringing vegetation communities, including (but not limited to):				
	• Darling River (Lake Wetherell to Weir 32) • Lake Menindee • Pamamaroo Lake • Lake Cawndilla	• Copi Hollow • Lake Speculation • Lake Eurobilli •	• Cawndilla Creek • Three Mile Creek • Washpen Waterhole	
Native fish[77]	• Australian smelt • bony herring • dwarf flathead gudgeon	• flat-headed gudgeon • Murray–Darling rainbowfish • spangled perch	• silver perch • golden perch • Murray cod	• olive perchlet (P) • carp gudgeon • unspecked hardyhead
Birds	99 water-dependent bird species recorded, including the following listed[78] waterbird species:			
	• Australasian bittern (E) • blue-billed duck (V) • brolga (V) • Caspian tern (J) • common greenshank (C,J,K)	• common sandpiper (C,J) • eastern great egret (J) • freckled duck (V) • Latham's snipe (J,K) • lesser sand-plover (V,C,J,K)	• magpie goose (V) • marsh sandpiper (C,J,K) • Pacific golden plover (C,J,K) • red-necked stint (C,J,K) • red knot (C,J,K)	• sanderling (V,C,J) • sharp-tailed sandpiper (C,J,K) • whimbrel (C,J,K) • white-winged black tern (C,J)
Native vegetation	14 water-dependent PCTs, including non-woody wetland, lignum & nitre goosefoot shrubland & wetland, river red gum forest, black box woodland and coolabah woodland			
Other species	• eastern sign-bearing froglet • green tree frog • inland forest bat (V)	• barking marsh frog • Peron's tree frog • little pied bat (V)	• spotted grass frog • Sudell's frog • broad-shelled turtle	• trilling frog • Hanley's river snail (CE) • Macquarie turtle

[77] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

[78] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Table 12 Environmental watering requirements for Lake Menindee and Lake Cawndilla
Representative gauges: Darling River at Lake Menindee – Storage Gauge (425022) and Lake Cawndilla Storage Gauge (425023)

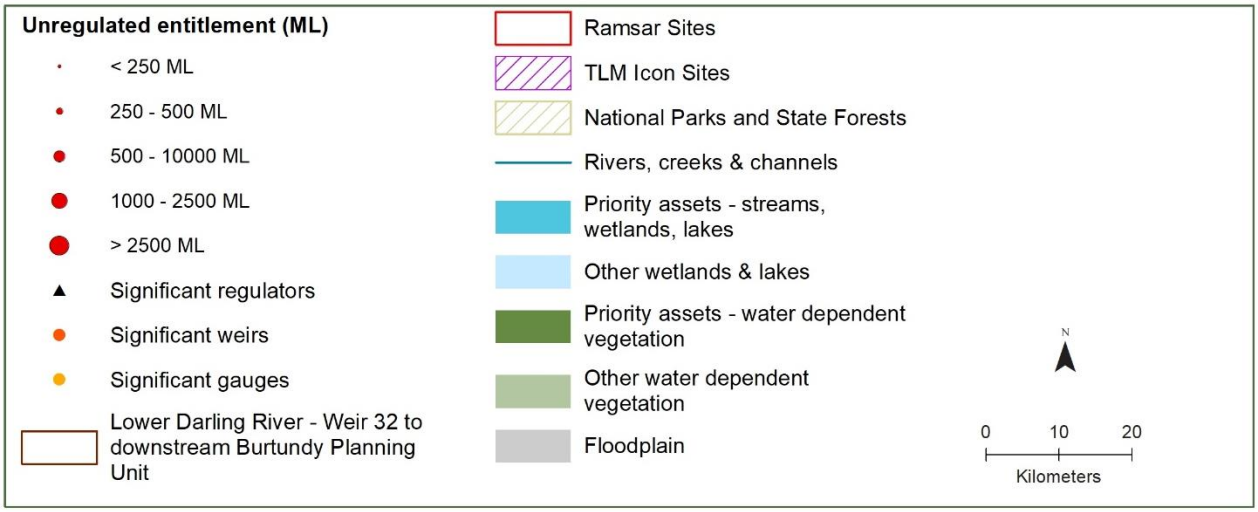
Flow category & EWR code[79]	Ecological objectives[79] (primary objectives in bold)	Gauge	Magnitude			Timing[79]	Duration[79] (retention time)	Frequency[79] *(and LTA frequency)*[80]	Maximum inter-event period[79]	Additional watering requirements[79]
			Lake level (mAHD)	Approx. volume (GL)	Approx. depth (m)					
Low-level lake fill (LLLF)	Native Fish: NF1 – survival (all species) Vegetation: NV2a, 3, 4e – **non-woody wetland,** fringing RRG, **lignum-nitre goosefoot shrublands** Waterbirds: WB1,2,5 – **maintain habitat** Ecosystem Functions: EF1, 2, 3, 4, 5 – **refuge habitat, productivity,** groundwater recharge	Lake Menindee	56.0	60	1.5	Anytime filling to be triggered by upstream flows in the Barwon–Darling River system~	Min: 3–5* months Drawdown ideally at <4 cm/d^{+}	6–8 years in 10 (70%) (the low level fill can be met by mid-high level fills i.e. not additional to)	2 years (very important to have a refill event before it dries)	*minimum of 5 months retention time if waterbird breeding is detected # Ideally no longer than 3 years between events for native fish, waterbird and vegetation outcomes + Drawdown rate of <4 cm/d to allow plant roots to track soil moisture. Drawdown rates need to also consider potential cultural heritage impacts (knowledge gap)
		Lake Cawndilla	53.8	50	1.5				7 years (ideally 3 years[#])	
Mid-level lake fill (MLLF)	Native Fish: NF4, 5, 6 – **dispersal & recruitment of flow pulse specialists in Lakes Menindee & Cawndilla & dispersal to downstream river systems;** spawning & recruitment of flow pulse & riverine specialists downstream in the LDR Vegetation: NV2a, 2b, 4b, 4e – **non-woody wetland, lignum-nitre goosefoot shrublands, fringing RRG, low-lying black box & coolibah** Waterbirds: WB1, 2, 4, 5 – colonial breeding & **habitat** Ecosystem Functions: EF2, 3, 4, 5, 6 – nutrient & carbon exchange, **productivity**, groundwater recharge	Lake Menindee	56.5	116	1.8	Anytime filling to be triggered by upstream flows in the Barwon–Darling River system~	Min: 3–5* months Drawdown ideally at < 4cm/d^{+} Drawdown of Cawndilla for at least 70 days to ensure connection with Murray for >30 days^	3–5 years in 10 (40%) (ideally clustered as groups of 2–3 successive events 3–18 months apart to maximise golden perch outcomes, promote lignum & black box recruitment & recovery, & maximise waterbird breeding outcomes)	4 years	* Duration – 3 months minimum retention for golden perch recruitment, 4–5 months retention at target level if colonial waterbird breeding is detected (extend to breeding completion) # Ideally no longer than 4 years between events for native fish, waterbird and vegetation outcomes ^Drawdown of Lake Cawndilla (releases to Redbank Creek & Darling Anabranch) should include an exit cue for fish & occur over at least 70 days to ensure a connection to the River Murray for >30 days for native fish dispersal. E.g. 7 days at 2000 ML/d followed by 63 days at 850–1000 ML/d (67–77 GL release). For sequential filling events, 2nd filling can be for a shorter duration to promote dispersal of golden perch recruits out of Cawndilla to Anabranch or back to Lake Menindee. While filling the lakes, allow translucent transfer of a proportion of early flows from
		Lake Cawndilla	54.5	84	2.2				7 years (ideally 4 years[#])	
High-level fill (HLLF)	Native Fish: Native Fish: NF4, 5, 6 – **dispersal & recruitment of flow pulse specialists in Lakes Menindee & Cawndilla & dispersal to downstream river systems;** spawning & recruitment of flow pulse & riverine specialists downstream in the LDR; Vegetation: NV2a, 2b, 3, 4c, 4d, 4e – **lignum & black box** Waterbirds: WB1,2,4,5 – **colonial breeding & habitat** Ecosystem Functions: EF1, 2, 3, 4, 5, 6 – nutrient & carbon exchange, **productivity,** groundwater recharge	Lake Menindee	57.5	*Information not available*		Anytime filling to be triggered by upstream flows in the Barwon–Darling River system~	Min: 3–5* months Max: 2 years Drawdown ideally <4cm/d^{+} Drawdown of Cawndilla for at least 70 days to ensure connection with Murray for >30 days^	1.5 year in 10 (15%) (ideally followed by a mid-level fill 3–18 months later, subject to natural triggers, to maximise ecological outcomes)	8 years	
		Lake Cawndilla	57.5	*Information not available*						
Very-High level fill (VHLLF)	Native Fish: Native Fish: NF4, 5, 6 – **dispersal & recruitment of flow pulse specialists in Lakes Menindee & Cawndilla & dispersal to downstream river systems;** spawning & recruitment of flow pulse & riverine specialists downstream in the LDR Vegetation: NV2a, 2b, 3, 4c, 4d, 4e – **non-woody**	Lake Menindee	58.5	410	3.8	Anytime filling to be triggered by upstream flows in the	Min: 3–5* months Max: 1 year Drawdown ideally <4cm/d^{+}	1 year in 10 (10%) (ideally followed by a high or mid-level fill 3–18 months later, subject to natural triggers, to	10 years	

[79] See Glossary: Definitions and explanatory text for EWRs.

[80] Long term average frequency (% of years).

Flow category & EWR code[79]	Ecological objectives[79] (primary objectives in bold)	Gauge	Magnitude			Timing[79]	Duration[79] (retention time)	Frequency[79] *(and LTA frequency)*[80]	Maximum inter-event period[79]	Additional watering requirements[79]
			Lake level (mAHD)	Approx. volume (GL)	Approx. depth (m)					
	wetland, lignum-nitre goosefoot shrublands, fringing RRG, high elevation black box & coolibah Waterbirds: WB1, 2, 4, 5 – **colonial breeding & habitat** Ecosystem Functions: EF1, 2, 3, 4, 5, 6 – nutrient & carbon exchange, **productivity,** groundwater recharge	Lake Cawndilla	58.5	470	5.8	Barwon–Darling River system~	Min: 3–5* months Max: 1 year Drawdown ideally <4cm/d[+]	maximise ecological outcomes)		the river upstream of the Menindee Lakes to the Lower Darling River to preserve flood related ecological cues.

PU16: Lower Darling River – Weir 32 to downstream of Burtundy



Priority environmental assets				
Rivers, creeks, lakes, wetlands & their associated floodplains & fringing native vegetation, including:				
	• Darling River • Darling Anabranch (from offtake regulator on lower Darling River to junction with Redbank Creek) • Yampoola Creek	• Charlie Stones Creek • Coonalhugga Creek • Tandao Creek (upper)Cuthero Creek • Frenchmans Creek (L.Darling)	• Emu Lake • Travellers Lake • Lake Are • Basin Lake • Paradise Lake • Lake Bintullia • Cuthero Lake • Yartla Lake	• Porters Lakes • Yampoola Lagoon • Stud Ewe Billabong • Deep Creek • Woolshed Billabong • Barnes Billabong • numerous unnamed wetlands along the lower Darling River
Native fish	• Australian smelt • bony herring • carp gudgeon	• dwarf flathead gudgeon • flat-headed gudgeon • freshwater catfish (eel-tailed catfish)	• golden perch • Murray cod • Murray–Darling rainbowfish	• silver perch • spangled perch • unspecked hardyhead
Birds	88 water-dependent bird species recorded, including the following listed[81] waterbird species:			
	• Australasian bittern (E) • blue-billed duck (V) • brolga (V) • Caspian tern (J)	• common greenshank (C,J,K) • common sandpiper (C,J) • curlew sandpiper (E,CE,C,J,K)	• eastern great egret (J) • freckled duck (V) • grey plover (C,J,K) • lesser sand-plover (V,C,J,K)	• marsh sandpiper (C,J,K) • red-necked stint (C,J,K) • sanderling (V,C,J) • sharp-tailed sandpiper (C,J,K)
Native vegetation	14 water-dependent PCTs, including non-woody wetland, lignum & nitre goosefoot shrubland & wetland, river red gum forest, & black box woodland			
Other species	• eastern sign-bearing froglet • green tree frog • inland forest bat (V)	• barking marsh frog • Peron's Tree Frog • little pied bat (V)	• spotted grass frog • Sudell's frog • yellow-bellied sheathtail-bat (V)	• regent parrot (V) • Hanley's river snail (CE) • broad-shelled turtle

[81] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Table 13 Environmental watering requirements for the lower Darling River – Weir 32 to downstream of Burtundy.
Representative gauges: Darling River upstream Weir 32 (425012) and Darling River at Burtundy (425007)

Flow Category & EWR code[82]		Ecological objective[82] (Primary objectives in bold)	Gauge	Flow rate[82] (ML/d)	Timing[82]	Duration[82]	Frequency[82] (& LTA frequency[83])	Maximum inter-event period[82]	Additional watering requirements
Cease-to-flow	CTF	Native Fish: NF1 – Survival (all species) Ecosystem Functions: EF1, 2, 4 – refuge habitat	Weir 32 & *(Burtundy)*	Cease to flow events are not desired – although CTF events did occasionally occur pre-development, the system is now significantly altered meaning that CTF events are likely to have significant negative impacts on ecosystems, especially native fish. When restarting flows from cease-to-flow or prolonged periods of flows <250 ML/d (Apr–Aug)/300 ML/d (Sep–Mar) at Weir 32, avoid harmful water-quality impacts such as de-oxygenated refuge pools. Requirements for restarting flows are: *(flows are at u/s Weir 32)* **Sep–Nov:** >1500 ML/d for a minimum of 7 days, followed by >800 ML/d until end of Nov (to support cod nesting & avoid dewatering nesting sites). If very low water availability, then recede to >300 ML/d for as long as possible. **Dec–Mar**: >2000 ML/d for a minimum of 3–4 days, followed by >1500 ML/d for 3–4 days, then >300 ML/d for as long as possible **Apr–Aug:** >500 ML/d for a minimum of 7 days, followed by >300 ML/d for as long as possible					
				< 150 *(<140)*	Apr-Sep only	40 days maximum	No greater than 1 year in 10 (10%)	NA	CTF events are undesirable but it is recognised that they will occur during prolonged droughts. The maximum recommended CTF frequency of 1 in 10 years is based on the need to protect the health and condition of Murray cod populations.
Very-low-flow	VF1	Native Fish: NF1 – survival (all species) Ecosystem Functions: EF1, 2 – refuge habitat (drought) ***Cool season months during drought only. Deliver baseflows BF1–2 at all other times.***	Weir 32	>150	Apr–Sep **(not suitable in warmer months – see BF1)**	365 days minimum per year	Annual (100%)	Consistent with CTF provisions (max. of 40 days below 150 ML/d, 1 year in 10)	150 ML/d is the minimum flow recommendation for the cooler months (Apr–Sep) under drought conditions only. This will not necessarily prevent water quality issues (e.g. low DO), especially if river conditions are conducive to excessive blue green algae growth or thermal stratification of the water column. Minimum flows under non-drought conditions are outlined under baseflows (BF1, 2). See requirements under CTF when restarting flows after a prolonged period of cease-to-flow or flows <300 ML/d, especially if thermal stratification &/or cyanobacteria blooms have developed.
			Burtundy	>140					
Baseflows	BF1a	Native fish: NF1 – **survival/condition (all species)** Native Vegetation: NV1 – non-woody in-channel Ecosystem Functions: EF1, 2 – **refuge habitat**, longitudinal connectivity	Weir 32 & (*Burtundy)*	>300 *(>200)*	Sep–Mar	211 days minimum during timing window	Annual *(100%)*	4 days	See requirements under CTF when restarting flows after a prolonged period of cease-to-flow or flows <300 ML/d, especially if thermal stratification &/or cyanobacteria blooms have developed. Flow velocity should be >0.03–0.05 m/s to prevent stratification of pools
	BF1b			>250 *(>180)*	Apr–Aug	153 days minimum during timing window		30 days (Apr to Aug only)	Minimum depth of 0.3 m to allow fish passage See requirements under CTF when restarting flows after a prolonged period of cease-to-flow or flows <250 ML/d, especially if thermal stratification &/or cyanobacteria blooms have developed.

[82] See Glossary: Definitions and explanatory text for EWRs

[83] Long-term average frequency (% of years)

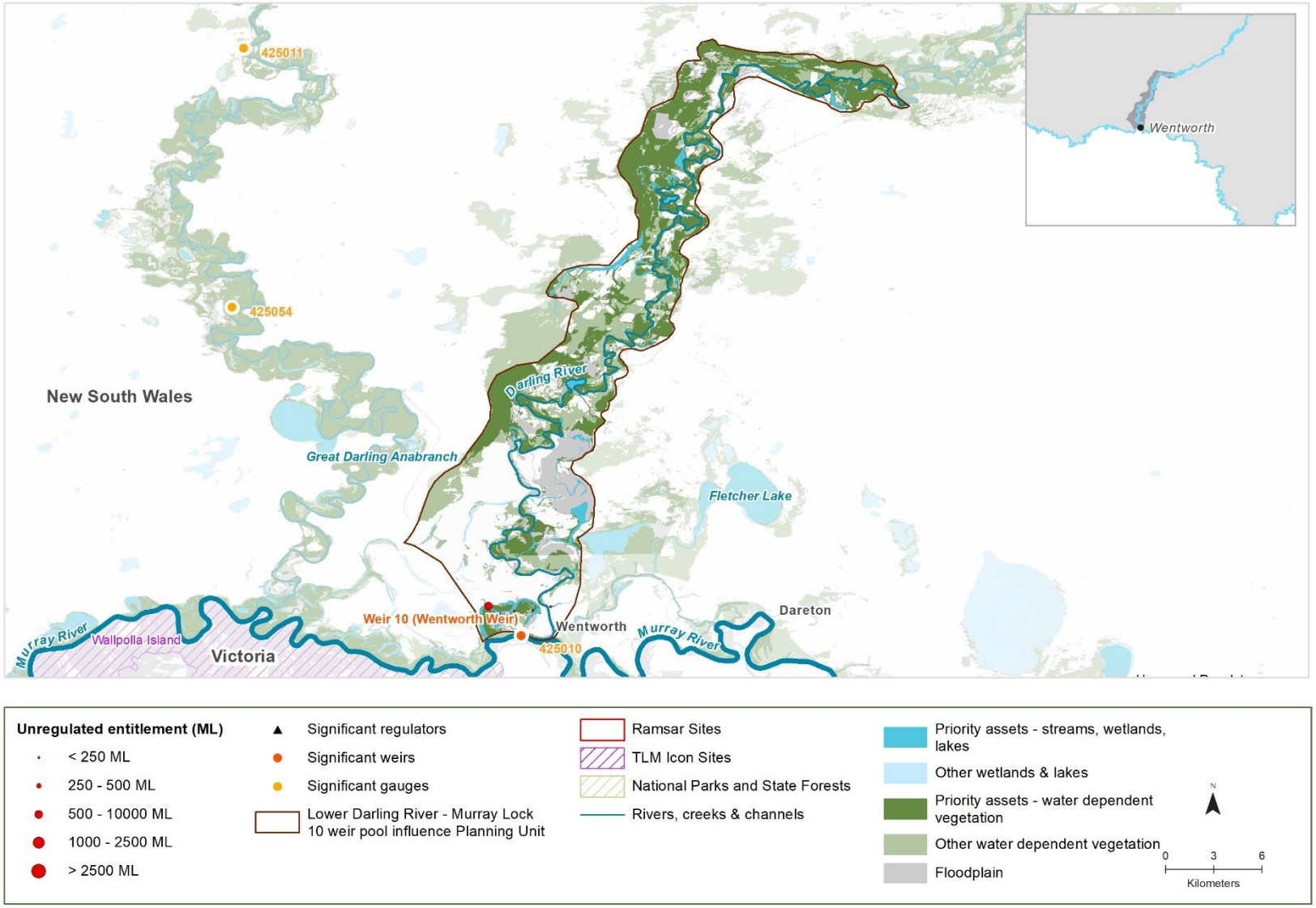
Flow Category & EWR code[82]		Ecological objective[82] (Primary objectives in bold)	Gauge	Flow rate[82] (ML/d)	Timing[82]	Duration[82]	Frequency[82] (& LTA frequency[83])	Maximum inter-event period[82]	Additional watering requirements
	BF2a	Native Fish: NF1, 2, 5, 6, 8, 9 – **Spawning, nesting & recruitment (riverine specialists, generalists)** Native Vegetation: NV1 – in-channel non-woody Ecosystem Functions: EF1, 2, 3, 4, 5, 7 – longitudinal connectivity, refuge habitat, small-scale productivity	Weir 32 & (*Burtundy)*	>400 *(>250)*	Mar–Aug	161 days minimum during timing window (ideally 184 days)	5–10 years in 10 years (75%) (ideally every year for recovery of native fish populations)	2 years	Deliver higher baseflows (BF2a–c) in sequence to maximise recruitment outcomes for Murray cod & other river specialists & generalist native fish. ^Ideally deliver > 2000 ML/d during Sep–Nov (small fresh 2) to maximise breeding outcomes. No sudden falls in water level for >21 days after Oct 1 or the detection of cod spawning to protect nesting habitat (see NFF1). Maximum rate of fall: 12% change in flow per day (or 9% during Oct–Nov cod nesting season).
	BF2b			>800^ *(>600)*	Sep–Nov	73 days minimum during timing window (ideally 91 days)			
	BF2c			>1100 *(>900)*	Dec–Feb	67 days minimum during timing window (ideally 90 days)			
Nesting support	NestS1	Native Fish: NF5, 6 – **Nesting of riverine specialists (especially Murray Cod)** (protect nesting sites by avoiding rapid changes in water levels) *NB. This EWR does not target a specific flow rate but recommends steady water levels under all water deliveries – see Baseflow 2b & Small fresh 2 for specific flow rates to support nesting species.*	Weir 32 Burtundy	If flows are 250 – 7000 ML/d at 1 Sep, hold flows steady to protect cod nests	Sep–Nov	60 days minimum starting 1 Oct (ideally 90 days Sep–Nov)	Annual	1 year (low to high water availability) 2 years (under extreme dry conditions i.e. cease-to-flow)	If flows (e-water or operational) are in this range at 1 Sep or start of Murray cod nesting, provide variable flows but avoid large sudden decreases in water level to prevent loss of nesting sites. Maximum daily rate of fall: 1% change in flow per day.
Small fresh	SF1	Native Fish: NF1,2,4,5,6 – **Dispersal/condition (flow pulse specialists, riverine specialists, generalists – autumn flow to support winter survival of adults & new recruits)**; dispersal of flow pulse specialists from Menindee Lakes^ Native Vegetation: NV1 – in-channel non-woody Ecosystem Functions: EF1,2,3,4,5,7 – Variable in-channel habitat; transport of nutrients, sediment & carbon; small-scale productivity pulse, connectivity with Murray	Weir 32 Burtundy	>2000 >1800	Mar–May	10 days minimum	5–10 years in 10 *(75%)*	2 years	Maximum rate of fall: 12% change in flow per day ^For dispersal of fish out of Menindee Lakes (see Other Requirements for Large Fresh 1, 2, 3) Where possible, preserve the integrity of flow pulses coming from upstream (Barwon Darling) as this will provide an opportunity for upstream dispersal of native fish (e.g. golden & silver perch)
	SF2	Native Fish: NF1,2,4,5,6 – **Spawning & nesting (riverine specialists & generalists)** Native Vegetation: NV1 – **in-channel non-woody** Ecosystem Functions: EF1–5,7 – Variable in-channel habitat; transport of nutrients, sediment & carbon; small-scale productivity, connectivity with Murray *Note: A smaller (more frequent) spawning & nesting flow is outlined under Baseflow 2b*	Weir 32 Burtundy	>2000 >1800	Sep–Nov	60 day minimum (ideally 90 days) *If only 60 days, then event should occur in Oct–Nov*	2–4 years in 10 *(30%)*	5 years	Hold flows steady throughout Sep–Nov to protect Murray cod nesting sites. Rapid changes in flow/water levels during this period can lead to loss (de-watering) of cod nesting sites. Ideally, commence recession in Dec. Maximum rate of fall: 1% change in flow per day.
	SF3	Native Fish: NF1–6, 8–10 – **Recruitment & dispersal following spring breeding (flow pulse specialists, riverine specialists & generalists)**; possible spawning of flow pulse specialists; dispersal of flow pulse specialist recruits from Menindee Lakes^ Native vegetation: NV1 – in-channel non-woody Ecosystem Functions: EF1,2,3,4,5,7 – as for SF1,2	Weir 32 Burtundy	>2000 >1800	Dec–Apr	14 days minimum	5–10 years in 10 years^ *(75%)*	2 years	Maximum rate of fall: 12% change in flow per day Where possible, preserve the integrity of flow pulses coming from upstream (Barwon Darling) as this will provide an opportunity for upstream dispersal of native fish (especially important for golden & silver perch)

Flow Category & EWR code[82]		Ecological objective[82] (Primary objectives in bold)	Gauge	Flow rate[82] (ML/d)	Timing[82]	Duration[82]	Frequency[82] (& LTA frequency[83])	Maximum inter-event period[82]	Additional watering requirements
Large Fresh	LF1	Native Fish: NF1, 3, 4, 6, 7 – **Dispersal of flow pulse specialist recruits, especially golden/silver perch from Menindee Lakes to lower Darling & Murray rivers^**; dispersal of floodplain specialists into/from low-lying wetlands Ecosystem Functions: EF2–6 – as for LF1 Other species: OS1,2 – frogs	Weir 32	>7000	Feb–June (or anytime for natural events connecting Menindee /Cawndilla lakes with LDR)	5 days minimum	3–5 years in 10 *(40%)* *Especially important following mass golden/silver perch recruitment in Menindee Lakes*	4 years	Maximum rate of fall: 13% change in flow per day. Avoid recession in Sep–Nov, to prevent cod nest drying (See Nesting Support NS1). LF2 – requirements for spawning of flow pulse specialists 1) Rapid rise to cue spawning (e.g. 20–56% increase in flow per day for flows up to 7000 ML/d, then ~11% increase for flows >7000 ML/d. These are equivalent to the 95th percentile of natural rates of rise & have been associated with previous spawning responses. 2) A short sharp spike, approximately half way up the rising limb of the fresh, may increase spawning response (rates of rise should be ~20–50% increase in flow per day) 3) >17^{0}C water temperature Provide exit cue for fish out of wetlands & lakes (short sharp drop in flow over 2–3 days, then plateau for a few days, then gradual recession to baseflows). ^For dispersal of fish out of Menindee Lakes 1) LF2 is particularly important in years with high flows in spring/summer which supported strong native fish spawning events (in Barwon–Darling & norther tributaries) 2) Ideally retain water in Lake Menindee & Cawndilla for at least 3 months following inflows & prior to release of flows from Lakes; &/or deliver a large fresh as a translucent flow from the Darling River upstream of Lake Menindee. Where possible, preserve the integrity of flow pulses coming from upstream (Barwon–Darling) to promote longitudinal connectivity to support the dispersal of biota; transport of nutrients & carbon; & productivity outcomes. # Wetland filling & retention times are a knowledge gap in the lower Darling River system. Shorter duration freshes may be sufficient to maintain inundation for 2–6 months.
			Burtundy	>6000					
	LF2	Native Fish: NF1–9 – **Spawning (flow pulse specialists)**; dispersal of floodplain specialists into/from low-lying wetlands; dispersal of flow pulse specialist recruits from Menindee Lakes^ Native Vegetation: NV1, 2, 3 – non-woody in-channel & wetland; fringing woodlands Ecosystem Functions: EF2–6 – **Lateral connectivity with low-lying wetlands, in-channel benches**; hydraulic diversity; geomorphic maintenance; productivity; **transport of nutrients, sediment, carbon;** biotic dispersal; connectivity with Murray	Weir 32	>7000	Dec–Apr (or anytime for natural events)	5 days minimum	5–10 years in 10 years *(75%)*	2 years	
			Burtundy	>6000					
	LF3	Native fish: NF1, 3, 4, 6, 7 Native Vegetation: NV1, 2a, 2b, 3 – **non-woody in-channel & wetland**; **fringing woodlands** Waterbirds: WB5 – condition of waterbird habitats Ecosystem Functions: EF2, 3, 4, 5, 6 – as for LF1, 2 but more productivity & longer connectivity with wetlands & the River Murray Other species: OS1,2 – frog habitat & condition	Weir 32	>7000	Aug–Dec (or anytime) *Avoid recession in Oct to protect Murray cod nests*	14 days minimum (to achieve 2–6 months of wetland inundation for non-woody vegetation outcomes#)	5–10 years in 10 years *(75%)*	2 years	
			Burtundy	>6000					

Flow Category & EWR code[82]		Ecological objective[82] (Primary objectives in bold)	Gauge	Flow rate[82] (ML/d)	Timing[82]	Duration[82]	Frequency[82] (& LTA frequency[83])	Maximum inter-event period[82]	Additional watering requirements
Bankfull flow – *natural events or relaxed constraints*	BK1	Native Fish: NF1–10 – Spawning (flow pulse specialists); dispersal (all species); dispersal of flow pulse specialists from Menindee Lakes^ Native Vegetation: NV1,2,3,4 –**non-woody wetland**; **fringing/floodplain woodlands** Waterbirds: WB1–5 – waterbird foraging habitat; support natural breeding events Ecosystem Functions: EF1–7 – **lateral connectivity with in-channel benches, wetlands (3–25% of wetland area) & the Darling Anabranch (meeting SF1 at Wycot);** dispersal of biota; channel maintenance; productivity; nutrient/carbon exchange between channel & wetlands/low-lying floodplain Other species: OS1,2 – frog habitat & breeding	Weir 32	>10,000 (10,000 – 12,000)	Ideally Aug–Oct or Jan – Apr (or anytime)	14 days minimum# (to achieve 2–6 months of wetland inundation)	5–8* years in 10 *(65%)*	2 years	Maximum rate of fall: 11% change in flow per day (9% during Oct–Nov, the cod nesting season) Provide exit cue for native fish to leave wetlands & lakes prior to recession (see Other Requirements for Large Freshes 1, 2, 3) If recession occurs in late winter/spring, apply slow recession Oct to mid-Nov once flows are <7000 ML/d (hold/vary 5000–7000 ML/d) – prevent cod nest drying & maintaining WLs in wetlands to support native vegetation & waterbird habitat & foraging. * Annual event for 2–3 consecutive years for recovery of wetland vegetation. ^ For dispersal of fish out of Menindee Lakes (see Other Requirements for Large Freshes 1, 2, 3)
			Burtundy	>9,000 (9,000 – 10,000)					
	BK2	Provide a large fresh in the Darling Anabranch targeting the Old Anabranch (LF1 (800 ML/d) in Darling Anabranch at Wycot). Objectives as for BK1 above (but only a partial connecting flow in the Anabranch).	Weir 32	> 12,000	Ideally Aug–May, or anytime for natural flows	21 days	2–3 years in 10 *(25%)*	4 years	
Small Overbank - *natural events only*	OB1	Native Fish: NF1–10 – dispersal (all species); floodplain specialists (survival, condition) Native vegetation: NV1, 2, 3, 4 **– non-woody wetland; fringing/floodplain woodlands & lignum/nitre goosefoot shrublands** Ecosystem functions (EF1–7) – Lateral connectivity with benches, wetlands (40–70%), low-lying floodplain & Darling Anabranch (meets BK1 at Wycot), **productivity** Other species: OS1,2 – frog habitat & breeding	Weir 32	> 15,000	Aug–Nov (or anytime)	14 days minimum	5 years in 10 *(50%)* (ideally clusters of 2 successive events 6–18 months apart)	3 years (ideally 2 years#)	Maximum rate of fall: 11% change in flow per day (7% during Oct–Nov, the cod nesting season) # ideally 2 years to support lignum condition
			Burtundy	>11,000					
	OB2	Native Fish: NF1–10 – dispersal (all species); floodplain specialists (survival, condition) Native vegetation: NV1–4 **– non-woody wetland; fringing/floodplain woodlands & lignum/nitre goosefoot shrublands** Ecosystem functions (EF1–7) – Lateral connectivity with >50% wetland area, low-lying floodplain & Darling Anabranch (meets OB1), **productivity** Other species: OS1, 2 – frog habitat & breeding	Weir 32	> 17,000	Anytime	14 days minimum	5 years in 10 *(50%)*	4 years	Maximum rate of fall: 11% change in flow per day (7% during Oct–Nov, the cod nesting season where possible)
			Burtundy	>13,000					
Medium Overbank – *natural events only*	OB3	Native Fish: NF1–10 – Spawning (floodplain specialists), dispersal (all species) Native Vegetation: NV1–4 – **non-woody wetland; RRG, black box & lignum/nitre goosefoot shrublands** Ecosystem functions (EF1–7) – **Lateral connectivity with Darling Anabranch (meeting LF1,BKF, OB1),** >65% wetlands along LDR & the low-lying floodplain; **between catchment connectivity^**	Weir 32	>20,000	Anytime	30 days minimum	2–3 years in 10 (20%)	10 years (ideally 8 years#)	^Achieves longitudinal connectivity between upstream & downstream of Weir 32 (including connection via Talyawalka/ Charlie Stone Creek & Tandou Creek. # ideally max. inter-event period of 8 years (OB3) to prevent major decline of black box condition
			Burtundy	>16,000					

Flow Category & EWR code[82]		Ecological objective[82] (Primary objectives in bold)	Gauge	Flow rate[82] (ML/d)	Timing[82]	Duration[82]	Frequency[82] (& LTA frequency[83])	Maximum inter-event period[82]	Additional watering requirements
Large Overbank - *natural events only*	OB4	Native fish: NF1, 3, 7, 10 – Dispersal & condition of floodplain specialists Native Vegetation: NV1, 2, 3, 4a, 4b, 4e – **non-woody wetland, RRG, Black box & lignum/nitre goosefoot shrublands** Waterbirds: WB1–5, breeding & habitat Ecosystem functions: EF2, 5, 6, 7 – broad scale lateral connectivity with wetlands (70–100% of wetland area), floodplain & Darling Anabranch (meets OB2); **productivity; between catchment connectivity^**	Weir 32	> 25,000	Anytime	45 days minimum	1 year in 10 *(10%)*	12 years (ideally 10 years#)	# ideally max. inter-event period of 10 years (OB4/5) to prevent major decline in black box condition
			Burtundy	>17,000					
	OB5	Native Vegetation: NV2, 3, 4a, 4b, 4e – **black box & lignum/nitre goosefoot** Waterbirds: WB1–5, breeding & habitat Functions: EF2, 5, 6, 7 – broad scale lateral connectivity with wetlands (100% total wetlands), floodplain & Darling Anabranch (meets OB3); **productivity; between catchment connectivity^**	Weir 32	> 45,000	Anytime	5 days minimum	1 year in 10 *(10%)*	14 years (ideally 10 years#)	
			Burtundy	> 22,000					

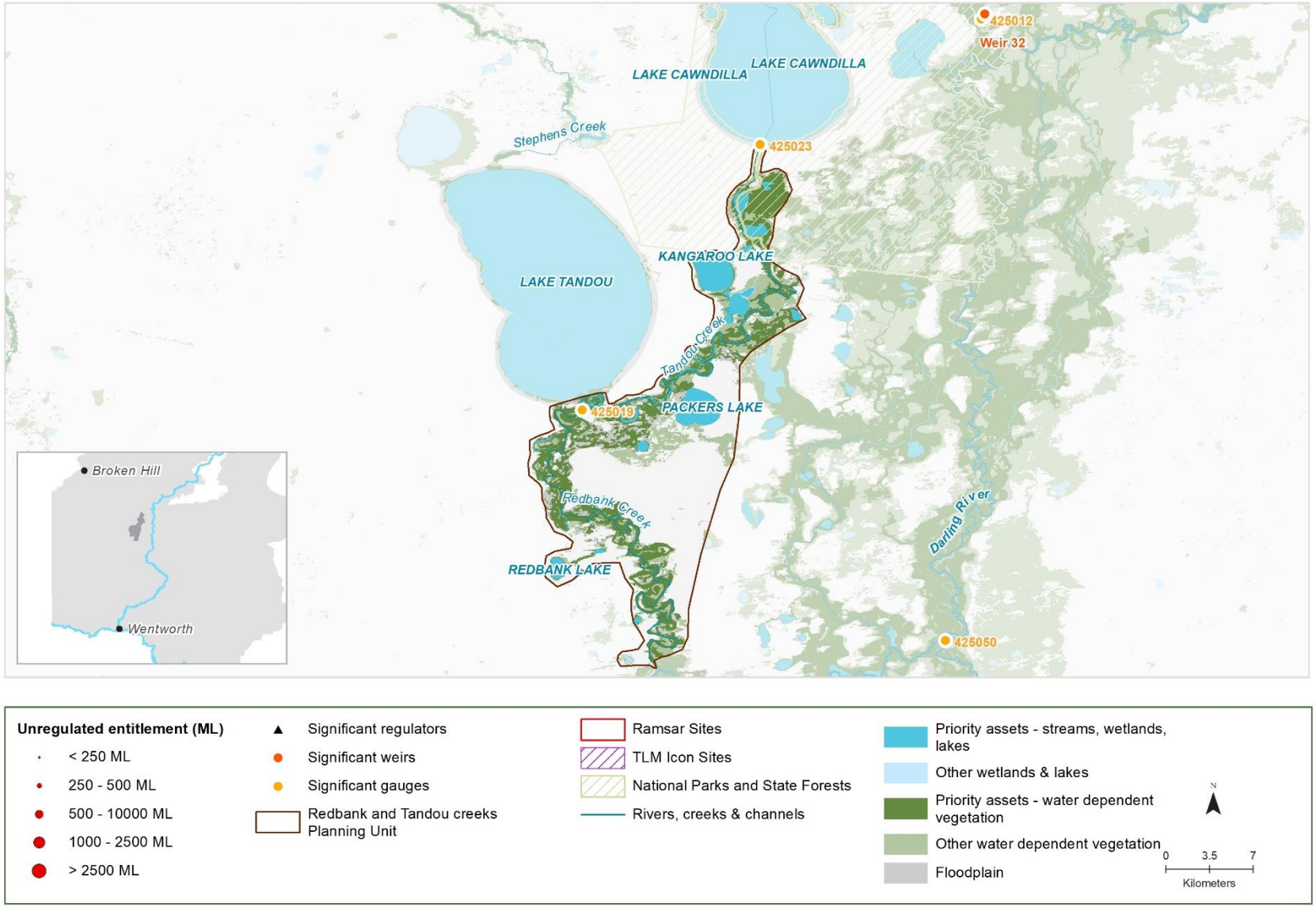
PU17: Lower Darling River – Murray Lock 10 weir pool influence



Priority environmental assets				
Rivers, creeks, wetlands, lakes & their associated floodplains & fringing native vegetation, including (but not limited to):				
	• Darling River (Murray Lock 10 weir pool influence from downstream Burtundy to Murray River) • Thegoa Lagoon • Andruco Lagoon • Sturts Billabong		• Tinghi Creek • Boydes Creek • Three Mile Creek • Tincha Creek • Several unnamed wetlands along the lower Darling River	
Native fish	• Australian smelt • bony herring • dwarf flathead gudgeon	• flat-headed gudgeon • freshwater catfish (eel-tailed catfish) • carp gudgeon	• golden perch • Murray cod • Murray–Darling rainbowfish	• silver perch • spangled perch • unspecked hardyhead
Birds	73 water-dependent bird species recorded, including the following listed[84] waterbird species:			
	• Australasian bittern (E) • brolga (V)	• Caspian tern (J) • cattle egret (J)	• eastern great egret (J) • long-toed stint (C,J,K)	• marsh sandpiper (C,J,K)
Native vegetation	10 water-dependent PCTs, including non-woody wetland, lignum & nitre-goosefoot shrubland & wetland, river red gum forests, & black box woodland			
Other species	• eastern banjo frog • eastern sign-bearing froglet • broad-shelled turtle	• barking marsh frog • Sudell's frog • eastern snake-necked turtle	• Peron's tree frog • Hanley's river snail (CE) • Macquarie turtle	• spotted grass frog • platypus
Unregulated WALs	There is 1054 ML of unregulated entitlements in the PU, of which 1032 ML are unregulated water access licences (WALs) for production. There are five productive WALs <250 ML & one between 500–1000 ML. Five of these WALs are located on Thegoa Lagoon & one is located near the lower Darling River just upstream of Wentworth.			
Environmental Water Requirements	This lower reach of the lower Darling River is influenced by Lock 10 on the Murray River (Wentworth weir), where it is not currently possible to vary weir pool levels. Ideally water levels at Lock 10 would be manipulated for environmental outcomes in the near future. A similar pattern of weir pool manipulations as outlined for Locks 7–9 (Table 10) could be followed. See also EWRs for lower Darling River at Burtundy (Table 13) & Murray River at Wentworth (Table 9) for recommended flows in this reach.			

[84] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

PU18: Redbank and Tandou creeks



Priority environmental assets				
Rivers, creeks, wetlands, lakes & their associated floodplains & fringing native vegetation, including (but not limited to):	• Tandou Creek (d/s of Cawndilla channel) • Redbank Creek	• Packers Lake • Kangaroo Lake • Collin's Lake	• Redbank Lake • Shadbolts Lake	
Native fish	• Australian smelt • bony herring	• carp gudgeon • flat-headed gudgeon • dwarf flat-headed gudgeon	• Murray cod • golden perch	• spangled perch • Murray-Darling rainbowfish
Birds	66 water-dependent bird species recorded, including the following listed[85] waterbird species:			
	• black-tailed godwit (C,J,K) • brolga (V)	• Caspian tern (J) • eastern great egret (J)	• freckled duck (V) • marsh sandpiper (C,J,K)	• sharp-tailed sandpiper (C,J,K)
Native vegetation	15 water-dependent PCTs, including non-woody wetland, lignum & nitre goosefoot shrubland & wetland, river red gum forest, & black box woodland			
Other species	• green tree frog	• Peron's tree frog	• spotted grass frog	
Environmental Watering Requirements	Presented in Table 14 along with EWRs for Planning Unit 19 – Darling Anabranch			

[85] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

PU19: Darling Anabranch

Priority environmental assets				
Rivers, creeks, wetlands, lakes & their associated floodplains & fringing native vegetation, including (but not limited to):	• Darling Anabranch • Nearie Lake • Yelta Lake • Traveller's Lake	• Lake Popio • Lake Mindona • Lake Popiltah • Little Lake	• Nialia Lake • Nitchie Lake • Warrawenia Lake • Lake Milkengay • Toora Lake
Native fish	• Australian smelt • carp gudgeon • golden perch	• spangled perch • Murray–Darling rainbowfish • flat-headed gudgeon	• dwarf flathead gudgeon • Murray cod • unspecked hardyhead	• olive perchlet (P) • bony herring
Birds	82 water-dependent bird species recorded, including the following listed[86] waterbird species:			
	• Caspian tern (J) • cattle egret (J) • common sandpiper (C,J)	• curlew sandpiper (E,CE,C,J,K) • eastern great egret (J)	• freckled duck (V) • grey plover (C,J,K) • Latham's snipe (J,K)	• marsh sandpiper (C,J,K) • red-necked stint (C,J,K) • sharp-tailed sandpiper (C,J,K)
Native vegetation	16 water-dependent PCTs, including non-woody wetland, lignum & nitre goosefoot shrubland & wetland, river red gum forest, & black box woodland			
Other species	• barking marsh frog • eastern banjo frog • eastern sign-bearing froglet • eastern snake-necked turtle	• green tree frog • barking marsh frog • little pied bat (V) • Macquarie turtle	• Peron's tree frog • spotted grass frog • yellow-bellied sheathtail-bat (V)	• Sudell's frog • inland forest bat (V) • broad-shelled turtle

[86] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E], or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Table 14 Environmental Watering Requirements for the Darling Anabranch and Redbank/Tandou creeks
Representative gauges: Great Darling Anabranch at Wycot (425013) and Redbank Creek at d/s Packer's Crossing (425019)

Flow Category & EWR code[87]	Ecological objective[87] Bold text indicates the primary objectives	Gauge	Flow rate[87] (ML/d)	Timing[87]	Duration[87]	Frequency[87] (& LTA frequency[88])	Maximum inter-event period[87]	Additional watering requirements[87]
Cease-to-flow CTF	Ecosystem Functions (EF2, 4) – drying regime; disturbance (for aquatic herbs etc); nutrient transformation; terrestrial productivity (i.e. to contribute carbon on re-wetting)	Redbank at Packers	<8	Anytime	162 days minimum 781 days maximum	5–10 years in 10 (75%)	1 year	
		Darling Anabranch at Wycot	<50	Anytime	85 days minimum 392 days maximum	5–10 years in 10 (75%)	1 year	
Small fresh SF1	<u>Partial connecting flow to Murray from lower Darling River</u> Native fish: NF4,5,6 – **Recruitment & dispersal of flow pulse specialists** Native vegetation: non-woody, fringing RRG, black box, lignum Waterbirds: WB1–5 – habitat & potential breeding Ecosystem functions: refuge; productivity	Darling Anabranch at Wycot	>100 *(100–1100)*	Aug–May (or anytime for natural flows from the LDR)	20 days minimum (ideally > 40 days)	5–8 years in 10 (65%)	2 years	Sourced preferably from lower Darling River (LDR) to avoid stranding of native fish recruits existing Lake Cawndilla. Can be sourced from Lake Cawndilla if lake at risk of drying out (to avoid stranding of native fish in lake). Timing ideally in line with natural events in LDR. Gradual rate of fall for a fish exit strategy if flows are sourced from the LDR (to cue fish to return to LDR). Full connection is preferable however a partial connection is beneficial for topping up refuge pools to support fish survival & for native vegetation. Some overbank flows may occur in Old Anabranch Offtake to Wycot at flows >500 ML/d at Wycot.
Large fresh 1 LF1	<u>Partial connecting flow to Murray sourced from lower Darling River (LDR)</u> Native Vegetation: NV1–4 – Old anabranch **non-woody in-channel & floodplain black box & lignum** Waterbirds: WB5: habitat condition Ecosystem Functions: EF1, 2, 3, 4, 5 – Connect Old Anabranch from LDR to Wycot	Darling Anabranch at Wycot	> 800 *(800–2000)* (sourced preferably from the lower Darling River)	Aug–May, (or anytime for natural flows from LDR or Darling flows upstream of Menindee Lakes)	21 days minimum	2–3 years in 10 (25%)	5 years (ideally 4 years)	Met by lower Darling flows of ~12,000–15,000 ML/d at Weir 32 (BK2 & OB1). Timing should ideally be driven by timing of natural flows in the Darling River u/s of Menindee. Deliver as semi-translucent flow from LDR (can delivery up to 2000 ML/d from the lower Darling River). Weir 32 flows need to be >14,000 ML/d to achieve 2000 ML/d at Wycot or >12000 ML/d to achieve 800 ML/d. Consider blue green algae (BGA) risk at water source prior to delivery. Delivery in cooler months will reduce the risk of BGA events & carp movement
Large Fresh 2 LF2	<u>Fully connecting flow to Murray from Lake Cawndilla (or combined with LDR flows)</u> Native fish: NV2, 4, 5, 6 – **Dispersal of flow pulse specialist recruits (especially golden perch) from Lake Cawndilla to the Murray River;** condition, breeding & recruitment of flow pulse specialists & generalists Native vegetation: NV1, 2, 4 – in-channel, fringing & floodplain vegetation in Redbank & Tandau creeks; in-channel & fringing in Darling Anabranch Ecosystem Functions: EF1–7: as for LF1 & longitudinal connectivity to the Murray, dispersal, **productivity** Other Species: OS1, 2, 4 – dispersal/breeding of frogs & yabbies	Redbank at Packers	>1000	Anytime^	70 day minimum (ideally >100 days)^	3–5 years in 10 (30%) (especially following golden perch recruitment in Menindee Lakes)	7 years (ideally 4 years)	^Deliver 3–12 months after inflows into Lake Cawndilla, dependant on golden perch size & recruitment status in the Lake. Minimum duration of 70 days is based on 40 day travel time to Murray plus a requirement for simultaneous connectivity at Murray/Anabranch junction & at Lake Cawndilla for >30 days, which is important to ensure dispersal of native fish to Murray River. Longer durations are better. Gradual recession spanning at least 15 days to promote exit of native fish to the Murray River Currently can deliver up to 1100 ML/d from Cawndilla (measured at Packers Crossing) but could supplement with flows from lower Darling River. Current delivery constraint at Packers Crossing is 1100 ML/d.
		Darling Anabranch at Wycot	> 800 *(800-2000)*					

[87] See Glossary: Definitions and explanatory text for EWRs
[88] Long-term average frequency (% of years)

Flow Category & EWR code[87]	Ecological objective[87] Bold text indicates the primary objectives	Gauge	Flow rate[87] (ML/d)	Timing[87]	Duration[87]	Frequency[87] (& LTA frequency[88])	Maximum inter-event period[87]	Additional watering requirements[87]
Bankfull BK1 Relies on relaxed constraints	Native Vegetation: NV1–4 – **in-channel, fringing, floodplain woodlands & non-woody** Native Fish: NF1, 2, 4 – spawning & recruitment (generalists); condition & dispersal (all species) Waterbirds: WB1,2,5 – habitat Ecosystem Functions: EF1–7– channel maintenance (pool scour); productivity Other species (OS1,2): frog breeding	Redbank at Packers	>1500	Anytime	15 days minimum	1 year in 10 (10%)	10 years	
		Darling Anabranch at Wycot	>2000			2–3 years in 10 (25%)	7 years (ideally 5 years)	
Small overbank OB1 *Natural events only*	Native vegetation: NV1–4 – in-channel, **fringing, floodplain (non-woody, RRG, blackbox, lignum)** Native Fish: NF1, 2, 4 – spawning & recruitment (generalists); condition & dispersal (all species) Waterbirds: WB1,2,5 – habitat Ecosystem functions: EF1–7 – lateral connectivity with wetlands & low-lying floodplains, productivity, transport of carbon, nutrients & sediment Other Species: OS1,2 – frog breeding	Darling Anabranch at Wycot	>3000	Anytime	20 days minimum (ideally >40 days)	2 years in 10 (20%)	7 years (ideally 5 years)	
Medium overbank OB2 *Natural events only*	Native Fish: NF1, 2, 4 – spawning & recruitment (generalists); condition & dispersal (all species) Native vegetation: NV1–4 - in-channel, **wetland, floodplain (non-woody, RRG, blackbox, lignum)** Waterbirds: WB1–5 – colonial & non-colonial breeding & habitat Ecosystem functions: EF1–7 – **lateral connectivity with some floodplain lakes, productivity** Other Species: OS1,2 – frog breeding	Darling Anabranch at Wycot	>8000 *Met by LDR Weir 32 flows >23,000 (OB4)*	Anytime	20 days minimum (ideally >40 days)	1–2 years in 10 (15%)	10 years	
Large overbank OB3 *Natural events only*	Native vegetation: NV1–4 – in-channel, **wetland, floodplain (non-woody, RRG, blackbox, lignum)** Native Fish: NF1, 2, 4 – spawning & recruitment (generalists); condition & dispersal (all species) Waterbirds: WB1–5 – **colonial & non-colonial breeding & habitat** Ecosystem functions: EF1–7 – **lateral connectivity with all Anabranch lakes, large scale productivity** Other Species: OS1,2 – frog breeding	Darling Anabranch at Wycot	>17,000 *Met by LDR Weir 32 flows >45,000 Ml/d (OB5)*	Anytime	15 days minimum (ideally >40 days)	1 year in 10 (10%)	14 years (ideally 10 years)	Ideally max. inter-event period of 10 years to prevent major decline in black box condition

3. Unregulated planning units

Unregulated planning units (PUs) represent areas that cannot be managed with discretionary environmental water delivered from storages or other types of regulated water delivery. Unregulated planning units include the upper Murray above Hume Dam and areas outside the floodplain of major rivers and creeks in the mid and lower Murray and lower Darling regions. In unregulated areas, the primary means of protecting environmentally important flows is via Water Sharing Plans (WSPs), which include rules to restrict pumping, trade and creation or new entitlements.

Pumping access rules for extraction from unregulated streams and off-channel pools (wetlands), as well as rules around trade are defined in the WSPs for:

- Murray Unregulated and Alluvial Water Sources
- Lower Murray-Darling Unregulated and Alluvial Water Sources.

Several rivers and creeks in the upper Murray are strongly influenced by river regulation for hydropower generation as part of the Snowy Mountain Scheme. These include the upper Murray River between Swampy Plains River and Hume Dam, the Swampy Plains River downstream of Khancoban Pondage, the Geehi River catchment (Swampy Plains water source) and the Tooma River (NSW DPI 2012). These rivers are not therefore truly unregulated but are classified as ‘unregulated’ in the WSP from the perspective that consumptive or environmental water entitlements cannot be ordered to sites along these rivers. For the purpose of the LTWP, these rivers are included in unregulated planning units but the influence of hydropower operations on their hydrology is acknowledged and addressed through recommended strategies to mitigate impacts in relevant planning units.

Unregulated planning unit boundaries in this LTWP (PUs 20-37) are typically aligned with the ‘water source’ boundaries defined in the Water Sharing Plans. However, some water sources have been split depending on how water is managed for environmental outcomes. Unregulated water sources along the Murray River downstream of Hume Dam, for example, have been split into regulated planning units that cover the area influenced by Hume Dam (i.e. the Murray River floodplain), and areas beyond the Murray River floodplain, which have been defined as unregulated planning units.

Water management in unregulated catchments of the northern basin (Barwon-Darling, Intersecting Streams as well as parts of the Gwydir, Macquarie and Border Rivers WRPAs) will be important for meeting EWRs and ecological outcomes in both regulated and unregulated planning units in the Lower Darling and Lower Murray Water Management Areas. Integration of Northern and Southern Basin LTWPs and WRPs is critical to meeting Lower Darling and Lower Murray EWRs, and more broadly, to achieving landscape-scale ecological outcomes basin-wide. Key mechanism for promoting longitudinal connectivity between the northern basin and the Murray-Lower Darling WRPA are outlined in Part A (Section 5).

3.1 Priority environmental assets in unregulated planning units

Priority environmental assets in unregulated planning units include any environmental assets[89] identified using criteria in Schedule 8 of the Basin Plan (see Part A, Section 2) that can be managed through planned environmental water, often in combination with other river flows. This definition covers all environmental assets that can be managed indirectly through WSP rules and directly through management of river operations and inter-catchment diversions as part of the Snowy Mountain Scheme.

In this LTWP area this is considered to include environmental assets[90]:

- located within 200 m of an existing unregulated water access license (WAL)
- located within 500 m of the Murray River
- located within 200 m of other natural rivers and creeks

3.2 Quantifying hydrological alteration and strategies for protecting ecologically significant flows

The broad alignment of unregulated planning unit boundaries with WSP water source boundaries means that the water requirements of priority assets and functions in the unregulated planning units can be more easily managed through the policy mechanisms that govern water in these areas.

For each unregulated planning unit, information is presented on the hydrology[91] and the degree of alteration, as determined by DPIE–Water in their *Murray-Lower Darling Water Resource Plan Risk Assessment* (DPIE–Water in prep) by comparing flows under modelled near natural conditions (with no dams or water extractions) and flows under modelled current conditions. Table 15 describes how the hydrological changes are presented for each planning unit.

Recommendations have been suggested for each PU[92] to ensure important ecological flows are protected to maintain or improve priority assets and functions.[93]

Table 15 Key to describing the degree of hydrological alteration in unregulated planning units

The degree of hydrological alteration from *Murray Lower Darling Water Resource Plan Risk Assessment* (NSW DPIE-Water, in prep)
L= Low: less than 20% departure (+/-) from the base case for each hydrologic metric
M = Medium: 20-50% departure (+/-); from the base case for each hydrologic metric

[89] Environmental assets include permanent and ephemeral water features (rivers, creeks, wetlands and lakes) as well as floodplain areas that support ecological values (e.g. water-dependant vegetation).

[90] Detailed floodplain inundation mapping is not available for the upper Murray or its tributaries. These criteria are based on a broad floodplain extent defined for the upper Murray River as part of the Basin-wide environmental watering strategy (MDBA, 2014).

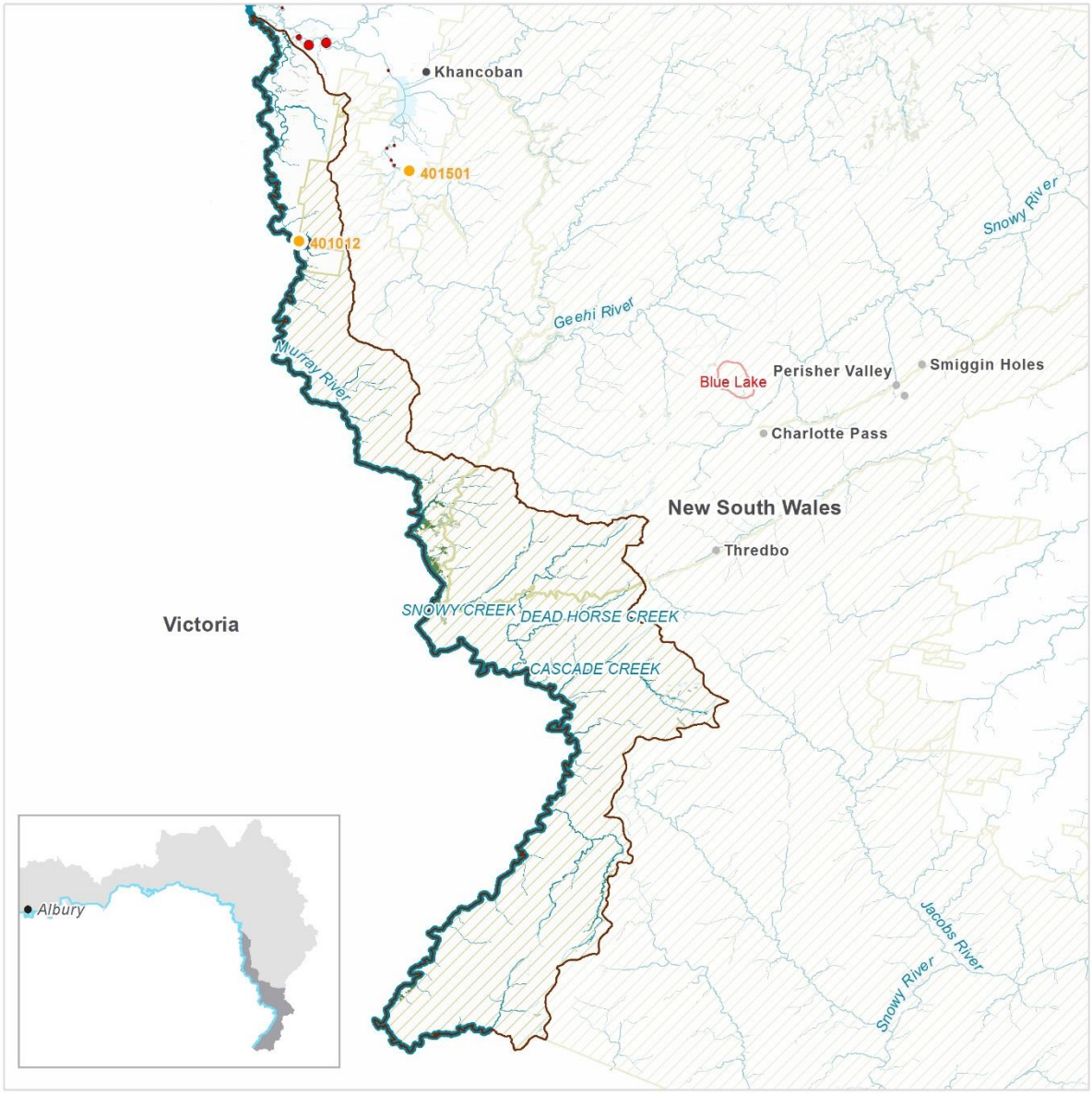
[91] The hydrology is presented as percentiles and Average Recurrence Intervals (ARIs) as determined by without-development modelling.

[92] Recommendations are based on the local hydrology, the degree of hydrological change, the water-dependent values and assets present (e.g. especially threatened native fish species), the relevant LTWP objectives, and the number, size and location of water access licenses (WALs) in the water source.

[93] To improve the specificity of rule change recommendations, a better understanding of the actual total amount of take and the individual water access licence conditions is often required.

H = High: greater than 50% departure (+/-) from the base case for each hydrologic metric
N/A = no risk outcome or modelling available due to no hydrological data available
$^{+}$ increase from near-natural condition
$^{-}$ decrease from near-natural condition
^{0} no change from near-natural condition

PU20: Indi water source (Murray headwaters to Swampy Plains River)



Priority environmental assets			
Rivers, creeks, wetlands & their associated in-channel & floodplain habitats & fringing vegetation communities, including (but not limited to): • Murray River from its headwaters to the junction with Swampy Plain River • Snowy Creek, Peach Tree Creek • Tin Mine Creek • Dales Creek • Cascade Creek • Deadhorse Creek • Leatherbarrel Creek • Pilot Creek			
Native fish[94]	• Australian smelt • mountain galaxias • obscure galaxias	• riffle galaxias • river blackfish • two-spined blackfish	• southern pygmy perch (P) • carp gudgeon
Birds	23 water-dependent bird species recorded, including the following listed[95] waterbird species: • Latham's snipe (J,K)		
Native vegetation	9 water-dependent PCTs, including: • non-woody wetland	• river red gum woodland	
Other species	• brown tree frog • common eastern froglet • platypus	• eastern banjo frog • Lesueur's frog	• Verreaux frog • eastern bentwing-bat (V)

Hydrology			
Gauge: 401012 *Murray River at Biggara*	**80th percentile**: 397 ML/d	**50th percentile**: 876 ML/d	**20th percentile**: 2242 ML/d
	1.5 ARI: 6663 ML/d	**2.5 ARI**: 9973 ML/d	**5 ARI**: 13,616 ML/d

Summary of hydrological alteration

There has been a low degree of change (<20% reduction) in flows of all categories (low flows, baseflows, freshes & high flows) compared to the 'without development' model scenario as assessed by the Murray–Lower Darling WRPA Risk Assessment.

The total volume of unregulated entitlements in the PU is 1896 ML, of which 1889 ML are water access licences (WALs) for production. There are ten production WALs <250 ML & two productive WALs between 250–500 ML that are all distributed along the Murray River near or downstream of Biggara.

	Cease-to-flow	Low flow or Baseflow	Freshes	High & infrequent flows		
				1.5 ARI	2.5 ARI	5 ARI
Hydrological alteration[96]	L-	L-	L-	L-	L-	L-
Relevant rules	Rivers & creeks: Cease-to-pump when there is no visible flow (equivalent to full flow through a 200m pipe) Natural in-river pools: Pumping not permitted from natural in-river pools when the water level in the pool is lower than its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident)					

[94] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

[95] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

[96] See Table 1 for definitions of hydrological alternation

	Natural off-river pools: Pumping is not permitted from natural off-river pools when the water level in the pool is lower than 80% of its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident) Trading rules: INTO water source: not permitted; WITHIN water source: trades permitted, subject to assessment; Conversion to high flow access: not permitted; Interstate trading: not permitted.

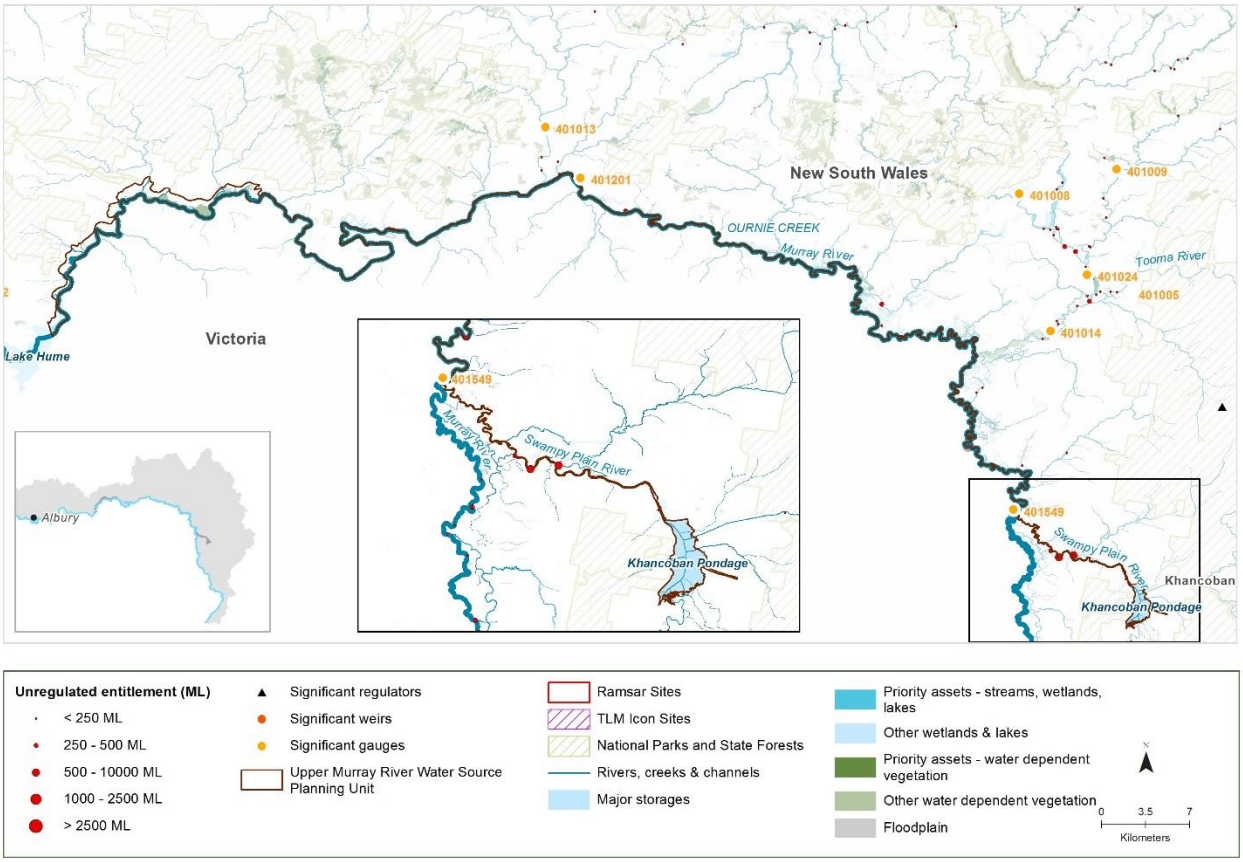
Recommendations

Ensure compliance with water access licence conditions including through metering of all licensed extraction.

Maintain existing rules in the WSP for the Murray Unregulated and Alluvial Water Sources.

Monitor for changes in water demand & review access rules if current usage is high or if the pattern of use changes.

PU21: Upper Murray water source



Priority environmental assets

Rivers, creeks, wetlands & their associated in-channel & floodplain habitats & fringing vegetation communities, including (but not limited to):

- Murray River from the junction with Swampy Plain River to Lake Hume (but not including Lake Hume)
- Swampy Plain River from (& including) Khancoban storage to the junction with the Murray River

Native fish[97]	• Australian smelt • carp gudgeon • dwarf flathead gudgeon • flat-headed gudgeon	• mountain galaxias • Murray cod • river blackfish • riffle galaxias • two-spined blackfish	• flathead galaxias (P) • southern pygmy perch (P) • golden perch
Birds	22 water-dependent bird species recorded, including the following listed[98] waterbird species: • eastern great egret (J)		
Native vegetation	8 water-dependent PCTs, including non-woody wetland, river red gum forest & woodland		

[97] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

[98] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Other species	• No frogs species recorded • platypus

Hydrology

Gauge: 401201 *Murray River at Jingellic*	**80th percentile**: 2081 ML/d	**50th percentile**: 4959 ML/d	**20th percentile**: 10,393 ML/d
	1.5 ARI: 39,625 ML/d	**2.5 ARI**: 49,056 ML/d	**5 ARI**: 61,402 ML/d

Summary of hydrological alteration

There has been a large (>50%) increase in the frequency of low flows, baseflows & freshes in the upper Murray River compared to the 'without development' model scenario as assessed by the Risk Assessment for the Murray & Lower Darling WRPA. These changes are the result of significant inter-valley diversions from the Upper Snowy River into the upper Murray River via the Geehi & Swampy Plains Rivers as part of the Snowy Mountains Hydroelectric Scheme, & the operation of Murray 1 & Murray 2 Power Stations & subsequent releases from Khancoban Pondage into the lower Swampy Plains River which then flows into Murray River (DPI 2012). These hydropower operations create large daily & hourly variations in flow in the upper Murray & Swampy Plains rivers. Large (unnatural) flow variability can pose a risk to native fish breeding (especially nesting species like Murray cod), in-channel vegetation & river bank stability. The frequency of higher flows has been reduced by <20% in the Murray River at Jingellic.

The total volume of unregulated entitlements in the PU is 5306 ML, of which 5223 ML are water access licences (WALs) for production. There are 14 production WALs <250 ML & five between 250–500 ML, two between 500–1000 ML, & one between 1000–2500 ML. They are all distributed along the Murray River downstream of Khancoban Dam until approximately Talmalmo.

Hydrological alteration	**Cease-to-flow**	**Low flow & Baseflow**	**Freshes**	**High & infrequent flows**		
				1.5 ARI	**2.5 ARI**	**5 ARI**
Murray at Jingellic (401201)	L^0	H^+	H^+	L^-	L^-	L^-
Relevant rules	Rivers & creeks (including natural in-river pools): Cease-to-pump when flows are at or below 600 ML/d at gauge 401201 & Cease-to-pump when there is no visible flow at pump sites Natural off-river pools: Pumping is not permitted from natural off-river pools when the water level in the pool is lower than 80% of its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident)					

Recommendations

Investigate opportunities to reduce extreme flow variability in the Upper Murray River water source within five years to reduce potential impacts on Murray cod nesting, in-channel vegetation, stranding of biota & bank stability. This is particularly important during the Murray cod nesting season (Oct–Nov). Specific recommendations include:

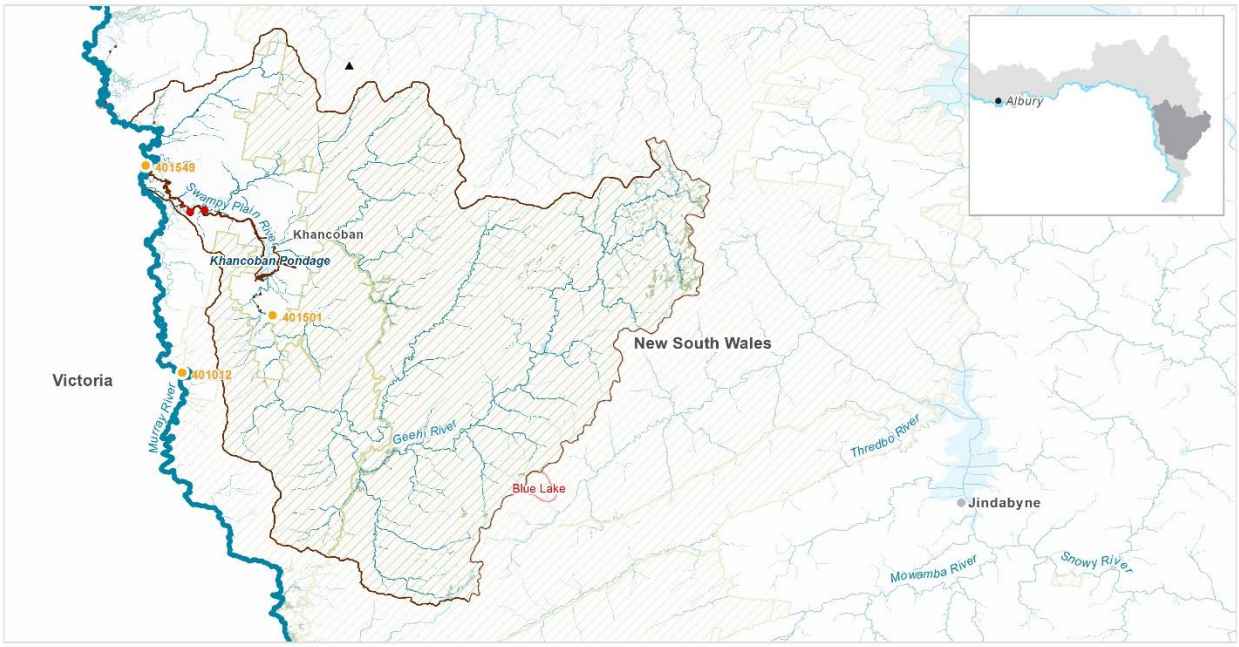
- Consider reviewing the timing & frequency of releases from Khancoban pondage to reduce flow variability where practicable, moving towards more stable baseflows (whilst maintain some variability) & longer duration freshes.
- Consider implementing limits on rates of rise & fall at key Murray River gauges (Bringenbong & Jingellic), ideally aligned with the 5th & 95th percentiles of without-development rates of fall.

Maintain existing rules in the WSP for the Murray Unregulated and Alluvial Water Sources.

Ensure compliance with water access licence conditions including through metering of all licensed extraction.

Monitor for changes in water demand & review access rules if current usage is high or if the pattern of use changes.

PU22: Swampy Plains water source



Priority environmental assets

Rivers, creeks, wetlands & their associated in-channel & floodplain habitats & fringing vegetation communities, including (but not limited to):

- Swampy Plain River (upstream of Khancoban storage)
- Geehi River
- Three Rocks Creek
- Valentine Creek
- Wilkinson Creek
- Devils Creek
- The Back Creek
- Bogong Creek
- Khancoban Creek
- Swampy Plains Creek
- Broken Back Creek
- Waterfall Creek
- Springflat Creek
- Bridge Creek

Native fish[99]	• climbing galaxias • mountain galaxias • Murray crayfish • obscure galaxias • riffle galaxias • two-spined blackfish • southern pygmy perch (P) • Australian smelt
Birds	56 water-dependent bird species recorded, including the following listed[100] waterbird species: • cattle egret (J) • eastern great egret (J) • Latham's snipe (J,K)
Native vegetation	12 water-dependent PCTs, including non-woody wetland, river red gum forest and woodland

[99] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

[100] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K])

Other species	• brown tree frog • common eastern froglet • eastern banjo frog	• Lesueur's frog • eastern bentwing-bat (V)	• smooth toadlet • Verreaux's frog • platypus

Hydrology

Gauge: 401501 *Swampy Plains at Khancoban*	**80th percentile**: 194 ML/d	**50th percentile**: 433 ML/d	**20th percentile**: 1105 ML/d
	1.5 ARI: 7061 ML/d	**2.5 ARI**: 7875 ML/d	**5 ARI**: 9385 ML/d

Summary of hydrological alteration

There has been a large (>50%) increase in the frequency of low flows, baseflows & freshes in the Swampy Plains River above Khancoban Pondage compared to the 'without development' model scenario as assessed by the Risk Assessment for the Murray & Lower Darling WRPA. The frequency of higher flows, on the other hand, has been reduced by 20–50%.

These changes are likely the result of significant inter-valley transfers from the upper Snowy River to the Swampy Plain water source as part of the Snowy Mountain Hydroelectric Scheme & by subsequent releases from Geehi Dam & intra-valley diversions (380 GL average per year) from the Geehi & upper reaches of the Swampy Plain to the lower reaches of the Swampy Plains River (thus bypassing the lower reaches of the Geehi river & upper reaches of the Swampy Plains River) (DPI 2012). A recent program to improve flows in Geehi River (part of the broader Snowy Montane Rivers Increased Flows program) includes a requirement for Snowy Hydro to release 20GL a year into the Geehi River from Geehi Dam. Nevertheless, the inter & intra valley transfers & operation of storages for hydropower generation creates large daily & hourly variations in flow. Large (unnatural) flow variability can pose a risk to native fish breeding (especially nesting species like Murray cod), in-channel vegetation & river bank stability.

The total volume of unregulated entitlements in the PU is 278 ML, of which 119 ML are water access licences (WALs) for production. There are three production WALs <250 ML that are found on Spring Flat Creek & Swampy Plain River.

	Cease-to-flow	Low flow & Baseflow	Freshes	High & infrequent flows		
Hydrological alteration	L^0	H^+	H^+	M^-	M^-	M^-
Relevant WSP rules	Rivers & creeks: Cease-to-pump when there is no visible flow (equivalent to full flow through a 200m pipe) Amendment provision: introduce a volumetric CtP rule (86 ML/d at gauge 401501) if the Bureau of Meteorology begin publishing real-time data for the Snowy Hydro Ltd Swampy Plain at Khancoban 2 gauge (401501). Natural in-river pools: Pumping not permitted from natural in-river pools when the water level in the pool is lower than its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident) Natural off-river pools: Pumping is not permitted from natural off-river pools when the water level in the pool is lower than 80% of its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident) Trading rules: INTO water source – not permitted; WITHIN water source: trades permitted, subject to assessment; Conversion to high flow access: not permitted; Interstate trading: not permitted.					

Recommendations

Investigate opportunities to reduce extreme flow variability in the Geehi & Swampy Plain rivers within five years to reduce potential impacts on native fish, in-channel vegetation, stranding of biota & bank stability.

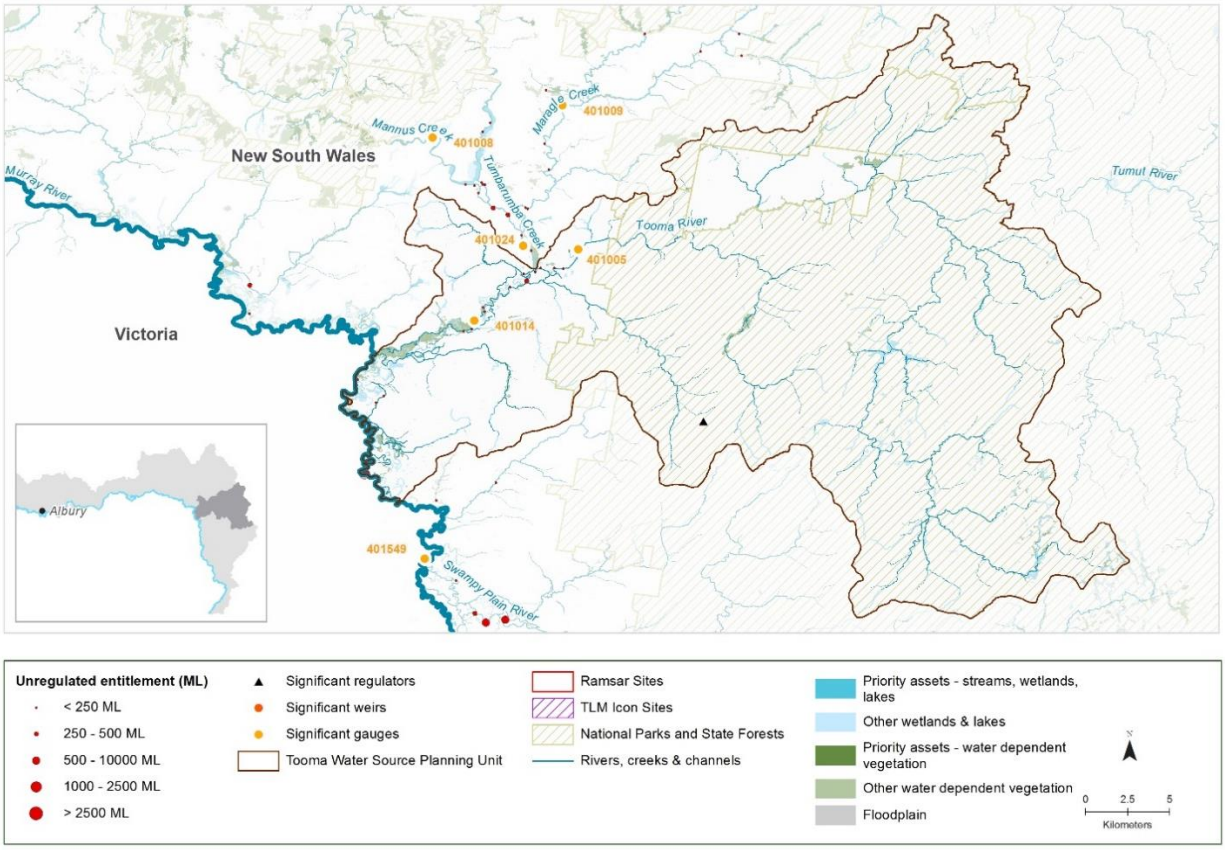
Implement a volumetric cease-to-pump rule of 86 ML/d (at gauge 401501) once real-time data for the gauge becomes available (consistent with the Amendment provision in the WSP).

As a minimum, maintain existing rules in the WSP for the Murray Unregulated & Alluvial Water Sources.

Ensure compliance with water access licence conditions including through metering of all licensed extraction.

Monitor for changes in water demand & review access rules if current usage is high or if the pattern of use changes.

PU23: Tooma water source



Priority environmental assets

Rivers, creeks, wetlands & their associated in-channel & floodplain habitats & fringing vegetation communities, including (but not limited to):

- Tooma River (including numerous wetlands in the lower reaches below the Welumbu Creek junction)
- Murray River floodplain wetlands along the short reach of the Murray adjacent to Tooma Water Source
- Welumba River
- Shingle Creek
- Deep Creek
- Little River
- Yellow Bog Creek
- Hellhole Creek
- Pugilistic Creek
- Bullshead Creek
- Pretty Plain Creek

Native fish[101]	• Australian smelt • dwarf flathead gudgeon • flat-headed gudgeon • Macquarie perch	• mountain galaxias • Murray crayfish • river blackfish • riffle galaxias	• flathead galaxias (P) • southern pygmy perch (P) • carp gudgeon • Murray cod

[101] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

	• two-spined blackfish	
Birds	22 water-dependent bird species recorded	
Native vegetation	11 water-dependent PCTs, including non-woody wetland, river red gum forest & woodland	
Other species	• No frog species recorded • eastern bentwing-bat (V)	• platypus

Hydrology			
Gauge: 401014 *Tooma River at Pinegrove*	**80th percentile**: 232 ML/d	**50th percentile**: 604 ML/d	**20th percentile**: 1693 ML/d
	1.5ARI: 6059 ML/d	**2.5ARI**: 11,395 ML/d	**5ARI**: 15,075 ML/d

Summary of hydrological alteration

Cease-to-flow periods are highly altered (>50% departure from base case) as assessed by the Risk Assessment for the Murray & Lower Darling WRPA. Cease-to-flow periods currently occur more frequently compared to the 'without development' model scenario. There has also been small (<20%) reduction in low flows, baseflows & freshes compared with the 'without development' model scenario.

These hydrological changes are likely to be influenced by the significant diversions (average of 295 GL/year) from the Tooma water source to the Tumut River in the Murrumbidgee WRPA as part of the Snowy Mountain Hydroelectric Scheme. Surface water extraction in the lower Tooma River, Maragle, Tumbarumba & Mannus water sources may also be contributing to the significant increase in cease-to-flow occurrence.

The total volume of unregulated entitlements in the PU is 1458 ML, of which 1453 ML are water access licences (WALs) for production. There are 13 production WALs <250 ML & one between 250–500 ML that are all located around or downstream of Tumbarumba Creek, in the lower reaches of the Tooma River.

	Cease-to-flow	**Low flow & Baseflow**	**Freshes**	**High & infrequent flows**		
Hydrological alteration	H^+	L^-	L^-	L^0	L^0	L^0
Relevant rules	Rivers & creeks (including natural in-river pools): Cease-to-pump when flows are at or below 79 ML/d (equating to the 95th percentile of flows during the critical month of February, as measured at reference point (gauge 401014)). Natural off-river pools: Pumping is not permitted from natural off-river pools when the water level in the pool is lower than 80% of its full capacity (i.e. the pool water level at the point where inflow & outflow of that pool becomes no longer evident) Trading rules: INTO water source: permitted at moderate flows of >297 ML/d, limited to 2,177 ML/d; WITHIN water source: trades permitted, subject to assessment; Conversion to high flow access: permitted; Interstate trading: not permitted unless there is an interstate agreement					

Recommendations

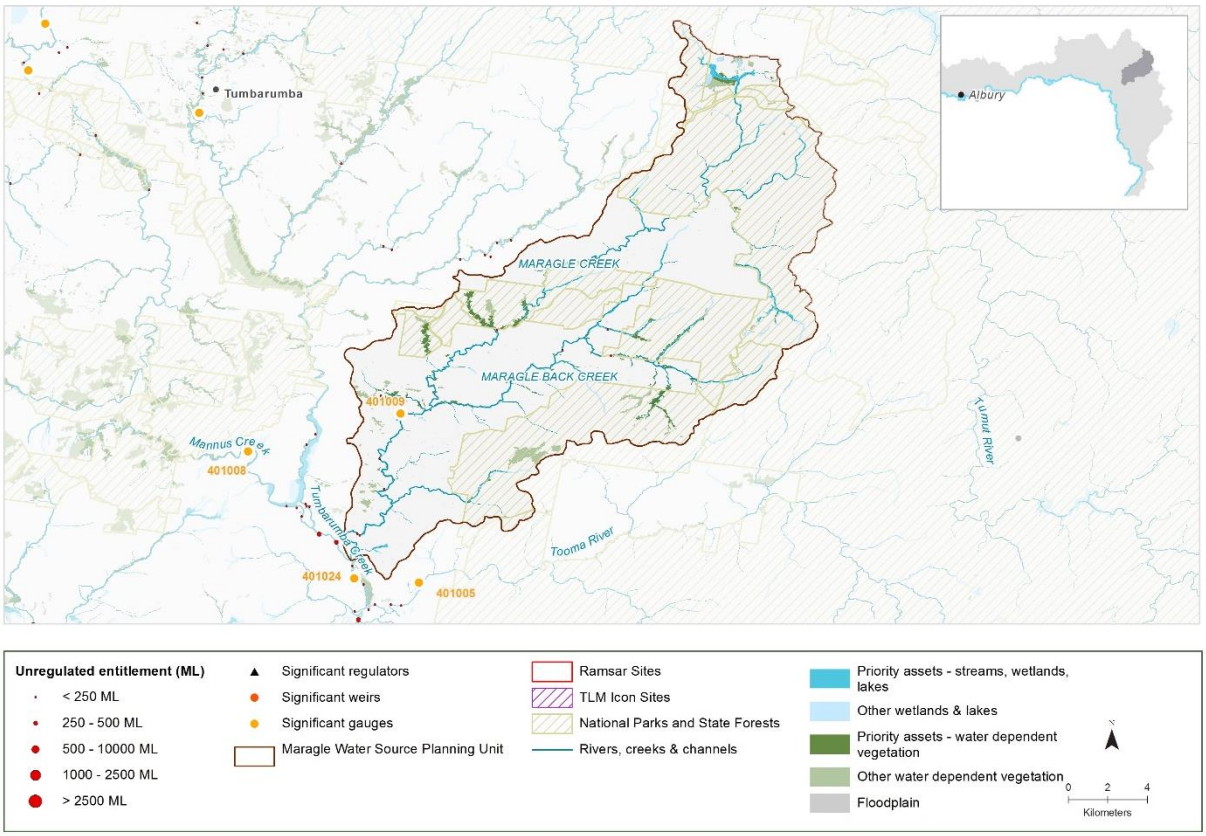
Investigate opportunities to reduce the frequency & duration of cease-to-flow periods in the water source within five years:

- Review the timing & frequency of diversions of flow to the Tumut River (Murrumbidgee catchment) as part of the Snowy Mountain Hydroelectric Scheme) during times of low flow. Consider implementing 'first flush' provisions to protect initial increases in flows after periods of very low flow (or cease-to-flow events)
- Consider implementing a commence-to-pump threshold which is higher than the cease-to-pump threshold – to protect initial increases in flows after periods of very low flow (or a cease-to-flow event), allowing water quality to improve & providing movement & breeding opportunities for native fish & other aquatic biota.
- Consider rostering landholder water access during low flow months
- Consider Individual &/or Total Daily Extraction Limits (IDELS / TDELS)

Maintain existing rules in the WSP for the Murray Unregulated and Alluvial Water Sources.

Ensure compliance with water access licence conditions including through metering of all licensed extraction.

PU24: Maragle water source



Priority environmental assets

Rivers, creeks, wetlands & their associated in-channel & floodplain habitats & fringing vegetation communities, including (but not limited to):

- Maragle Creek & its tributaries
- Maragle Back Creek & its tributaries

Native fish[102]	• Australian smelt • flat-headed gudgeon • mountain galaxias	• river blackfish • obscure galaxias • two-spined blackfish	• flathead galaxias (P) • carp gudgeon • Murray cod
Birds	*27* water-dependent bird species recorded		
Native vegetation	9 water-dependent PCTs, including non-woody wetland & river red gum woodlands		
Other species	• Bibron's toadlet • Booroolong frog (E) • common eastern froglet • platypus	• eastern banjo frog • eastern sign-bearing froglet • Lesueur's Frog	• Peron's tree frog • spotted grass frog • superb parrot (V)

Hydrology

Gauge: 401009 *Maragle Creek at Maragle*	**80th percentile**: 15 ML/d	**50th percentile**: 48 ML/d	**20th percentile**: 143 ML/d
	1.5ARI: 913 ML/d	**2.5ARI**: 150 ML/d	**5ARI**: 2167 ML/d

[102] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

Summary of hydrological alteration

Streams in the Maragle water source are characterised by very low flows. Water is mainly diverted when the rainfall has been inadequate. This means that lower flows may be impacted by extraction (as confirmed by the risk assessment).

There has been a moderate increase (20–50%) in the occurrence of cease-to-flow periods as assessed by the Risk Assessment for the Murray & Lower Darling WRPA. There has also been small (<20%) reduction in low flows, baseflows & freshes compared with the 'without development' model scenario.

The total volume of unregulated entitlements in the PU is 409 ML, of which 400 ML are water access licences (WALs) for production. There are ten production WALs <250 ML that are located along the mid & lower reaches of Maragle & Maragle Back creeks.

	Cease-to-flow	Low flow & Baseflow	Freshes	High & infrequent flows		
Hydrological alteration	M^+	L^-	L^-	L^0	L^0	L^0
Relevant rules	Rivers & creeks (including natural in-river pools): Cease-to-pump when flows are at or below 10 ML/d (equating to the 85th percentile of flows on all flow days as measured at reference point (gauge 401009) & Cease-to-pump when there is no visible flow (equivalent to full flow through a 200m pipe) at pump site Natural off-river pools: Pumping is not permitted from natural off-river pools when the water level in the pool is lower than 80% of its full capacity (i.e. the pool water level at the point where inflow & outflow of that pool becomes no longer evident) Trading rules: INTO water source: permitted at high flows of >41 ML/d, limited to 567 ML/d; WITHIN water source: trades permitted, subject to assessment; Conversion to high flow access: permitted; Interstate trading: not permitted unless there is an interstate agreement					

Recommendations

Investigate opportunities to reduce the frequency & duration of cease-to-flow periods within five years:

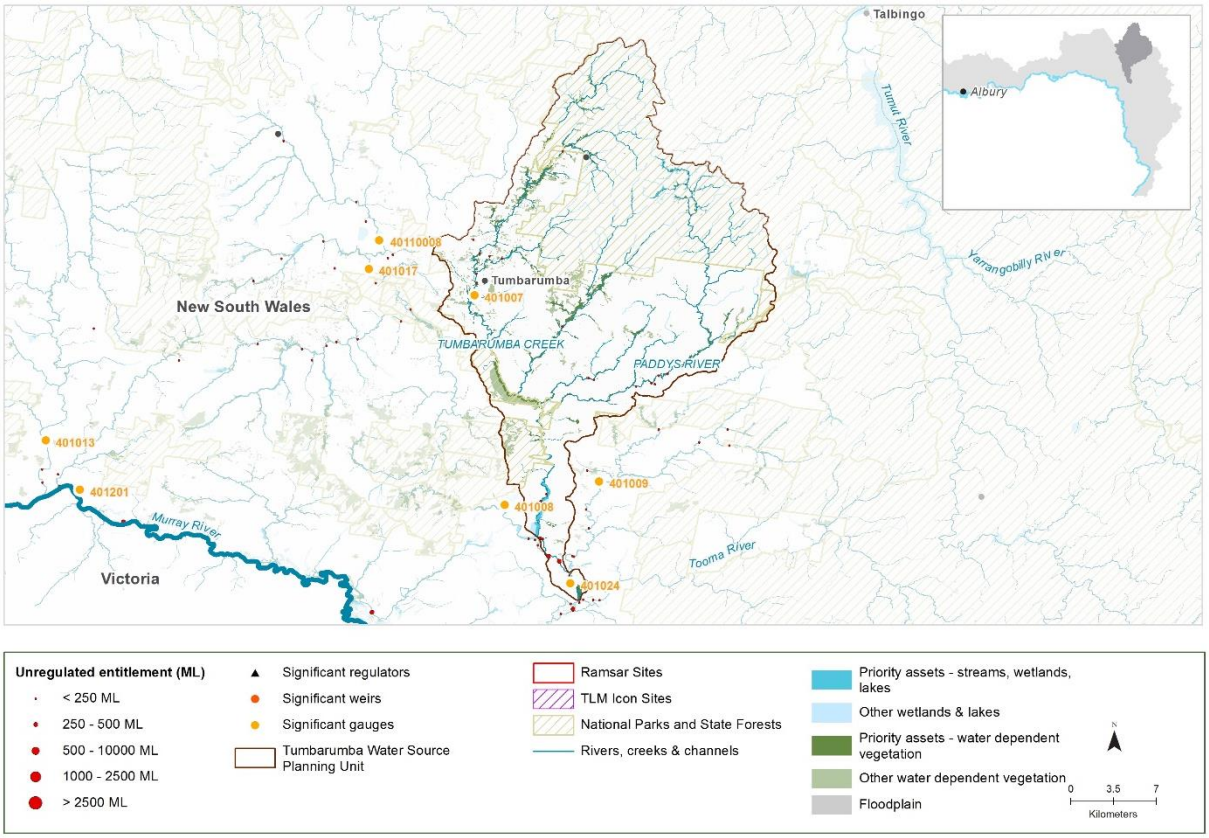
- Consider implementing a commence-to-pump threshold which is higher than the cease-to-pump threshold – to protect initial increases in flows after periods of very low flow (or a cease-to-flow event), allowing water quality to improve & providing movement & breeding opportunities for native fish & other aquatic biota.
- Consider reviewing existing cease-to-pump rules to ensure that visible flow is maintained downstream of extraction points (currently extraction can occur until there is no visible flow at pump sites i.e. until the stream stops flowing).
- Consider rostering landholder water access during low flow months
- Consider Individual &/or Total Daily Extraction Limits (IDELS / TDELS)

Maintain existing rules in the WSP for the Murray Unregulated and Alluvial Water Sources.

Ensure compliance with water access licence conditions including through metering of all licensed extraction.

Monitor for changes in water demand & review access rules if current usage is high or if the pattern of use changes.

PU25: Tumbarumba water source



Priority environmental assets

Rivers, creeks, wetlands & their associated in-channel & floodplain habitats & fringing vegetation communities, including (but not limited to):

- Tumbarumba Creek & its tributaries
- Burra Creek & its tributaries
- Paddys River & its tributaries

Native fish	• Australian smelt • carp gudgeon • flat-headed gudgeon • Murray cod	• mountain galaxias • Murray crayfish • obscure galaxias	• river blackfish • riffle galaxias • two-spined blackfish
Birds	44 water-dependent bird species recorded, including the following listed[103] waterbird species: • cattle egret (J) • eastern great egret (J)		
Native vegetation	10 water-dependent PCTs, including non-woody wetland & river red gum woodland		
Other species	• common eastern froglet • eastern banjo frog • eastern bentwing-bat (V)	• eastern sign-bearing froglet • Lesueur's frog • platypus	• Peron's tree frog • spotted grass frog • Verreaux's frog • eastern snake-necked turtle

[103] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Hydrology

Gauge: 401014 & 401024 *Correlation between Tooma River at Pinegrove & Tumbarumba Creek at Tooma (Bakers)*	**80th percentile**: 145 ML/d	**50th percentile**: 378 ML/d	**20th percentile**: 1058 ML/d
	1.5ARI: 3749 ML/d	**2.5ARI**: 7125 ML/d	**5ARI**: 9427 ML/d

Summary of hydrological alteration

Cease-to-flow periods are highly altered (>50% departure from base case) as assessed by the Risk Assessment for the Murray & Lower Darling WRPA. Cease-to-flow periods currently occur more frequently compared to the 'without development' model scenario.

There has been small (<20%) reduction in low flows, baseflows & freshes compared with the 'without development' model scenario.

The total volume of unregulated entitlements in the PU is 1513 ML, of which 965 ML are water access licences (WALs) for production. There are 16 production WALs <250 ML & two between 250-500 ML that are located in the middle reaches of Tumbarumba Creek (near the town of Tumbarumba), Burra Creek & Paddys River.

	Cease-to-flow	Low flow & Baseflow	Freshes	High & infrequent flows		
Hydrological alteration	H^+	L^-	L^-	L^0	L^0	L^0
Relevant rules	Rivers & creeks (including natural in-river pools): Upper management zone - Cease-to-pump when flows are at or below 14 ML/d (equating to the 95th percentile of flows on all days), as measured at reference point (gauge 401007) Lower management zone - Cease-to-pump when flows are at or below 32 ML/d (equating to the 95th percentile of flows on all days), as measured at reference point (gauge 401024) Natural off-river pools: Pumping is not permitted from natural off-river pools when the water level in the pool is lower than 80% of its full capacity (i.e. the pool water level at the point where inflow & outflow of that pool becomes no longer evident) Trading rules: INTO water source: permitted at moderate flows of >79 ML/d, limited to 1,233 ML/year in the upper management zone & >120 ML/d, limited to 960 ML/year in the lower management zone; WITHIN water source: trades permitted, subject to assessment; Conversion to high flow access: permitted; Interstate trading: not permitted unless there is an interstate agreement					

Recommendations

Investigate opportunities to reduce the frequency & duration of cease-to-flow periods & extraction pressure on low flows & baseflows within five years:

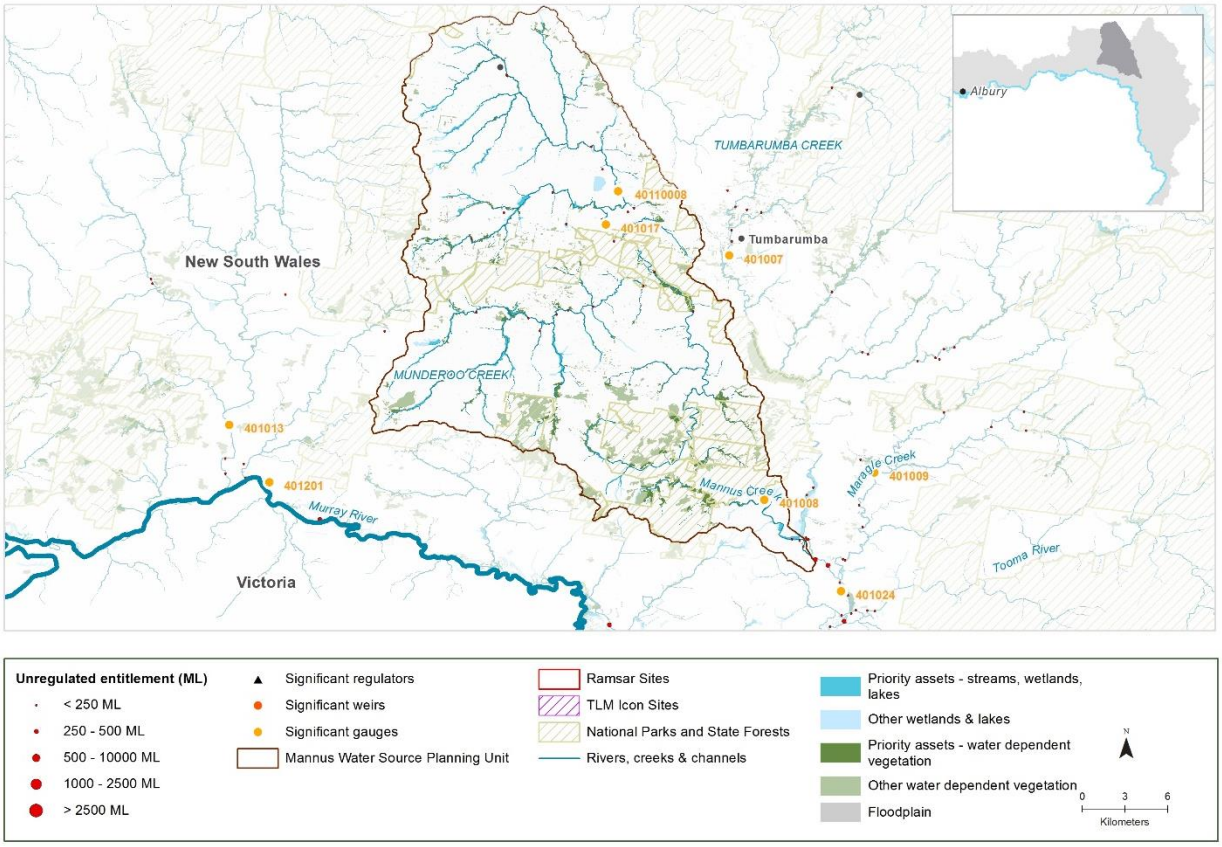
- Consider installing a streamflow gauge on Paddy's River & adding a volumetric cease-to-pump rule for Paddy's River (as there are several WALs on Paddy's River but no operational gauge), or consider installing staff gauges at/near pump sites on Paddy's River.
- Consider reviewing existing volumetric cease-to-pump rules to ensure that visible flow is maintained downstream of all extraction points.
- Consider implementing commence-to-pump thresholds, which are higher than the cease-to-pump thresholds – to protect initial increases in flows after periods of very low flows (or cease-to-flow event), allowing water quality to improve & providing movement & breeding opportunities for native fish & other aquatic biota.

Maintain existing rules in the WSP for the Murray Unregulated and Alluvial Water Sources.

Ensure compliance with water access licence conditions including through metering of all licensed extraction.

Monitor for changes in water demand & review access rules if current usage is high or if the pattern of use changes.

PU26: Mannus water source



Priority environmental assets

Rivers, creeks, wetlands & their associated in-channel & floodplain habitats & fringing vegetation communities, including (but not limited to):

- Mannus Creek & its tributaries
- Boggy Creek
- Munderoo Creek & its tributaries
- Shallow swamp wetlands along Mannus & Munderdoo creeks

Native fish[104]	• Australian smelt • carp gudgeon • flat-headed gudgeon • Murray cod	• Macquarie perch (P) • mountain galaxias • obscure galaxias	• riffle galaxias • river blackfish • two-spined blackfish
Birds	48 water-dependent bird species recorded, including the following listed[105] waterbird species: • eastern great egret (J)		
Native vegetation	10 water-dependent PCTs, including non-woody wetland & river red gum woodland		
Other species	• Bibron's toadlet • Booroolong frog (E) • brown tree frog	• eastern banjo frog • eastern sign-bearing froglet	• Peron's tree frog • Sloane's froglet (V) • spotted grass frog

[104] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

[105] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

	• common eastern froglet • platypus	• Lesueur's frog	• Verreaux's frog

Hydrology

Gauge: 401008 *Mannus Creek at Tooma*	**80th percentile**: 18 ML/d	**50th percentile**: 57 ML/d	**20th percentile**: 268 ML/d
	1.5ARI: 2892 ML/d	**2.5ARI**: 5919 ML/d	**5ARI**: 7996 ML/d

Summary of hydrological alteration

Cease-to-flow periods are highly altered (>50% departure from base case) as assessed by the Risk Assessment for the Murray & Lower Darling WRPA. Cease-to-flow periods currently occur more frequently compared to the 'without development' model scenario.

There has been small (<20%) reduction in Low Flows, Baseflows & Freshes compared with the 'without development' model scenario.

The total volume of unregulated entitlements in the PU is 1095 ML, of which 1079 ML are water access licences (WALs) for production. There are 21 production WALs <250 ML located along Mannus, Munderoo & Mannus creeks.

	Cease-to-flow	Low flow & Baseflow	Freshes	High & infrequent flows		
Hydrological alteration	H^+	L^-	L^-	L^-	L^0	L^0
Relevant rules	Rivers & creeks (including natural in-river pools): **Upper Management Zone**: Cease-to-pump when flows are at or below 0.2 m (ref gauge 4011008) – includes amendment clause to change to a volumetric CtP rule once new telemetered gauge is constructed. **Lower Management Zone:** Cease-to-pump when flows are at or below 9.4 ML/d (equating to 0.45 meters & the 72nd percentile of flows on all flow days as measured at reference point (gauge 401017) & Cease-to-pump when there is no visible flow (equivalent to full flow through a 200m pipe) at pump site Includes amendment provision to introduce a volumetric CtF once a new telemetered gauge is constructed Natural off-river pools: Pumping is not permitted from natural off-river pools when the water level in the pool is lower than 80% of its full capacity (i.e. the pool water level at the point where inflow & outflow of that pool becomes no longer evident) Trading rules: INTO water source: permitted at very high flows of >61 ML/d, limited to 1668 ML/d; WITHIN water source: trades permitted, subject to assessment; Conversion to high flow access: permitted; Interstate trading: not permitted unless there is an interstate agreement					

Recommendations

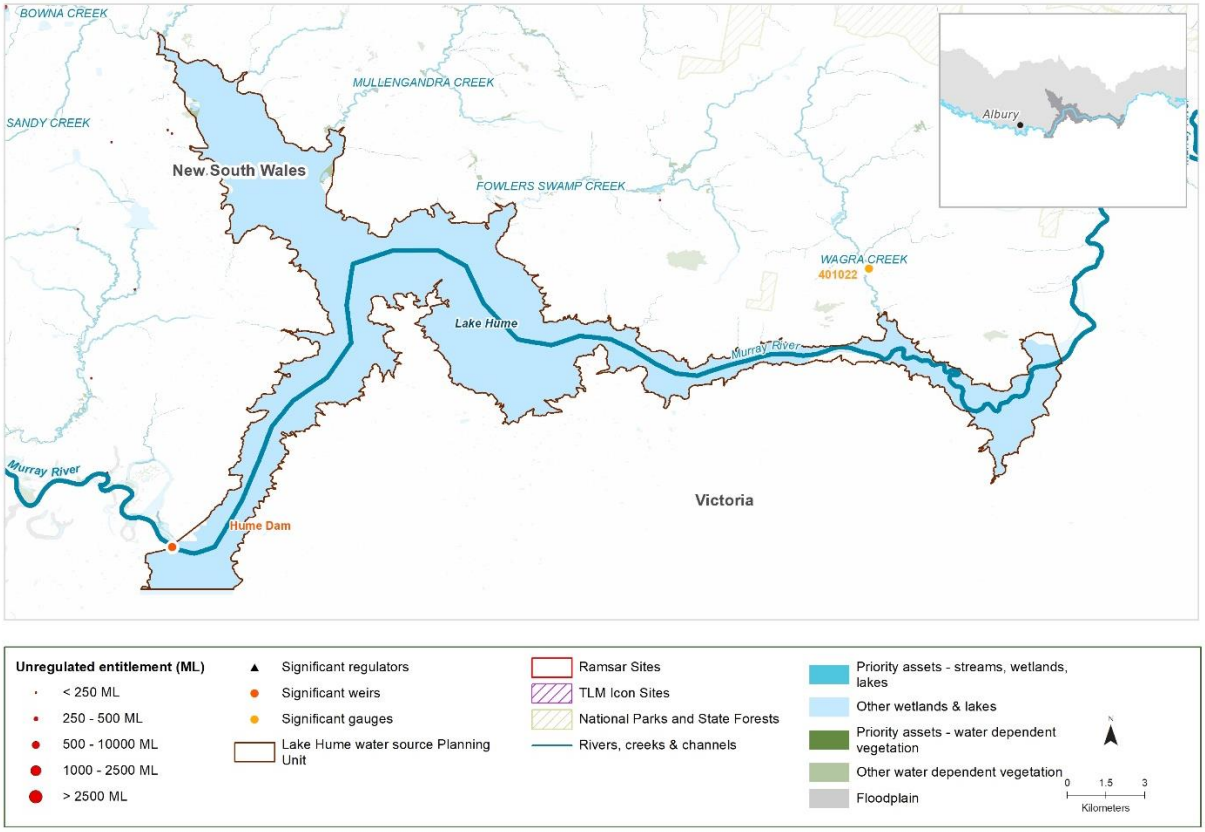
Consider decommissioning & removal of Mannus Dam to protect native fish populations (this is a high priority action due to the presence of the last remaining population (in the NSW Murray) of the critically endangered Macquarie perch)

Investigate opportunities to reduce the frequency & duration of cease-to-flow periods & reduce extraction pressure on low flows & baseflows within five years:

- Install new telemetered streamflow gauge at Glenroy (just near existing 40110008) as outlined in the Amendment Provisions in the Water Sharing Plan
- Review license conditions for Mannus Dam to ensure translucent release rules are appropriate for protecting the critically endangered Macquarie Perch population located downstream of the dam.
- Implement WSP Amendment Provision to change to a volumetric CtP rule in the Upper Management Zone. Ensure that the volumetric CtP is at least 0.2m (ideally >0.3m) above the

cease-to-flow level measured at the relevant gauge & in reaches with surface water extraction licenses. • Consider implementing commence-to-pump thresholds, which are higher than existing cease-to-pump thresholds – to protect initial increases in flows after periods of very low flows (or cease-to-flow event), allowing water quality to improve & providing movement & breeding opportunities for native fish & other aquatic biota. • Consider reviewing existing cease-to-pump rules to ensure that visible flow is maintained downstream of all extraction points (currently, in many cases, extraction can occur until there is no visible flow	
As a minimum, maintain existing rules in the WSP for the Murray Unregulated and Alluvial Water Sources. Ensure compliance with water access licence conditions including through metering of all licensed extraction. Monitor for changes in water demand & review access rules if current usage is high or if the pattern of use changes.	

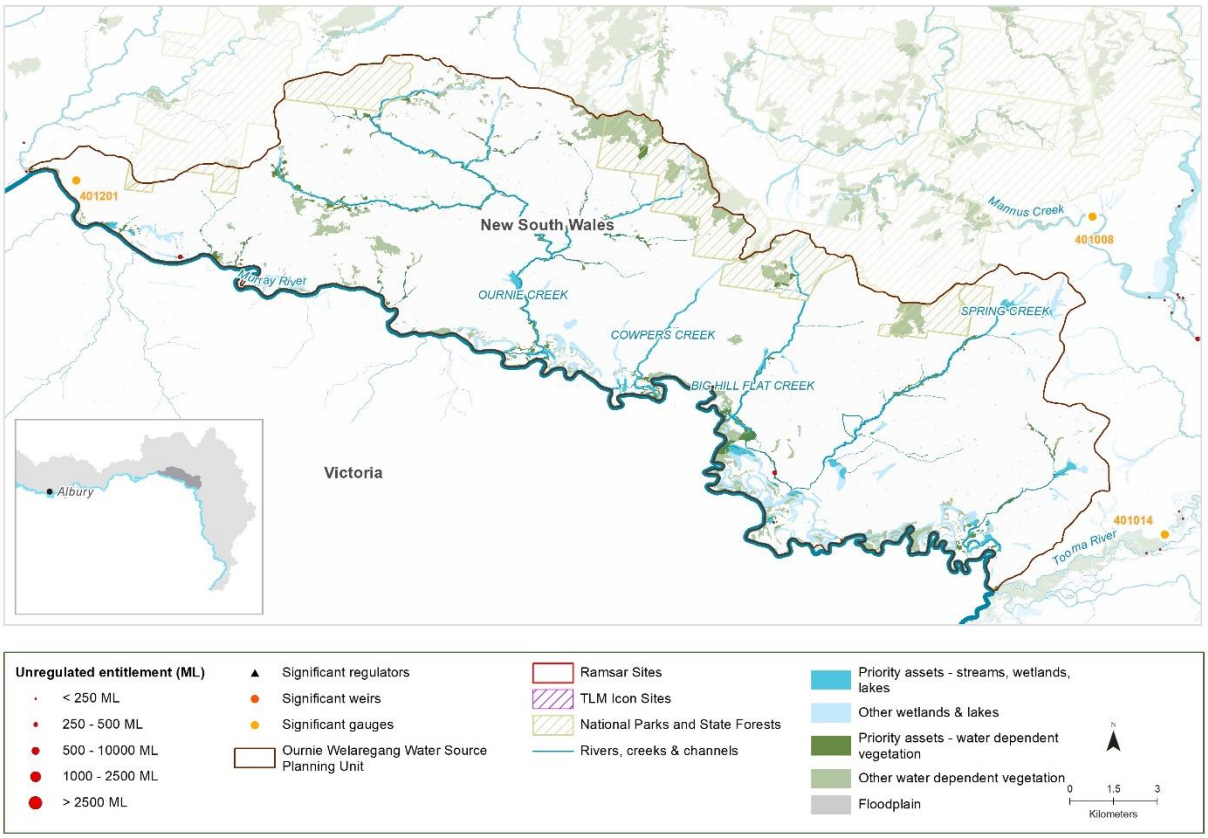
PU27: Lake Hume water source



Priority environmental assets			
Lake Hume			
Native fish	• river blackfish • mountain galaxias • carp gudgeon	• flat-headed gudgeon • dwarf flathead gudgeon	• Australian smelt • golden perch • Murray cod
Birds	36 water-dependent bird species recorded, including the following listed[106] waterbird species: • Caspian tern (J)	• eastern great egret (J)	• freckled duck (V)
Native vegetation	7 water-dependent PCTs, including non-woody wetland & river red gum forest		
Other species	No frog species recorded		
Hydrology			
N/A – Water source includes only the artificial storage of Lake Hume & no assessment of hydrological alteration has been undertaken.			

[106] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

PU28: Ournei Welaregang water source



Priority environmental assets

Rivers, creeks, wetlands & their associated in-channel & floodplain habitats & fringing vegetation communities, including (but not limited to):

- Ournie Creek & its tributaries
- Welumba Creek
- Spring Creek
- Cowpers Creek
- Welaregang Creek
- Big Hill Flat Creek
- Murray River floodplain wetlands (Tooma River to Jingellic)

Native fish[107]	• southern pygmy perch (P) • dwarf flathead gudgeon • two-spined blackfish • flathead galaxias • flat-headed gudgeon	• Murray crayfish • river blackfish • obscure galaxias • riffle galaxias • climbing galaxias	• Australian smelt • carp gudgeon • Murray cod • trout cod • mountain galaxias
Birds	38 water-dependent bird species recorded, including the following listed[108] waterbird species: • Latham's snipe (J,K)		

[107] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

[108] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Native vegetation	10 water-dependent PCTs, including non-woody wetland, & river red gum forest & woodland	
Other species	• Booroolong frog (E) • eastern snake-necked turtle	• platypus • Macquarie turtle

Hydrology

Gauge: 401016 *Welumba Creek at The Square*	**80th percentile**: 7 ML/d	**50th percentile**: 25 ML/d	**20th percentile**: 69 ML/d
	1.5ARI: 320 ML/d	**2.5ARI**: 651 ML/d	**5ARI**: 874 ML/d

Creeks in the Ournie Welaregang water source are largely perennial & water is mainly diverted when the rainfall has been inadequate.

There has been a low degree of change (<20% reduction) in low flows, baseflows & freshes in compared to the 'without development' model scenario as assessed by the Risk Assessment for the Murray & Lower Darling WRPA.

The total volume of unregulated entitlements in the PU is 263 ML, which is made up of one water access licence (WAL) for production. The one production WALs <250 ML is located near the Murray River, close to Welaregang.

	Cease-to-flow	Low flow & Baseflow	Freshes	High & infrequent flows		
Hydrological alteration	L^0	L^-	L^-	L^0	L^0	L^0
Relevant rules	Rivers & creeks: Cease-to-pump when there is no visible flow (equivalent to full flow through a 200m pipe) Natural in-river pools: Pumping not permitted from natural in-river pools when the water level in the pool is lower than its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident) Natural off-river pools: Pumping is not permitted from natural off-river pools when the water level in the pool is lower than 80% of its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident) Trading rules: INTO water source – not permitted; WITHIN water source: trades permitted, subject to assessment; Conversion to high flow access: not permitted; Interstate trading: not permitted.					

Recommendations

Ensure compliance with water access licence conditions including through metering of all licensed extraction.

Maintain existing rules in the WSP for the Murray Unregulated and Alluvial Water Sources.

Monitor for changes in water demand & review access rules if current usage is high or if the pattern of use changes.

PU29: Jingellic water source

Priority environmental assets			
Rivers, creeks, wetlands & their associated in-channel & floodplain habitats & fringing vegetation communities, including (but not limited to):			
• Jingellic Creek & its tributaries • Lankeys Creek • Coppabella Creek • Yarara Creek		• Vyners Creek • Two Mile Creek • Horse Creek & its tributaries	
Native fish[109]	• Australian smelt • flat-headed gudgeon • mountain galaxias • southern pygmy perch (P)	• obscure galaxias • southern pygmy perch • two-spined blackfish • flathead galaxias (P)	• golden perch • carp gudgeon • Murray cod • river blackfish
Birds	55 water-dependent bird species recorded, including the following listed[110] waterbird species: • common sandpiper (C,J) • eastern great egret (J) • Latham's snipe (J,K)		
Native vegetation	7 water-dependent PCTs, including river red gum forest & woodlands		
Other species	• Booroolong frog (E) • Peron's tree frog	• common eastern froglet • spotted grass frog	• eastern sign-bearing froglet

Hydrology			
Gauge: 401013 *Jingellic Creek at Jingellic*	**80th percentile**: 17 ML/d	**50th percentile**: 52 ML/d	**20th percentile**: 200 ML/d
	1.5 ARI: 1923 ML/d	**2.5 ARI**: 3658 ML/d	**5 ARI**: 5624 ML/d

Summary of hydrological alteration

There has been a low degree of change (<20% reduction) in low flows, baseflows & freshes in Jingellic Creek compared to the 'without development' model scenario as assessed by the Risk Assessment for the Murray & Lower Darling WRPA.

The total volume of unregulated entitlements in the PU is 281 ML, of which 279 ML are water access licences (WALs) for production. There are seven production WALs <250 ML located in the downstream half of the PU.

	Cease-to-flow	Low flow & Baseflow	Freshes	High & infrequent flows		
				1.5 ARI	2.5 ARI	5 ARI
Hydrological alteration	L^0	L^-	L^-	L^0	L^0	L^0
Relevant rules	Rivers & creeks: Cease-to-pump when there is no visible flow (equivalent to full flow through a 200m pipe) Natural in-river pools: Pumping not permitted from natural in-river pools when the water level in the pool is lower than its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident)					

[109] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

[110] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

	Natural off-river pools: Pumping is not permitted from natural off-river pools when the water level in the pool is lower than 80% of its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident) Trading rules: INTO water source – not permitted; WITHIN water source: trades permitted, subject to assessment; Conversion to high flow access: not permitted; Interstate trading: not permitted.

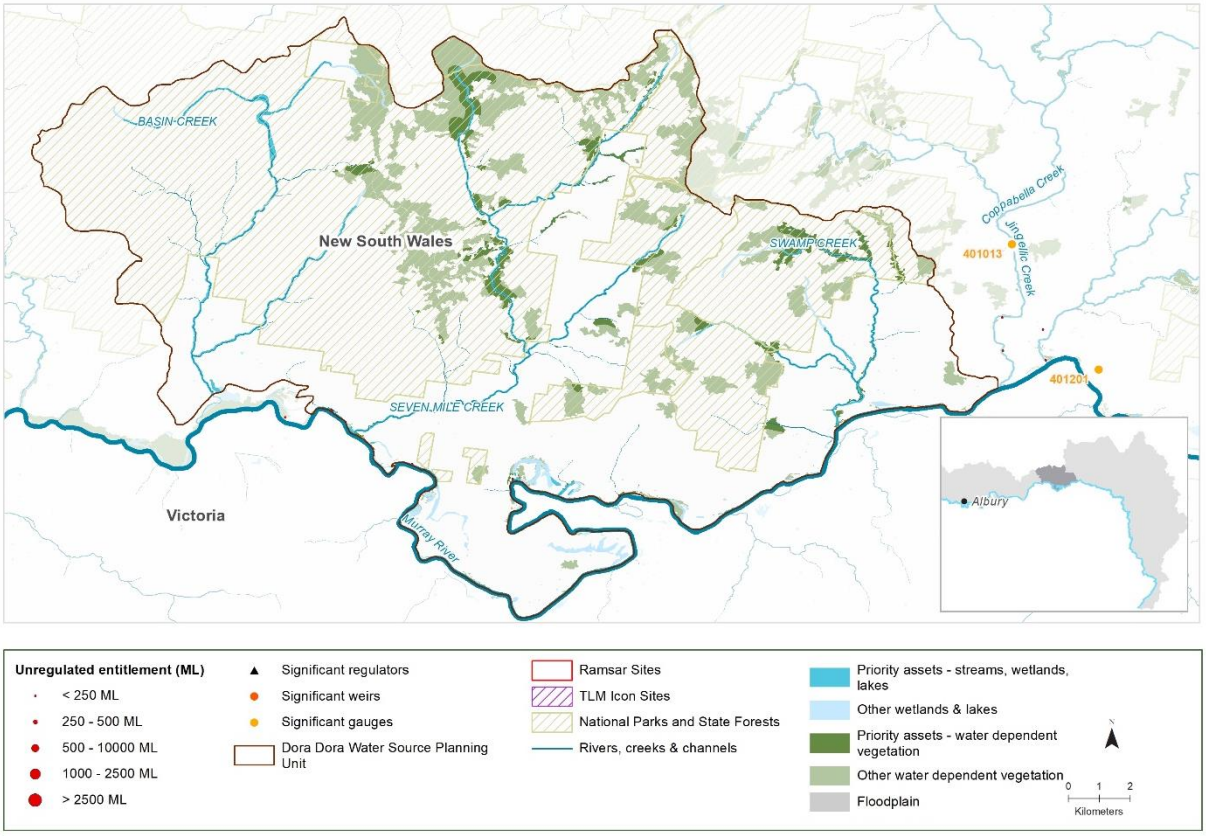
Recommendations

Ensure compliance with water access licence conditions including through metering of all licensed extraction.

Maintain existing rules in the WSP for the Murray Unregulated and Alluvial Water Sources.

Monitor for changes in water demand & review access rules if current usage is high or if the pattern of use changes.

PU30: Dora Dora water source



Priority environmental assets

Rivers, creeks, wetlands & their associated in-channel & floodplain habitats & fringing vegetation communities, including (but not limited to):

- Basin Creek & its tributaries
- Seven Mile Creek & its tributaries
- Swamp Creek & its tributaries
- Murray River floodplain wetlands

Native fish[111]	• Australian smelt • flat-headed gudgeon • climbing galaxias • mountain galaxias • southern pygmy perch (P) • obscure galaxias • river blackfish • two-spined blackfish • flathead galaxias (P) • golden perch • trout cod • carp gudgeon • Murray cod
Birds	56 water-dependent bird species recorded, including the following listed[112] waterbird species: • eastern great egret (J) • freckled duck (V) • Latham's snipe (J,K)
Native vegetation	9 water-dependent PCTs, including non-woody wetland, & river red gum forest & woodland

[111] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

[112] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Other species	• Bibron's toadlet • Booroolong frog (E) • brown-striped frog • brown tree frog • Corben's long-eared bat (V) • broad-shelled turtle	• common eastern froglet • eastern banjo frog • Peron's tree frog • platypus • eastern snake-necked turtle	• Sloane's froglet (V) • southern bell frog (E) • spotted grass frog • yellow-bellied sheathtail-bat (V) • Macquarie turtle

Hydrology

Gauge: NOT MODELLED (no streamflow gauges in PU)

Summary of Hydrological Alteration

Flows do not seem to be altered by more than 20% compared to the 'without development' model scenario as assessed by the Risk Assessment for the Murray & Lower Darling WRPA.

There are no unregulated water access licences in the PU.

	Cease-to-flow	Low flow & Baseflow	Freshes	High & infrequent flows		
				1.5 ARI	2.5 ARI	5 ARI
Hydrological alteration	L^0	L^0	L^0	L^0	L^0	L^0
Relevant rules	Rivers & creeks: Cease-to-pump when there is no visible flow (equivalent to full flow through a 200m pipe) Natural in-river pools: Pumping not permitted from natural in-river pools when the water level in the pool is lower than its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident) Natural off-river pools: Pumping is not permitted from natural off-river pools when the water level in the pool is lower than 80% of its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident) Trading rules: INTO water source – not permitted; WITHIN water source: trades permitted, subject to assessment; Conversion to high flow access: not permitted; Interstate trading: not permitted.					

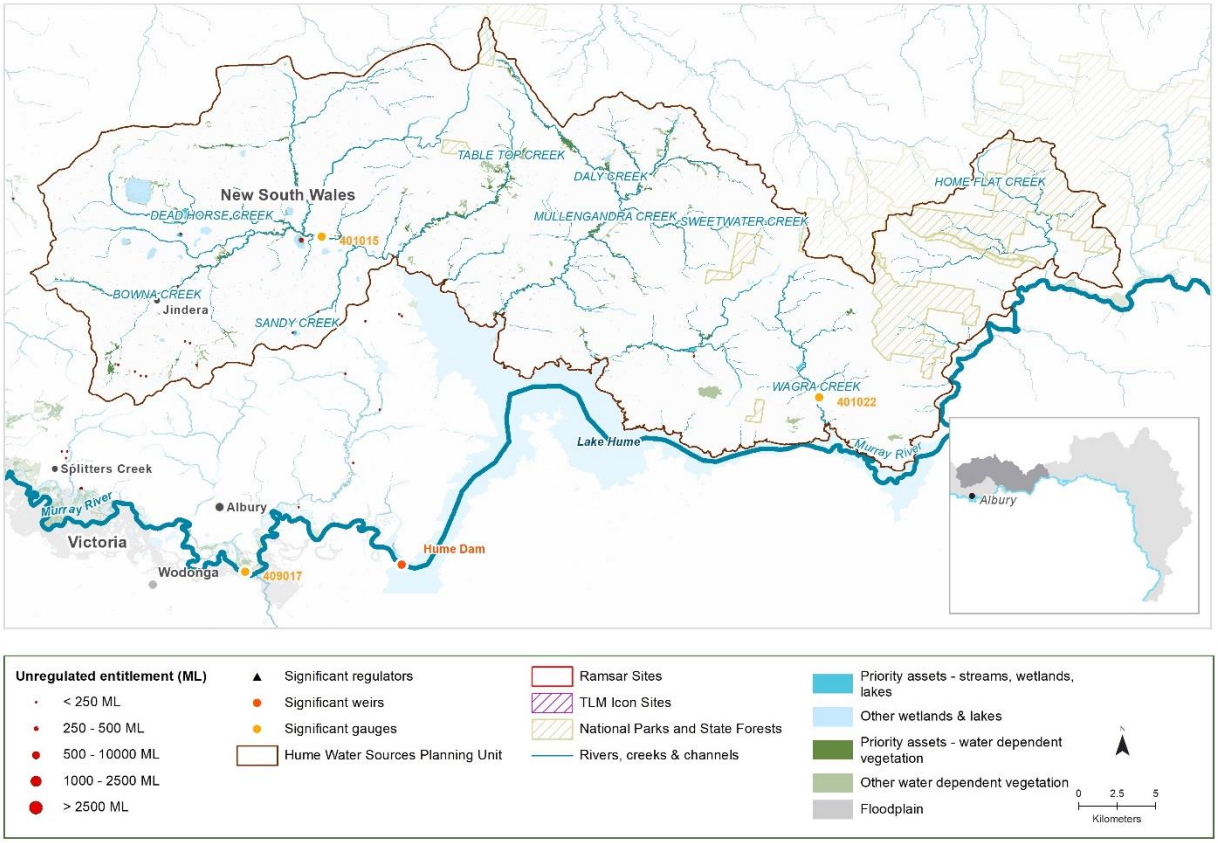
Recommendations

Ensure compliance with water access licence conditions including through metering of all licensed extraction.

Maintain existing rules in the WSP for the Murray Unregulated and Alluvial Water Sources.

Monitor for changes in water demand & review access rules if current usage is high or if the pattern of use changes.

PU31: Hume water source



Priority environmental assets

Rivers, creeks, wetlands & their associated in-channel & floodplain habitats & fringing vegetation communities, including (but not limited to):

- Bowna Creek & its tributaries
- Mullengandra Creek
- Sweetwater Creek
- Daly Creek
- Four Mile Creek
- Dead Horse Creek
- Sandy Creek
- Home Flat creek

Native fish[113]	• Australian smelt • dwarf flathead gudgeon • flat-headed gudgeon	• mountain galaxias • river blackfish • obscure galaxias	• flathead galaxias (P) • carp gudgeon • Murray cod
Birds	77 water-dependent bird species recorded, including the following listed[114] waterbird species: • Australian painted snipe (E)	• Caspian tern (J) • Cattle egret (J)	• Eastern great egret (J) • Latham's snipe (J,K)
	13 water-dependent PCTs, including		

[113] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

[114] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Native vegetation	• non-woody wetland	• lignum shrubland & wetland	• river red gum forest & woodland
Other species	• Bibron's toadlet • common eastern froglet • eastern banjo frog • superb parrot (V) • Macquarie turtle	• eastern sign-bearing froglet • giant banjo frog • platypus	• smooth toadlet • spotted grass frog • Peron's tree frog • eastern snake-necked turtle

Hydrology

Gauge: 401015 *Bowna Creek at Yambla*	**80th percentile**: 0 ML/d	**50th percentile**: 0.4 ML/d	**20th percentile**: 22 ML/d
	1.5 ARI: 1686 ML/d	**2.5 ARI**: 4833 ML/d	**5 ARI**: 6637 ML/d

Summary of hydrological alteration

There has been a moderate degree of change (20-50%) in low flows & baseflows as assessed by the Risk Assessment for the Murray & Lower Darling WRPA. Low flows & baseflows currently occur less frequently compared to the 'without development' model scenario.

There has also been low degree of change (<20% reduction) in freshes compared with the 'without development' model scenario.

The total volume of unregulated entitlements in the PU is 715 ML, of which 676 ML are water access licences (WALs) for production. There are six production WALs <250 ML & one between 250-500 ML located in the lower half of the PU, west of Yambla.

	Cease-to-flow	Low flow & Baseflow	Freshes	High & infrequent flows		
				1.5 ARI	2.5 ARI	5 ARI
Hydrological alteration	L^0	M^-	L^-	L^0	L^0	L^0
Relevant rules	Rivers & creeks: Cease-to-pump when there is no visible flow (equivalent to full flow through a 200m pipe) Natural in-river pools: Pumping not permitted from natural in-river pools when the water level in the pool is lower than its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident) Natural off-river pools: Pumping is not permitted from natural off-river pools when the water level in the pool is lower than 80% of its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident) Trading rules: INTO water source – not permitted; WITHIN water source: trades permitted, subject to assessment; Conversion to high flow access: not permitted; Interstate trading: not permitted.					

Recommendations

Investigate opportunities to reduce extraction pressure on low flows, baseflows & freshes in the water source within five years:

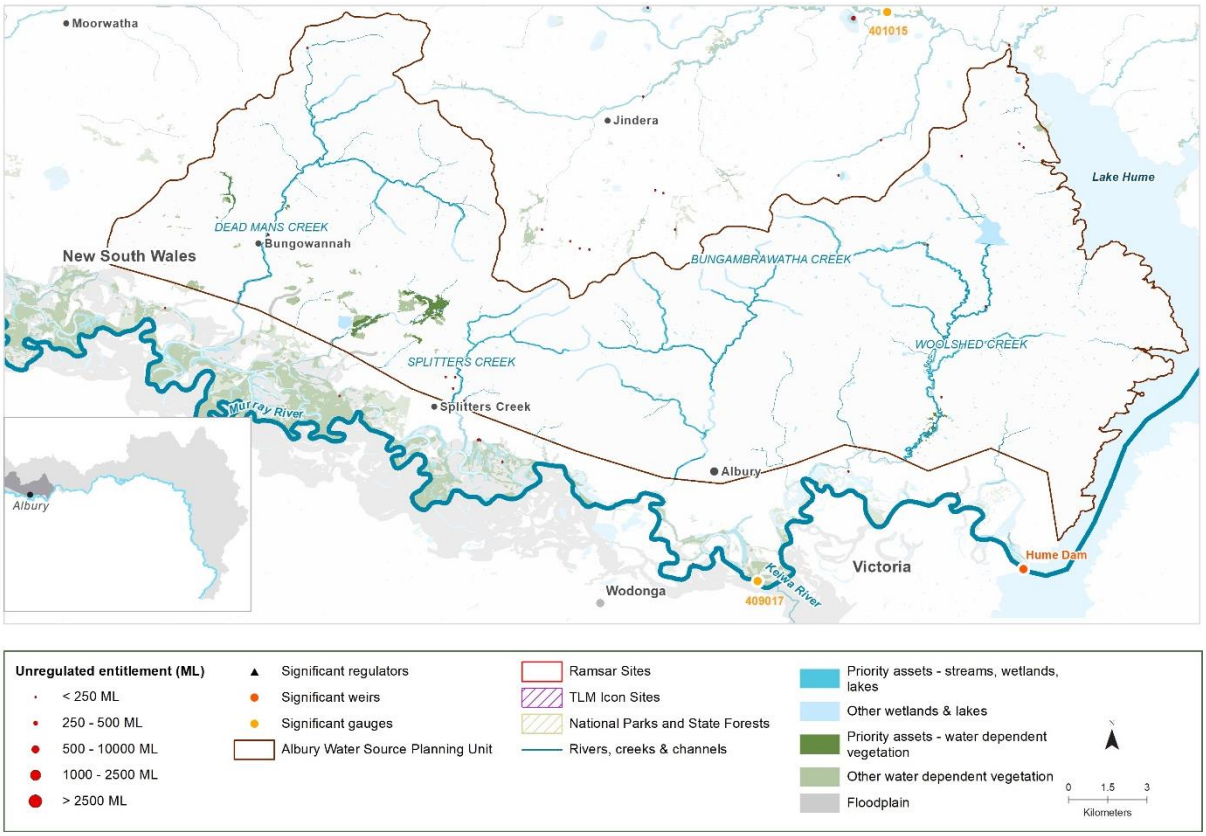
- Consider reviewing existing cease-to-pump rules to ensure that visible flow is maintained downstream of extraction points on streams (the current rules mean that extraction can occur until there is no visible flow i.e. until the stream stops flowing)
- Consider installing staff gauges at/near pump sites to assist WAL holders in assessing streamflow conditions near extraction sites.
- Consider implementing a commence-to-pump threshold which is higher than the cease-to-pump threshold – to protect the initial increases in flows after a very low flow period (or cease-to-flow event), allowing water quality to improve & providing movement & breeding opportunities for native fish & other aquatic biota.
- Consider rostering landholder water access during low flow months
- Consider IDELS &/or TDELS (would require improved gauging)

Maintain existing rules in the WSP for the Murray Unregulated and Alluvial Water Sources.

Ensure compliance with water access licence conditions including through metering of all licensed extraction.

Monitor for changes in water demand & review access rules if current usage is high or if the pattern of use changes.

PU32: Albury water source



Priority environmental assets

Rivers, creeks, wetlands & their associated in-channel & floodplain habitats & fringing vegetation communities, including (but not limited to):

- Woolshed Creek & its tributaries
- Bungambrawatha Creek & its tributaries
- Splitters Creek & its tributaries
- Dead Mans Creek & its tributaries

Native fish[115]	• river blackfish • mountain galaxias	• flat-headed gudgeon • Australian smelt	• flathead galaxias (P) • carp gudgeon
Birds	79 water-dependent bird species recorded, including the following listed[116] waterbird species:		
	• blue-billed duck (V) • brolga (V) • Caspian tern (J)	• cattle egret (J) • eastern great egret (J)	• Latham's snipe (J,K) • sharp-tailed sandpiper (C,J,K)

[115] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

[116] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE] or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Native vegetation	4 water-dependent PCTs, including non-woody wetland vegetation & river red gum forest		
Other species	• Bibron's toadlet • brown tree frog • common eastern froglet • superb parrot (V) • eastern snake-necked turtle	• eastern sign-bearing froglet • giant banjo frog • Peron's tree frog • Sloane's froglet (V) • platypus	• smooth toadlet • southern bell frog (E) • spotted grass frog • Victorian frog • broad-shelled turtle

Hydrology

Gauge: 401015 *Bowna Creek at Yambla*	**80th percentile**: 0 ML/d	**50th percentile**: 0.13 ML/d	**20th percentile**: 7.2 ML/d
	1.5 ARI: 550 ML/d	**2.5 ARI**: 1578 ML/d	**5 ARI**: 2167 ML/d

Summary of hydrological alteration

Low flows & baseflows have been highly altered (>50% departure from base case) as assessed by the Risk Assessment for the Murray & Lower Darling WRPA. Low flows currently occur less frequently compared to the 'without development' model scenario. There has also been a low degree of change (<20% reduction) in freshes.

The total volume of unregulated entitlements in the PU is 343 ML, of which 329 ML are water access licences (WALs) for production. There are 10 production WALs <250 ML that are distributed throughout the PU.

	Cease-to-flow	Low flow & Baseflow	Freshes	High & infrequent flows		
				1.5 ARI	2.5 ARI	5 ARI
Hydrological alteration	L^0	H^-	L^-	L^0	L^0	L^0
Relevant rules	Rivers & creeks: Cease-to-pump when there is no visible flow (equivalent to full flow through a 200m pipe) Natural in-river pools: Pumping not permitted from natural in-river pools when the water level in the pool is lower than its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident) Natural off-river pools: Pumping is not permitted from natural off-river pools when the water level in the pool is lower than 80% of its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident) Trading rules: INTO water source – not permitted; WITHIN water source: trades permitted, subject to assessment; Conversion to high flow access: not permitted; Interstate trading: not permitted.					

Recommendations

Investigate opportunities to reduce extraction pressure on low flows, baseflows & freshes in the water source within five years:

- Consider installing a streamflow gauge on Eight Mile Creek & Splitters Creek, which are currently ungauged but have several surface water extraction sites.
- Consider reviewing existing cease-to-pump rules to ensure that visible flow is maintained downstream of extraction points on streams (the current rules mean that extraction can occur until there is no visible flow i.e. until the stream stops flowing)
- Consider installing staff gauges at/near pump sites to assist WAL holders in assessing streamflow conditions near extraction sites.
- Consider implementing a commence-to-pump threshold which is higher than the cease-to-pump threshold – to protect the initial increases in flows after a very low flow period (or cease-to-flow event), allowing water quality to improve & providing movement & breeding opportunities for native fish & other aquatic biota.
- Consider rostering landholder water access during low flow months

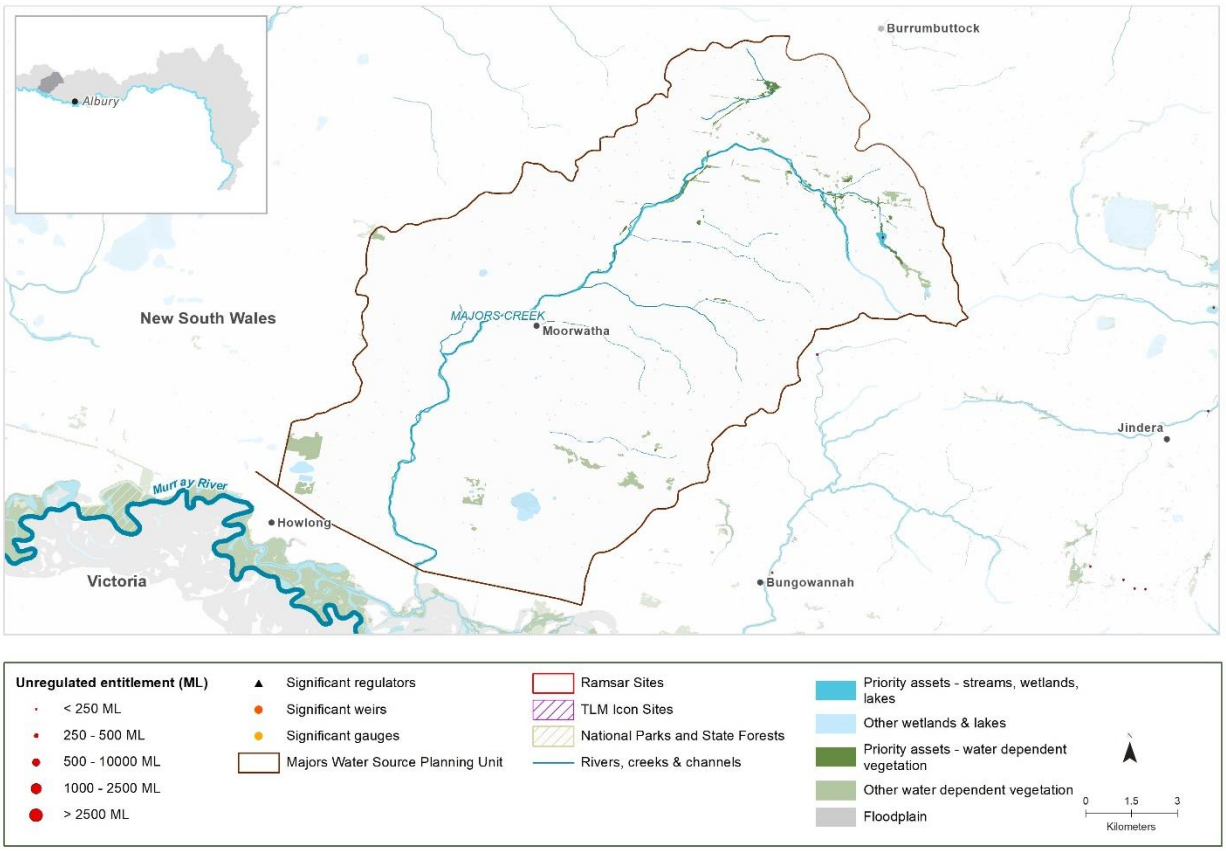
- Consider IDELS &/or TDELS (would require improved gauging)

Maintain existing rules in the WSP for the Murray Unregulated and Alluvial Water Sources.

Ensure compliance with water access licence conditions including through metering of all licensed extraction.

Monitor for changes in water demand & review access rules if current usage is high or if the pattern of use changes.

PU33: Majors water source



Priority environmental assets

Rivers, creeks, wetlands & their associated in-channel & floodplain habitats & fringing vegetation communities, including Majors Creek & its tributaries.

Native fish	• Australian smelt • carp gudgeon	• flat-headed gudgeon • mountain galaxias	• river blackfish
Birds	32 water-dependent bird species recorded.		
Native vegetation	9 water-dependent PCTs, including non-woody wetland, lignum shrubland & wetland, & river red gum woodland		
Other species	• eastern sign-bearing froglet	• Sloane's froglet • spotted grass frog	• Sudell's frog • superb parrot (V)

Hydrology			
Gauge: 401015 *Bowna Creek at Yambla*	**80th percentile**: 0 ML/d	**50th percentile**: 0.087 ML/d	**20th percentile**: 4.7 ML/d
	1.5 ARI: 363 ML/d	**2.5 ARI**: 1039 ML/d	**5 ARI**: 1427 ML/d

Summary of hydrological alteration

Flows in Majors Creek are represented by Bowna Creek in an adjacent water source as there are no existing streamflow gauges in the Majors water source. Flows do not seem to be altered by more than 20% compared to the 'without development' model scenario as assessed by the Risk Assessment for the Murray & Lower Darling WRPA.

The total volume of unregulated entitlements in the PU is 81 ML & includes one water access license for production of 76 ML that is located on a pool in the upper part of the PU.

	Cease-to-flow	Low flow & Baseflow	Freshes	High & infrequent flows		
				1.5 ARI	2.5 ARI	5 ARI
Hydrological alteration	L^0	L^-	L^-	L^-	L^0	L^0
Relevant rules	Rivers & creeks: Cease-to-pump when there is no visible flow (equivalent to full flow through a 200m pipe) Natural in-river pools: Pumping not permitted from natural in-river pools when the water level in the pool is lower than its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident) Natural off-river pools: Pumping is not permitted from natural off-river pools when the water level in the pool is lower than 80% of its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident) Trading rules: INTO water source – not permitted; WITHIN water source: trades permitted, subject to assessment; Conversion to high flow access: not permitted; Interstate trading: not permitted.					

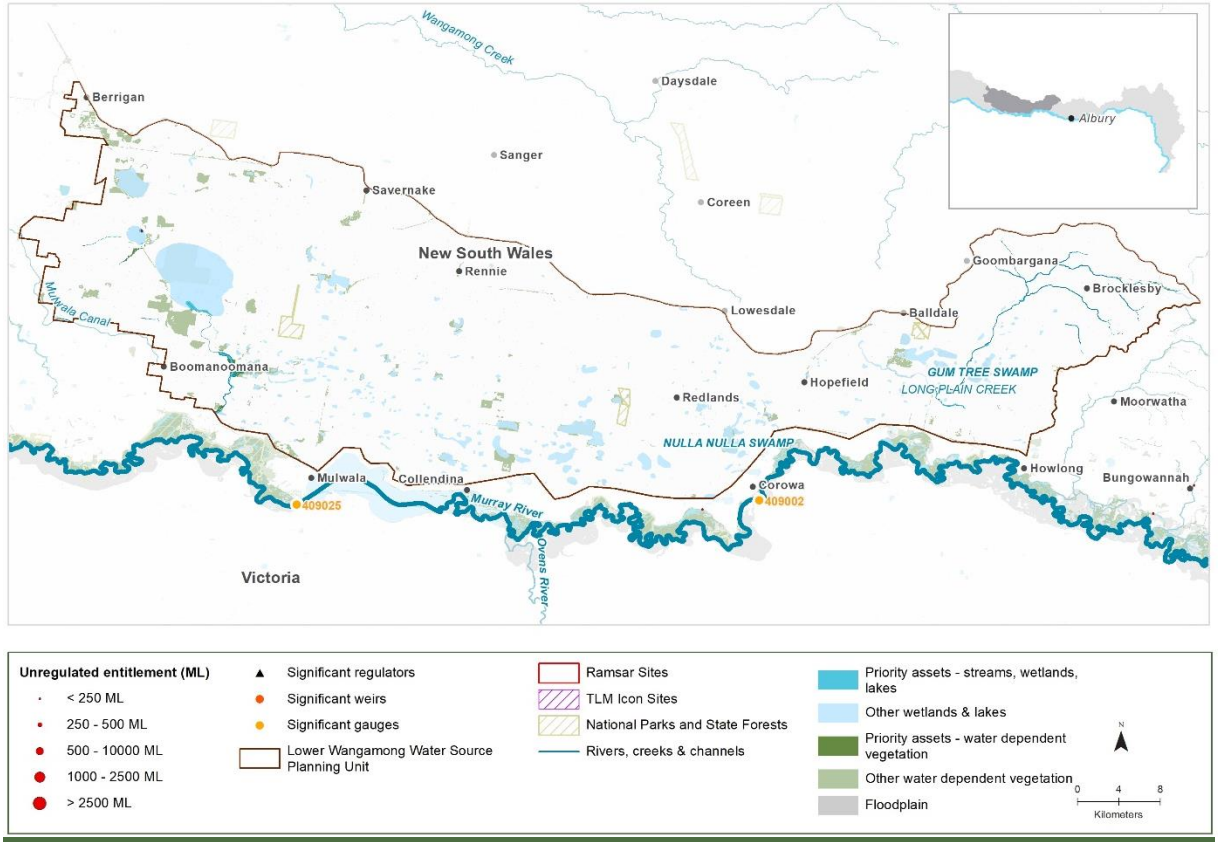
Recommendations

Ensure compliance with water access licence conditions including through metering of all licensed extraction.

Maintain existing rules in the WSP for the Murray Unregulated and Alluvial Water Sources.

Monitor for changes in water demand & review access rules if current usage is high or if the pattern of use changes.

PU34: Lower Wangamong water source



Priority environmental assets

Creeks, wetlands & their associated in-channel & floodplain habitats & fringing vegetation communities, including (but not limited to):

- Long Plain Creek & its tributaries
- Numerous wetlands throughout water source including Nulla Nulla Swamp, Gum Tree Swamp & many unnamed wetlands

Native fish	• Australian smelt • carp gudgeon • dwarf flathead gudgeon • flat-headed gudgeon • mountain galaxias • river blackfish
Birds	85 water-dependent bird species recorded, including the following listed[117] waterbird species: • Australasian bittern (E) • Australian painted snipe (E) • brolga (V) • Caspian tern (J) • cattle egret (J) • eastern great egret (J) • freckled duck (V) • Latham's snipe (J,K) • sharp-tailed sandpiper (C,J,K)
Native vegetation	19 water-dependent PCTs, including non-woody wetlands, lignum shrubland & wetland, river red gum forest & woodland, & black box woodlands

[117] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Other species	• common eastern froglet • eastern banjo frog • eastern sign-bearing froglet	• giant banjo frog • barking marsh frog • Sloane's froglet • superb parrot (V)	• spotted grass frog • Sudell's frog • wrinkled toadlet • southern myotis

Hydrology

Information not available due to multiple small streams with no appropriate streamflow gauges

Summary of hydrological alteration

Flows do not seem to be altered by more than 20% compared to the 'without development' model scenario as assessed by the Risk Assessment for the Murray & Lower Darling WRPA.

There is only one stock & domestic unregulated water access licence that is 7 ML & located on a pool in the far west of the PU.

	Cease-to-flow	Low flow & Baseflow	Freshes	High & infrequent flows		
				1.5 ARI	2.5 ARI	5 ARI
Hydrological alteration	L^0	L^0	L^0	L^0	L^0	L^0
Relevant rules	Rivers & creeks: Cease-to-pump when there is no visible flow (equivalent to full flow through a 200m pipe) Natural in-river pools: Pumping not permitted from natural in-river pools when the water level in the pool is lower than its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident) Natural off-river pools: Pumping is not permitted from natural off-river pools when the water level in the pool is lower than 80% of its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident) Trading rules: INTO water source – not permitted; WITHIN water source: trades permitted, subject to assessment; Conversion to high flow access: not permitted; Interstate trading: not permitted.					

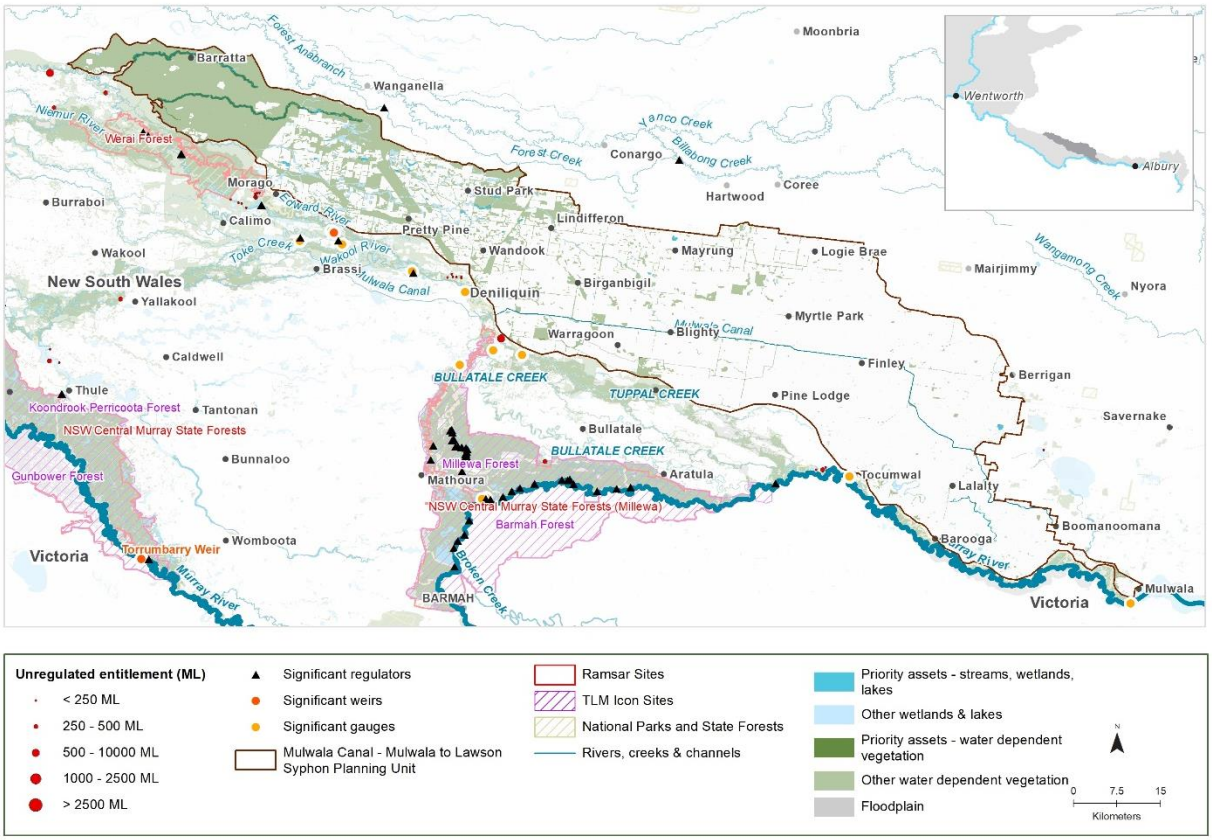
Recommendations

Ensure compliance with water access licence conditions including through metering of all licensed extraction.

Maintain existing rules in the WSP for the Murray Unregulated and Alluvial Water Sources.

Monitor for changes in water demand & review access rules if current usage is high or if the pattern of use changes.

PU35: Mulwala Canal - Mulwala to Lawson Syphon[118]



Priority environmental assets

Creeks, wetlands & their associated in-channel & floodplain habitats & fringing vegetation communities, including (but not limited to):

- Clarkes Creek
- Dry Creek
- Turn Back Kims [creek]
- Numerous unnamed wetlands that can received environmental water via Murray Irrigation infrastructure

Native fish	• Australian smelt • bony herring • carp gudgeon	• dwarf flathead gudgeon • flat-headed gudgeon • golden perch	• Murray cod • Murray–Darling rainbowfish • Unspecked hardyhead

Birds

99 water-dependent bird species recorded, including the following listed[119] waterbird species:

- Australasian bittern (E)
- Australian painted snipe (E)
- black-tailed godwit (V,C,J,K)
- blue-billed duck (V)
- brolga (V)
- cattle egret (J)
- common greenshank (C,J,K)
- curlew sandpiper (E,CE,C,J,K)
- eastern great egret (J)
- freckled duck (V)
- Latham's snipe (J,K)
- magpie goose (V)
- marsh sandpiper (C,J,K)
- red-necked stint (C,J,K)
- ruff (C,J,K)
- sharp-tailed sandpiper (C,J,K)
- white-winged black tern (C,J)
- wood sandpiper (C,J,K)

[118] This planning unit is part of the broader Murray Below Mulwala water source.

[119] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Native vegetation	27 water-dependent PCTs, including non-woody wetland, lignum shrublands/wetlands, nitre goosefoot floodplain, river red gum forest & woodland, & black box woodland		
Other species	• common eastern froglet • barking marsh frog • platypus	• spotted grass frog • wrinkled toadlet • yellow-bellied sheathtail-bat (V)	• eastern sign-bearing froglet • superb parrot (V)

Hydrology

Information not available due to multiple small streams with no appropriate streamflow gauges

There are no unregulated water access licences in this PU.

	Cease-to-flow	Low flow & Baseflow	Freshes	High & infrequent flows		
				1.5 ARI	2.5 ARI	5 ARI
Hydrological alteration	N/A	N/A	N/A	N/A	N/A	N/A
Relevant rules	Rivers & creeks: Cease-to-pump when there is no visible flow (equivalent to full flow through a 200m pipe) Natural in-river pools: Pumping not permitted from natural in-river pools when the water level in the pool is lower than its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident) Natural off-river pools: Pumping is not permitted from natural off-river pools when the water level in the pool is lower than 80% of its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident) Trading rules: INTO water source – not permitted; WITHIN water source: trades permitted, subject to assessment; Conversion to high flow access: not permitted; Interstate trading: not permitted.					

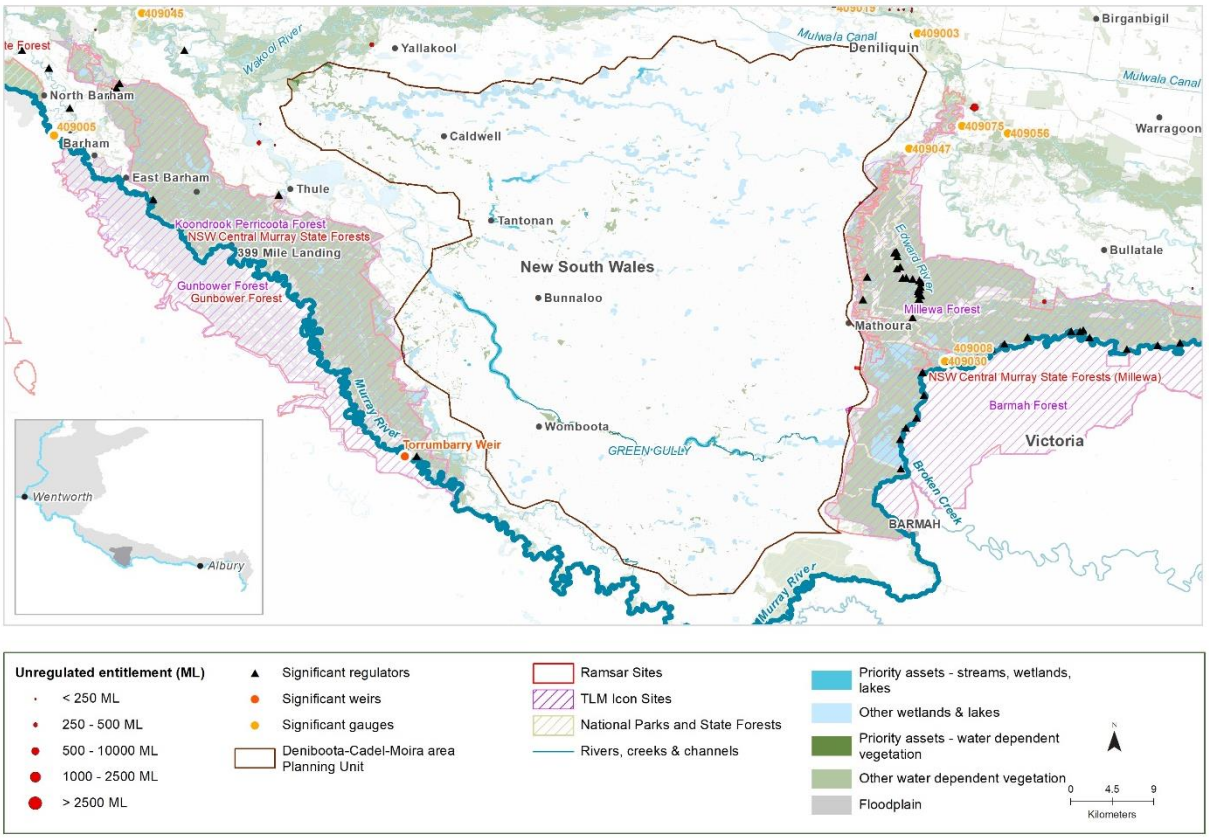
Recommendations

Ensure compliance with water access licence conditions including through metering of all licensed extraction.

Maintain existing rules in the WSP for the Murray Unregulated and Alluvial Water Sources.

Monitor for changes in water demand & review access rules if current usage is high or if the pattern of use changes.

PU36: Deniboota-Cadell-Moira area[120]



Priority environmental assets

Wetlands & their associated in-channel & floodplain habitats & fringing vegetation communities, including numerous unnamed wetlands that can received environmental water via Murray Irrigation infrastructure

Native fish	• bony herring • Murray-darling rainbowfish • dwarf flathead gudgeon • flat-headed gudgeon • carp gudgeon • Australian smelt • unspecked hardyhead
Birds	87 water-dependent bird species recorded, including the following listed[121] waterbird species: • Australasian bittern (E) • blue-billed duck (V) • brolga (V) • cattle egret (J) • eastern great egret (J) • freckled duck (V) • Latham's snipe (J,K) • common greenshank (C,J,K) • red-necked stint (C,J,K) • sharp-tailed sandpiper (C,J,K)
Native vegetation	16 water-dependent PCTs, including non-woody wetland, lignum shrublands & wetlands, nitre goosefoot floodplain, river red gum forest & woodland, & black box woodland

[120] This planning unit is part of the broader Murray Below Mulwala water source.

[121] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Other species	• spotted grass frog • superb parrot (V)

Hydrology

Information not available due to few defined streams & no appropriate streamflow gauges

There are no unregulated water access licences in this PU.

	Cease-to-flow	Low flow & Baseflow	Freshes	High & infrequent flows		
				1.5 ARI	2.5 ARI	5 ARI
Hydrological alteration	N/A	N/A	N/A	N/A	N/A	N/A
Relevant rules	Rivers & creeks: Cease-to-pump when there is no visible flow (equivalent to full flow through a 200m pipe) Natural in-river pools: Pumping not permitted from natural in-river pools when the water level in the pool is lower than its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident) Natural off-river pools: Pumping is not permitted from natural off-river pools when the water level in the pool is lower than 80% of its full capacity (pool water level at the point where inflow & outflow of that pool becomes no longer evident) Trading rules: INTO water source – not permitted; WITHIN water source: trades permitted, subject to assessment; Conversion to high flow access: not permitted; Interstate trading: not permitted.					

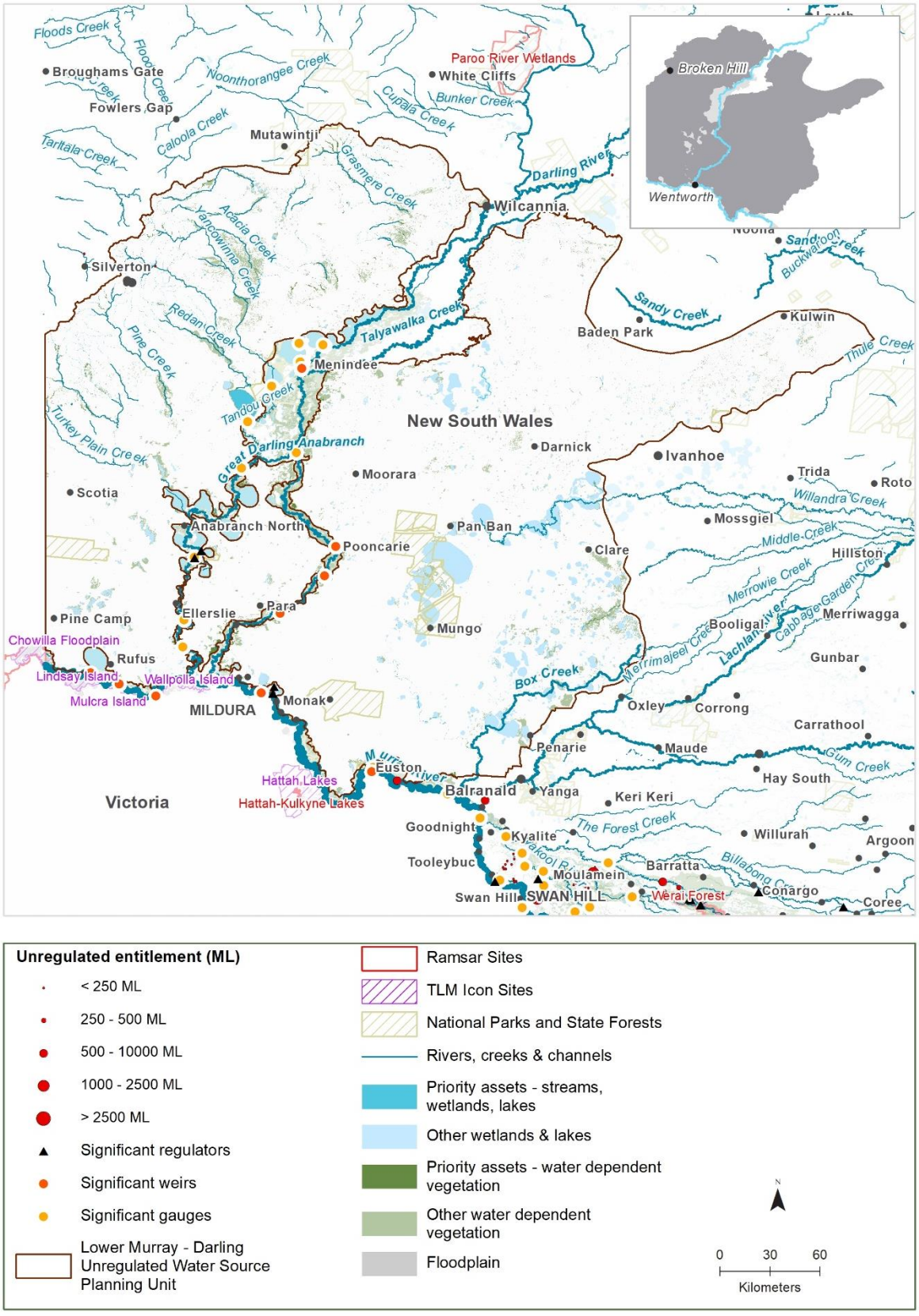
Recommendations

Ensure compliance with water access licence conditions including through metering of all licensed extraction.

Maintain existing rules in the WSP for the Murray Unregulated and Alluvial Water Sources.

Monitor for changes in water demand & review access rules if current usage is high or if the pattern of use changes.

PU37: Lower Murray Darling Unregulated



Unregulated entitlement (ML)

- < 250 ML
- 250 - 500 ML
- 500 - 10000 ML
- 1000 - 2500 ML
- > 2500 ML
- Significant regulators
- Significant weirs
- Significant gauges
- Lower Murray - Darling Unregulated Water Source Planning Unit
- Ramsar Sites
- TLM Icon Sites
- National Parks and State Forests
- Rivers, creeks & channels
- Priority assets - streams, wetlands, lakes
- Other wetlands & lakes
- Priority assets - water dependent vegetation
- Other water dependent vegetation
- Floodplain

N

0 30 60

Kilometers

Priority environmental assets

Creeks, wetlands & their associated in-channel & floodplain habitats & fringing vegetation communities, including (but not limited to):

- All wetlands, lakes, anabranches & creeks located on the floodplain of major regulated rivers (Murray, Darling, Darling Anabranch, Edward, Wakool rivers) & regulated creeks (e.g. Yallakool & Colligen creeks) – i.e. those listed in regulated PU report cards. Note that these priority environmental assets are technically located in the *Lower Murray Darling Unregulated Water Source* according to the Water Sharing Plan, but for the purpose of the LTWP, they have been included in regulated PUs because they can receive HEW & PEW or can be managed through management of major storages. They are mentioned here because they can also be influenced by extraction under unregulated water access licenses.
- Wetlands or creeks with existing WALs include: Thegoa Lagoon & Peacock Creek

Native fish[122]	• Australian smelt • dwarf flathead gudgeon • Murray-darling rainbowfish • flat-headed gudgeon	• golden perch • Murray cod • spangled perch	• olive perchlet (P) • bony herring • carp gudgeon
Birds	104 water-dependent bird species recorded, including the following listed[123] waterbird species:		
	• Australasian bittern (E) • Australian painted snipe (E) • bar-tailed godwit (V,C,J,K) • blue-billed duck (V) • brolga (V) • Caspian tern (J) • cattle egret (J) • common greenshank (C,J,K)	• common sandpiper (C,J) • curlew sandpiper (E,CE,C,J,K) • eastern great egret (J) • freckled duck (V) • Latham's snipe (J,K) • little curlew (C,J,K) • long-toed stint (C,J,K) • magpie goose (V)	• marsh sandpiper (C,J,K) • pectoral sandpiper (J,K) • red-necked stint (C,J,K) • ruddy turnstone (C,J,K) • sharp-tailed sandpiper (C,J,K) • whimbrel (C,J,K)
Native vegetation	33 water-dependent PCTs, including non-woody wetland, lignum & nitre goosefoot shrubland & wetland, river red gum forest & woodland, black box woodland, coolibah woodland		
Other species	• desert tree frog • eastern banjo frog • eastern sign-bearing froglet • giant banjo frog • regent parrot (V) • inland forest bat	• green tree frog • barking marsh frog • Peron's tree frog • rough frog • Corben's long-eared bat (V) • little pied bat (V) • eastern snake-necked turtle	• spotted grass frog • Sudell's frog • trilling frog • water-holding frog • eastern bentwing-bat • yellow-bellied sheathtail-bat (V)

[122] Native fish species recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (P) are native fish species expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016).

[123] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K]).

Hydrology

Information not available due to multiple small streams with no appropriate streamflow gauges

Summary of hydrological alteration

This water source covers a large area across the entire Lower Murray-Darling catchment & a description of hydrological change is not possible at this time. The PU includes many wetlands, minor creeks (that are not covered by the regulated WSP) & floodplain areas that receive PEW, HEW & unregulated flows from regulated rivers & creeks. Some of these environmental assets have unregulated surface water extraction licenses.

There is one unregulated entitlement of 6300 ML (town water supply) near Broken Hill. There are however 12 unregulated WALs located in the Murray Lower-Darling unregulated water source (totalling 2453 ML) that fall within nearby regulated PUs in this LTWP. These sites have been included in regulated PUs because they can receive or are affected by regulated water deliveries.

	Cease-to-flow	Low flow & Baseflow	Freshes	High & infrequent flows		
				1.5 ARI	2.5 ARI	5 ARI
Hydrological alteration	N/A	N/A	N/A	N/A	N/A	N/A
Relevant rules	Cease-to-Pump (CtP) 1. For access licenses extracting from pools or lagoons listed in Schedule 5 of the plan, a CtP will be set at 50 per cent of the average 'full level' volume 2. If environmental water is diverted into Thegoa Lagoon when the water level is below the CtP level, then licensed extractions are not permitted until water enters the lagoon via the western culvert, or water allocated for extraction is diverted into the lagoon. 3. For access licenses extracting from pools or lagoons not listed in Schedule 5 of the plan, a zero per cent drawdown will apply. 4. For access licenses extracting from a streambed (not from a lagoon or pool) a CtP will be set at visible flow Reference points 1. At a gauge board in the lagoon / pool's environs 2. At the pump site in streams Trading rules: INTO water source – not permitted; WITHIN water source: trade is not permitted into lagoons. Subject to assessment, water access licenses that nominate works on lagoons may be traded to works not located on lagoons, Conversion to high flow access: not permitted; Interstate trading: not permitted unless there is an interstate agreement					

Recommendations

As a priority, consider introducing cease-to-pump & commence-to-pump rules (& any associated required amendments to license conditions) that protect environmental water entering unregulated streams & off-channel pools (wetlands), in-line with the Basin Plan requirement for implementation of Prerequisite Policy Measures (PPM), including the protection of environmental water).

Ensure compliance with water access licence conditions including through metering of all licensed extraction.

Maintain existing rules in the WSP for the Lower Murray Darling Unregulated and Alluvial Water Sources.

Monitor for changes in water demand & review access rules if current usage is high or if the pattern of use changes.

References

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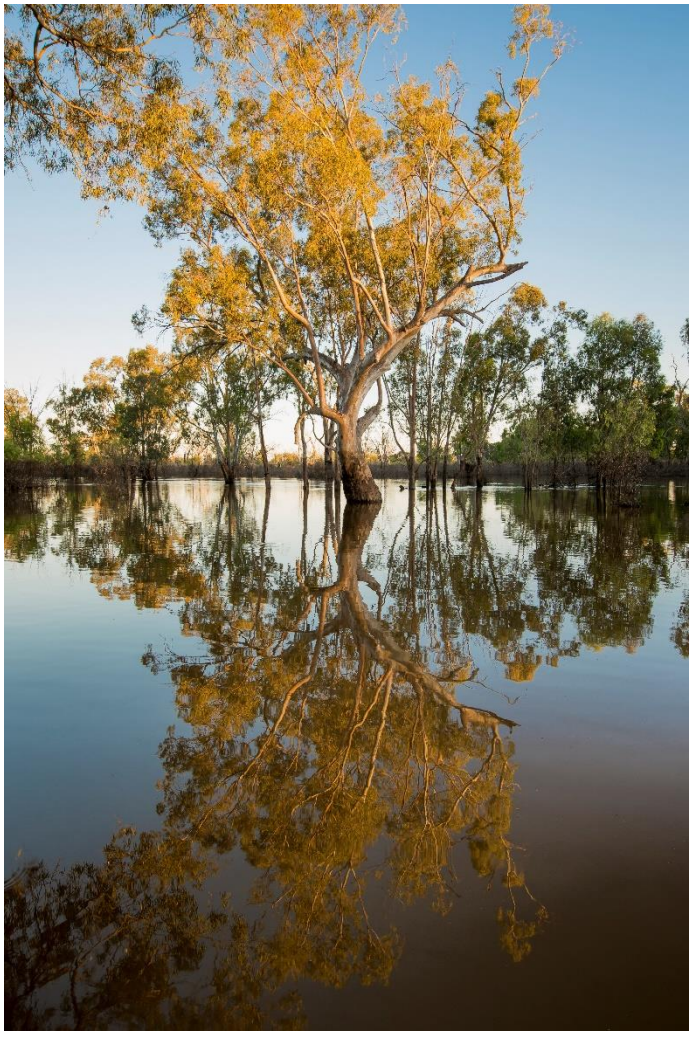

Figure 6 **River red gum**
Photo: John Spencer