DEPARTMENT OF PLANNING, INDUSTRY AND ENVIRONMENT

Intersecting Streams Long Term Water Plan

Parts A and B

Draft for exhibition

Cover photo: Royal spoonbills (*Platalea regina*) at Narran Lake. Photo Neal Foster.

Published by:

Department of Planning, Industry and Environment
59 Goulburn Street, Sydney NSW 2000
PO Box A290, Sydney South NSW 1232
Phone: +61 2 9995 5000 (switchboard)
Phone: 1300 361 967 (DPIE and national parks enquiries)
TTY users: phone 133 677, then ask for 1300 361 967
Speak and listen users: phone 1300 555 727, then ask for 1300 361 967
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

Report pollution and environmental incidents
Environment Line: 131 555 (NSW only) or info@environment.nsw.gov.au
See also www.environment.nsw.gov.au

ISBN 978-1-925974-47-8
EES 2019/0307
July 2019

Find out more about your environment at:

www.environment.nsw.gov.au

Contents

List of tables

List of figures

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 Intersecting Stream system, the Department of Planning, Industry and Environment pays its respects to Kurnu–Baakandji, Budjiti, Euahlayi, Guwamu/Kooma, Kamilaroi, Kunja, Murrawarri, and Ngemba, among others. Traditional Owners past, present and future, as well as those of other nations for whom this river is significant. 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 Creeping monkey-flower (*Mimulus repens*) at Toorale Station
Photo: Joanne Ocock.

Abbreviations

Basin Plan	Murray–Darling Basin Plan
BCT	NSW Biodiversity Conservation Trust
BWS	Basin-wide environmental watering strategy
CAMBA	China – Australia Migratory Bird Agreement
CEWH	Commonwealth Environmental Water Holder
CEWO	Commonwealth Environmental Water Office
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DoI–W	NSW Department of Industry – Water
DPIE–Water	NSW Department of Planning, Industry and Environment–Water
DPIF	NSW Department of Primary Industries Fisheries
EWR	Environmental water requirement
HEW	Held environmental water
JAMBA	Japan – Australia Migratory Bird Agreement
LLS	Local Land Services (NSW)
LTWP	Long Term Water Plan
MDBA	Murray–Darling Basin Authority
MER	Monitoring, evaluation and reporting
mg/L	milligrams per litre
ML	megalitre
ML/d	megalitres per day
m/s	metres per second
NPWS	NSW National Parks and Wildlife Services
NRAR	NSW Natural Resources Access Regulator
NSW	New South Wales
OEH	NSW Office of Environment and Heritage
PEW	Planned environmental water
PU	Planning unit
RAS	Resource availability scenario
RoKAMBA	Republic of Korea – Australia Migratory Bird Agreement
SDL	Sustainable diversion limit
TEC	Threatened Ecological Community
WQMP	Water quality management plan
WRP	Water resource plan
WRPA	Water resource plan area
WSP	Water sharing plan

Glossary

Adaptive management	A procedure for implementing management while learning about which management actions are most effective at achieving specified objectives.
Allocation	The volume of water made available to water access licence or environmental water accounts in a given year by DPIE–Water, which is determined within the context of demand, inflows, rainfall forecasts & stored water.
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 & flood runners & wetlands located within the meander train. Inundates all in channel habitats including all benches, snags & backwaters.
Baseflow	Low-flow events within a river channel that typically inundate geomorphic units such as pools & riffle areas & connect main pools within reaches, allowing for minimal levels of movement for aquatic fauna.
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	This typically occurs when water moves across a floodplain & accumulates organic carbon leached from the soil & leaf litter. The water takes on a black or tea colour due to the presence of tannins & other carbon compounds. Blackwater plays an important role in transferring essential nutrients, such as carbon, from wetlands into rivers & vice versa. Carbon is a basic building block of the aquatic food web & an essential part of a healthy river system. Can sometimes result in water quality issues (see 'Hypoxia').
Catch per unit effort (CPUE)	A standardised measure of the abundance of a target species.
Cease-to-flow (CF)	The absence of flowing water in a stream channel, which is usually associated with drying of the river channel. Streams contract to a series of disconnected pools.
Cease-to-pump (access rule in WSP)	Water sharing plan rules that indicate when water take for irrigation or other purposes must cease. These rules typically aim to protect water levels in stream pools, & can vary by WSPA, planning unit & approved work.
Constraints	The physical or operational constraints that affect 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, or land uses in & around wetlands & floodplains.
Constraints management strategy (MDBA)	The strategy developed by the Murray–Darling Basin Authority that identified constraints to environmental water delivery. Specific NSW catchments covered by the strategy include: Murray–Lower Darling, Murrumbidgee & Gwydir.
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). Consumptive water deliveries may contribute or support environmental water requirements prior to the point of extraction.
Cultural water-dependent asset	A place that has social, spiritual & cultural value based on its cultural significance to Aboriginal people & is related to the water resource.
Cultural water-dependent value	An object, plant, animal, spiritual connection or use that is dependent on water & has value based on its cultural significance to Aboriginal people.

Discharge	The amount of water moving through a river system, most commonly expressed in megalitres per day (ML/d).
Dissolved Organic Carbon (DOC)	A measure of the amount of carbon from organic matter that is soluble in water. DOC is transported by water from floodplains to river systems & is a basic building block available to bacteria & algae that microscopic animals feed on, that are in turn consumed by fish larvae, small-bodied fish species, yabbies & shrimp. DOC is essential for building the primary food webs in rivers, wetlands & floodplains, ultimately generating a food source for large bodied fish like Murray cod & golden perch & predators such as waterbirds.
Ecological asset	The physical places that make up an ecosystem.
Ecological function	The resources & services that sustain human, plant & animal communities & are provided by the processes & interactions occurring within & between ecosystems.
Ecological objective	Objective for the protection &/or restoration of an ecological asset or function.
Ecological target	Level of measured performance that must be met 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 that has value based on its ecological significance.
Ecosystem	A biological community of interacting organisms & their physical environment. It includes all the living things in that community, interacting with their non-living environment (weather, earth, sun, soil, climate & atmosphere) & with each other.
Environmental water	Water for the environment. It serves a multitude of benefits to not only the environment, but to communities, industry & society. It includes water directly managed by the NSW & Australian governments (held environmental water) or protected from extraction from waterways (planned environmental water) for meeting the requirements of water-dependent ecosystems.
Environmental water requirement (EWR)	The flow event/s required to support the completion of key known 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. EWRs can be met by various flows in a system including natural inflows, held environmental water, planned environmental water, essential supplies, conveyance water & consumptive orders.
Floodplain harvesting	The collection, extraction or impoundment of water flowing across floodplains. NSW is currently bringing floodplain harvesting extraction under regulation & licencing framework & to be included under water sharing plans.
Flow component	The classification of flow in a river defined by its magnitude (e.g. bankfull).
Flow regime	The pattern of flow events in a stream over time.
Freshes	A typically short-term in-channel flow usually in response to rainfall runoff or release from water storages.
Groundwater	Water that is located below the earth's surface in soil pore spaces & in the fractures of rock formations. Groundwater is recharged from, & eventually flows to, the surface naturally.
Held environmental water (HEW)	Water available under a water access licence or 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. In NSW, typically managed by either the Commonwealth Environmental Water Holder or NSW DPIE.
Hydrograph	A graph showing the rate of flow &/or water level over time at a specific point in a river. The rate of flow is typically expressed in megalitres per day (ML/d).

Hydrological connectivity	Flows that connect along & between streams, & that typically link environmental assets & values.
Hydrology	The study of the occurrence, distribution & movement of water across the landscape. In this context, it is used to describe the characteristics of the surface water flow regime.
Hypoxia	Occurs when dissolved oxygen (DO) levels, as measured in milligrams per litre (mg/litre), fall below the level needed to sustain native fish & other water dependent species. Native fish begin to stress when DO levels fall below 4 mg/litre & fish mortality occurs when DO levels are less than 2 mg/litre. Bacteria that feed on dissolved organic carbon consume oxygen. When this rate exceeds the rate at which oxygen can enter the water from the atmosphere, oxygen levels fall & a hypoxic (low oxygen) condition occurs.
Large fresh	High-flow that remains in-channel, connects most in-channel habitats, enables longitudinal connectivity, often by drowning out of low-level weirs & other in channel barriers & may engage flood runners & inundate low-lying wetlands.
Lateral connectivity	The flow linking rivers channels & the floodplain
Long Term Water Plan (LTWP)	A requirement of the Basin Plan that gives effect to the Basin-Wide Watering Strategy for each river system & will guide the management of water over the longer term. DPIE is responsible for the development of nine plans for river catchments across NSW, with objectives for five, 10 & 20-year timeframes.
Longitudinal connectivity	The downstream flow along the length of a river.
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, a water sharing plan, or a plan made under State water management law to achieve environmental outcomes.
Planning Unit	In the context of this LTWP, a spatial division of a water resource plan area based on water requirements or a sub-catchment boundary.
Population structure	The range of age & size classes within a species population. A population with a range of age & size, with a good number of sexually mature individuals, demonstrates regular recruitment & is healthy.
Priority ecological function	Ecological functions defined by the MDBA that can be affected by held environmental water.
Priority ecological asset	A place meeting ecological criterion set by the MDBA that is water-dependent & can be affected by held environmental water.
Recruitment	The part of a plant or animal’s life cycle from germination/birth/spawning through stages of immature development & growth, & then entry into the breeding population; so that they can contribute to the next generation.
Refugia	Sections of river channel or waterholes that are deep relative to the rest of the channel which retain water for longer periods of time can provide refuge for aquatic biota during periods of no flow. Refugial waterholes and lakes can also be present in floodplain areas. Not only do these features provide refugial habitat & nursery sites for aquatic life, they are important sinks for nutrients & DOC cycling within the riverine environment.
Registered cultural asset	A cultural water-dependent asset that is registered in the Aboriginal Heritage Information Management System (AHIMS).
Regulated river	A river that is gazetted under the *NSW Water Management Act 2000.* &Major dams, water storages & weirs largely control flow. River regulation increases reliability of water supplies in some years but alters the natural flow regime required by water-dependent environmental assets & values.

Riffle	A rocky or shallow part of a river where river flow is rapid & broken.
Riparian	The part of the landscape adjoining rivers & streams that has a direct influence on the water & aquatic ecosystems within them.
Risk management strategy	A plan of management to overcome risks to achieving environmental outcomes.
Small fresh	Low-magnitude in-channel flow pulse that can inundate low lying benches, connect sections of a channel or river & trigger animal movement.
Spell	The time between flow events
Supplementary access	A category of water entitlement where water is made available to licence holder accounts during periods of high river flows that cannot be controlled by river operations (i.e. supplementary event).
Supplementary event	An unregulated flow (such as a tributary flow below a regulating structure) that is accessible for extraction under supplementary water access licences, as announced by the Minister for a set time period.
Surface water	Water that exists above the ground in rivers, streams creeks, lakes & reservoirs. Although separate from groundwater, they are interrelated & over extraction of either will impact on the other.
Sustainable diversion limit (SDL)	The grossed-up amount of water that can be extracted from Murray–Darling Basin rivers for human uses while leaving enough water in the system to achieve environmental outcomes.
Targeted wetlands & floodplains	Areas of wetlands & floodplains that can be supported (at least partially) by the deliveries of managed held or planned environmental water.
Unregulated river	A waterway where flow is mostly not controlled by major dams, also defined as all other streams than those regulated streams gazetted under the *NSW Water Management Act 2000.*
Very low flow	Any flow that joins river pools, thus providing partial or complete connectivity in a reach. Supports the persistence of waterhole refugia in river channels & can improve DO saturation or reduce stratification in pools. Does not provide the same degree of faunal connectivity as baseflows.
Water quality management plan (WQMP)	A document prepared by state authorities, as part of the Water Resource Plan, which is accredited by the Australian Government under the Basin Plan. It aims to provide a framework to protect, enhance & restore water quality.
Water resource plan (WRP)	A policy package prepared by State authorities & accredited by the Australian Government under the Basin Plan. It describes how water will be managed & shared between users in an area & meet Basin Plan outcomes.
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 & trading water between the various water users & 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 & survival.

Summary

Rivers, creeks, wetlands and floodplains play a vital role in sustaining healthy communities and economies. They provide productivity and connections across the landscape for people, plants and animals with benefits that extend well beyond the riverbank and floodplains. Over the past 200 years, many rivers, wetlands and floodplains in New South Wales (NSW) have had their natural flow regimes disrupted because of dams, weirs, floodplain development, water regulation and water extraction.

The NSW Intersecting Streams located in the northern Murray–Darling Basin are a network of relatively free-flowing systems connected to the Barwon–Darling River that rely on intermittent flow events that may occur several times a year. The level of water extraction for human use from the NSW-portion of these systems is relatively minor compared to other NSW water resource plan areas (WRPAs). However, the volume, duration and frequency of flows that support water-dependent ecological communities are substantially affected by water extraction in Queensland.

The Intersecting Streams Long Term Water Plan (LTWP) is an important step to describing the flow regimes that are required to maintain or improve environmental outcomes in the Intersecting Streams. The LTWP identifies water management strategies for maintaining and improving the long-term health of the Intersecting Streams riverine, floodplain and wetland environmental assets and the ecological functions they perform. This includes detailed descriptions of ecologically important river flows and risks to water for the environment.

Importantly, the LTWP does not prescribe how environmental water should be managed in the future, rather it aims to help water managers make decisions about where, when and how available water can be used to achieve long-term ecological objectives. The LTWP looks at all sources of water and how these can be managed to help support environmental outcomes in the system. This recognises that the Murray–Darling Basin Plan (Basin Plan) specifically requires environmental water managers to act adaptively by making timely decisions based on the best-available knowledge, and from monitoring and evaluating the outcomes from water use.

Background to Long Term Water Plans

The Basin Plan (Pt 4, Ch. 8) establishes a framework for managing environmental water at the Basin and catchment-scale. The framework is designed to ensure environmental water managers work collaboratively to prioritise water use to meet the long-term needs of native fish, water-dependent native vegetation and waterbirds and co-ordinate water use across multiple catchments to achieve Basin-scale outcomes.

The *Basin-wide Environmental Watering Strategy* (BWS) (MDBA 2014) and LTWPs are central features of this framework. The BWS establishes long-term environmental outcomes and targets for the Basin and its catchments. LTWPs, which apply to catchment-scale WRPAs, must contribute to the achievement of the BWS by identifying:

- priority environmental assets and functions in a WRPA
- ecological objectives and ecological targets for those assets and functions
- environmental water requirements (EWRs) needed to meet those targets and achieve the objectives.

Water resource plans (WRPs) must have regard to LTWPs.

The Intersecting Streams Long Term Water Plan

The Intersecting Streams LTWP is one of nine plans being developed by the NSW Department of Planning, Industry and Environment (DPIE) to cover the NSW portion of the Murray–Darling Basin. Development of the LTWP has involved five main steps:

- using the best-available information, undertaking a comprehensive **stocktake** of water-dependent environmental assets and ecosystem functions across the catchment to identify native fish, water-dependent bird and vegetation species, and river processes that underpin a healthy river system
- determining specific and quantifiable **objectives and targets** for the key species and functions in the Intersecting Streams
- determining the **environmental water requirements** (EWR's) (including volume, frequency, timing and duration) needed to sustain and improve the health and/or extent of priority environmental assets and ecosystem functions
- identifying **risks, constraints and management strategies** to meet EWRs
- identifying actions for **going forward and measuring progress** to secure improvements in river and wetland health across the Intersecting Streams.

This LTWP presents this information in seven chapters in two parts, with accompanying appendices.

Environmental values of the Intersecting Streams

The Intersecting Streams supports a range of water-dependent ecosystems, including instream aquatic habitats, riparian forests, and floodplain watercourses, woodlands and wetlands. These ecosystems benefit many water-dependent species, including NSW and Australian Government-listed threatened ecological communities, threatened and migratory waterbirds, and threatened native fish species by providing habitat and food resources.

The Intersecting Streams, which includes the Condamine–Balonne and the Warrego catchments, supports large areas of DIWA-mapped wetlands (QLD and NSW combined). The ecological populations and habitats within the Intersecting Streams are connected to the Barwon–Darling River, which provides a critical drought refuge and movement corridor for fish and waterbirds to both the southern Basin and other northern Basin streams.

The ecological condition of the Intersecting Streams water-dependent environmental assets is largely driven by inflows and flows that connect the instream benches, cut-off channels, anabranches, floodplains and wetlands. Flows that provide these functions support organic carbon transfer and nutrient cycling, trigger movement and breeding of native fish and waterbirds, and directly impact vegetation condition and habitat availability. Large overbank events are associated with major colonial waterbird breeding events in some parts of the system, such as the Narran Lakes and the Yantabulla Swamp fed by Cuttaburra Creek.

Information to support this LTWP was sourced from local, traditional and scientific sources collected in partnership with water managers, natural resource managers and environmental water holders. Information about the Intersecting Streams environmental values closely aligns with material in the *NSW Intersecting Streams Water Resource Plan Risk Assessment* (DPIE–Water in prep.).

Water for the environment

The Intersecting Streams LTWP contains ecological objectives and targets for priority environmental assets and ecosystem functions in the Intersecting Streams system. The Basin Plan defines priorities as those assets and functions that can be managed with environmental water. The objectives and targets have been identified for native fish, native vegetation, waterbirds and ecosystem functions. As noted in the BWS (MDBA 2014), each of these themes is a key indicator of river and wetland health and is generally responsive to flow regimes.

The proposed environmental objectives in this plan reflect the current understanding of environmental outcomes that are expected from implementation of the Basin Plan in the rivers, wetlands, floodplains, and watercourses of Intersecting Streams. The targets for each ecological objective are intended to provide a measurable means of evaluating progress towards the achievement of objectives. Success will be determined by the long-term success of water management strategies, complimentary measures and the weather and climatic conditions experienced within the life of the objectives.

Protection of water for the environment

The NSW Intersecting Streams is an unregulated system. This means that the achievement of flows to meet EWRs is contingent on inflows and extraction rules that protect a sufficient portion and pattern of inflows. It is also a system where natural flow is not controlled by major dams.

Complementary investments

There are complementary measures that may be required to ensure the LTWPs objectives and targets are achieved. For the NSW Intersecting Streams this includes addressing major barriers to fish movement, maintaining and boosting sympathetic land management of riparian areas, wetlands and lakebeds and screening irrigation pumps to protect fish.

For example, the NSW and Australian Governments have partnered in the Toorale Water Infrastructure Project to modify dams and other water-related infrastructure to facilitate fish passage and the downstream delivery of flows previously used for irrigation on the property.

Monitoring and evaluation of the Intersecting Streams Long Term Water Plan

Monitoring and evaluation of the health of the streams, wetlands and floodplains of the Intersecting Streams WRPA is critical, with outcomes:

- providing information to test the assumptions and conditions that underpin this LTWP
- helping to demonstrate progress (or otherwise) against the identified objectives and targets
- informing water management.

Monitoring and evaluation activities in the Intersecting Streams will draw upon contributions from NSW and Australian Government agencies, as well as university and other research institutions.

Review and update of the LTWP

As knowledge and evidence of ecological processes in the Intersecting Streams improves, it may be necessary to review and update the LTWP. To ensure the information in this LTWP is the best available and remains relevant and up-to-date, this plan will be reviewed and updated no later than five years after it is implemented. Additional reviews may also be triggered by:

- accreditation or amendment to the WSP or WRP for the Intersecting Streams
- revision of the BWS that materially affects this LTWP
- a sustainable diversion limit (SDL) adjustment
- new information arising from evaluating responses to watering
- new knowledge about the water-dependent cultural values and assets of the catchment

- new knowledge about the ecology of the catchment that is relevant to environmental watering
- improved understanding of the effects of climate change and its impacts on the catchment, EWRs and water management
- changes to the river operating environment or the removal of constraints that affect watering strategies
- material changes to river and wetland health, not considered within this LTWP.

Table 1 A summary of the environmental outcomes sought in the Intersecting Streams LTWP

Environmental Outcome	Overarching objectives	Example uses of water for the environment to achieve LTWP outcomes and objectives
To maintain the extent and improve the health of water-dependent native vegetation and wetlands	Maintain and improve the viability and extent of: • river red gum, black box and coolibah communities • lignum shrublands • non-woody wetland vegetation	• Improve the extent and condition of vegetation within or closely fringing river channels of the Intersecting Streams following flood events • Maintain the extent and improve the condition of important floodplain woodlands
To maintain the diversity of waterbird species and increase their numbers across the catchment	Restoration of waterbird habitat to contribute to recovery of waterbird populations across the Murray-Darling Basin	• Maintain and increase number of waterbirds • Improve foraging and breeding habitat for waterbirds
To maintain the diversity and improve the population of native fish in the catchment	Increase native fish distribution and abundance, and ensure stable population structures	• Provide improved conditions for native fish recruitment and dispersal in the Intersecting Streams River and wetlands • Improve the connection between the Intersecting Streams and Darling rivers for fish dispersal
To maintain and protect a variety of wetland habitats and support the movement of nutrients throughout the river system	• Maintain and improve river and floodplain habitat • Support lifecycles of plants and animals • Connect riverine and floodplain systems	• Maintain and improve river and floodplain habitat • Support lifecycles of plants and animals • Connect riverine and floodplain systems

Intersecting Streams Long Term Water Plan
Part A: Intersecting Streams catchment

Figure 2 **The Culgoa River near Collerina**
Photo: Neal Foster.

1. Introduction

1.1 About the Intersecting Streams

The Intersecting Streams Water Resource Plan Area (WRPA) is located in far northern NSW and occupies a combined area of approximately 120,431 square kilometres (NOW 2011). The river systems within the NSW Intersecting Streams WRPA are unique and include some of the largest, natural free flowing systems in the Murray–Darling Basin. This Long Term Water Plan (LTWP) covers the NSW Intersecting Streams and connected floodplains that occur within NSW.

The Intersecting Streams WRPA comprises six surface water catchments including Yanda Creek catchment, which occurs entirely within NSW, as well as five water sources that originate in Queensland and flow across the border into NSW. These are the Paroo River, Warrego River, Culgoa River, Narran River and Moonie River. Many of these systems are ephemeral but provide intermittent connecting flows to the Barwon–Darling system, especially during wet periods. While the Intersecting Streams water sources include headwater and slopes zones, most of their length within NSW flows through flat, semi-arid rangelands. The flat landscape, low local runoff and intermittent flow conditions have led to the evolution of distinctive ecology in lowland river reaches.

Water resources in the Intersecting Streams WRPA are shared between consumptive users and the environment. Consumptive use includes:

- 312 ML/year for town water supply access licences
- 2458 ML/year for stock and domestic basic rights requirements
- 197 ML/year for domestic and stock access licences (DoI-W 2017).

Critical issues for the Intersecting Streams centre on water sharing between consumptive users and environmental requirements, and the threat of prolonged drought. During times of critical water shortage, securing water for critical human need is a focus. The alteration of the river's natural flow regime and significant water extraction provide a challenging context for maintaining riverine health.

Grazing is the main landuse in the western portion of the WRPA, with significant cotton production in the east. The majority of water use occurs through the diversion of periodic unregulated flow events and overland flows that overbank and cross the floodplains. Large capacity pumps that divert water during unregulated flow events into private on-farm storages support irrigation in the region.

The NSW Government has developed the Intersecting Streams LTWP to inform watering requirements and other measures to protect and improve the health of the Intersecting Streams riverine and floodplain ecosystems. It also recognises the Intersecting Streams contribution to the environmental health of Barwon–Darling River system.

Climate

The climate of the Intersecting Streams WRPA is characterised by hot summers (average daily maximum ~35°C; BOM 2019) and relatively mild winters (average daily maximum ~19°C). The average total annual rainfall across the Intersecting Streams WRPA ranges from 280 mm in the west (at Wanaaring) to approximately 500 mm in the east (at Mungindi; DPI 2017). Rainfall is variable, resulting in mostly intermittent river flows. The highest rainfall typically occurs during summer. Significant flow events generally result from heavy rainfall in elevated headwater areas rather than runoff from lowland areas, which usually makes only a minor contribution.

Streamflow

While some water is captured in Queensland storages such as E.J. Beardmore Dam (DoI-W 2017), all rivers within this WRPA are categorised as unregulated systems. Variability in stream flows occurs between seasons and across the catchments with sporadic flooding associated with cyclonic rain depressions in the Queensland portions of the water sources (NOW 2011). The wetter months and subsequent higher flows occur in summer–autumn with the drier periods during late winter–spring. The wetlands of the Paroo, Warrego, Narran and other rivers in the Intersecting Streams water source are primarily towards the end of each system (DoI-W 2017).

The average annual discharge of the Intersecting Stream system into the Barwon–Darling system is around 100,000 megalitres per year (ML/year) for the Moonie River, 460,000 ML/year for the Culgoa and Narran rivers, 10,000 ML/year for the Warrego River and 1000 ML/year for the Paroo River (NOW 2011). There is no reliable data for discharge of Yanda Creek.

Downstream from St George, the Condamine–Balonne River divides into five separate channels. The Culgoa and Narran rivers are the main channels, conveying 35% and 28% of the long-term mean annual flow at St George respectively; while the Ballandool, Bokhara and Birrie rivers flow only during higher discharge periods (Thoms et al. 2007). The Condamine–Culgoa Rivers, which includes the Narran, Birrie and Bokhara rivers, contributes 20% of flow to the long-term average flow in the Darling River at Menindee (DoI-W 2017).

Flows in the Culgoa, Narran and Moonie rivers are heavily impacted by regulation and extraction for irrigation (DoI-W 2017). Since 1993–1994, the mean annual volume of water diverted from the unregulated section of the Condamine–Culgoa catchment (downstream of St George) has increased by 339% (DoI-W 2017). The extent of irrigated cotton increased from approximately 4300 ha in 1988 to 38,650 ha in 1999, and the storage capacity of dams increased more than tenfold from 54,750 ML to approximately 626,185 ML over the same period (Sims 2004). These systems have experienced a high degree of flow alteration with the average cross border flows into NSW halving since 1993 compared to natural conditions (SMEC 2006).

In Yanda Creek and the western portion of the Paroo and Warrego Rivers, flow and water in these river systems is dominated by occasional heavy rainfall events in the upstream headwaters or localised rainfall that can re-fill isolated wetlands, rather than by the regulation of public dams and other infrastructure.

Ecological assets

The Intersecting Streams WRPA includes several high-value ecological assets. The Narran Lakes system, a large terminal wetland on the lower reaches of the Narran River between Brewarrina and Walgett is the eastern-most tributary of the Lower Balonne system. It comprises a complex network of river channels (channelised floodplain), floodplain lakes and ephemeral wetlands, some of which are listed under the Ramsar Convention or the Directory of Important Wetlands in Australia (DIWA; DEWHA 2001). One such site is the Narran Lake Nature Reserve which is one of the most important areas for waterbirds in NSW, ranked among the highest for species richness, number of breeding species and total abundance when it is inundated (MDBA 2012). During flood years, the lignum and river cooba vegetation of the lakes host massive colonial waterbird breeding events.

The two Paroo River wetlands listed under the Ramsar Convention (Nocoleche Nature Reserve and the Peery block in the Paroo-Darling National Park) are unique examples of near natural, arid inland wetland systems. The natural pattern of flow is maintained, as there are no major diversions, dams or weirs. They provide a significant refuge for biological diversity including newly identified plants and macroinvertebrates and a separate breeding population of golden perch (*Macquaria ambigua*). Yantabulla Swamp is inundated by a combination of local rainfall; channel flows from the Warrego River (via Cuttaburra Creek) and overflows when the Paroo River is in flood. Yantabulla Swamp is one of the most important waterbird breeding sites in NSW (Kingsford and Porter 1999).

The Australian Government has purchased water access licences for environmental watering purposes (held environmental water or HEW). This LTWP will guide management of both planned and held environmental water in the future.

Cultural assets

The Intersecting Streams is central to the Indigenous people whose Nations include its waterways and beyond. These Nations include Kurnu–Baakandji, Budjiti, Euahlayi, Guwamu/Kooma, Kamilaroi, Kunja, Murrawarri, and Ngemba. Traditional owners have longstanding and continuing ties to country, the waterways and life sustained by it.

The Aboriginal Heritage Information Management System (AHIMS) contains information about registered Aboriginal objects or features that are of cultural significance to the Aboriginal people. Querying the system is not intended to substitute for consultation about sites. However, it is used to demonstrate the presence and variety of sites registered with the Intersecting Streams WRPA.

Significant Aboriginal cultural water dependent sites that are registered in AHIMS were also included as water dependent assets in the LTWP. This identified areas such as Aboriginal ceremony and dreaming sites, fish traps and sites of resource collection, scarred or modified trees, artefact sites, occupation sites and water holes. The NSW State Heritage Register and Register of Aboriginal Places names five sites of relevance to this LTWP. These registered examples provide some small insight into the significance of the area to Indigenous people.

- The Angledool Reserve and Cemetery became a station camp in the 19th Century and the site of a major Aboriginal Reserve settlement in the early 20th Century. However, its significance to Aboriginal people dates back to before the camp was settled. The settlements location was in close association with the Narran Lake dreaming and ceremonial tracks and for many members of the Lightning Ridge, Brewarrina, Goodooga, Walgett and wider Aboriginal communities the site remains an important place of significance for them. It was recognised as an Aboriginal place in 2013.
- Old Gerara Springs Aboriginal Place is located within Ledknapper Nature Reserve east of Enngonia and has been historically disturbed through excavations. As part of the Artesian Springs Ecological Community, it has recently been included as a key management site as part of the NSW Government's Saving Our Species program.
- The Ngemba originally named Byrock Waterhole Bai. This granite outcrop and waterhole is in the Bourke Shire and is associated with an Ngemba creation story. The story describes how Baiame – the great creator – had his home at this place in the dreamtime and dug the rockhole with his stone axe. The small waterhole called 'Wuggarbuggarnea" was an important camping place for Ngemba, both before and after this part of the country became occupied by European settlers.
- Dennawan Aboriginal Place is located on the southern border of Culgoa National Park, between two paddocks known locally as Bourah (or Bowrah) and Tatala. Dennawan first came to the notice of the NSW Government as an important place to the local Aboriginal community in the early 1970s, when the Western Lands Commission undertook a survey and two site visits to Dennawan to locate the reserve and its burial ground. Originally, it was home to a community of Aboriginal people and was essentially a pastoral labour camp that serviced the surrounding pastoral properties, several of which are now managed as Culgoa National Park.
- Mount Drysdale Station, located 35km from Cobar was proclaimed an Aboriginal place in 2001.

1.2 Approach to developing the Intersecting Streams Long Term Water Plan

The Intersecting Streams LTWP applies to the Intersecting Streams WRPA and is one of nine catchment-based plans covering the NSW portion of the Murray–Darling Basin. The LTWP has been developed to be consistent with the requirements of the Murray–Darling Basin Plan (Basin Plan) (MDBA 2012).

The Intersecting Streams LTWP is the product of best available information and engagement with water managers, natural resource managers, environmental water holders and community members. It draws together local, traditional and scientific knowledge to identify the river's priority environmental assets and ecosystem functions to guide the management of water to protect and restore condition over the long-term.

Development of the Intersecting Streams LTWP has involved five main steps:

- undertaking a **comprehensive stocktake** of water-dependent environmental assets and ecosystem functions across Intersecting Streams to identify native fish, water-dependent bird and vegetation species, and river processes that underpin a healthy river system
- determining **specific and quantifiable objectives and targets** for the key species and functions in the Intersecting Streams
- determining the **water requirements** (including volume, frequency, timing and duration) needed to sustain and improve the health and/or extent of priority environmental assets and ecosystem functions
- identifying potential **risks and constraints** to meeting the long-term water requirements of environmental assets and ecosystem functions.
- identifying **potential management strategies** for guiding water management decisions and investment into the future.

1.3 Implementing the Long Term Water Plan

Implementation of the LTWP requires strong partnerships and coordination between all land managers and water users. The LTWP provides the foundation to support future coordination efforts by:

- informing and guiding annual and longer-term water management deliberations and planning by the Department of Planning, Industry and Environment (DPIE) and the Commonwealth Environmental Water Office (CEWO)
- informing planning processes that influence river and wetland health outcomes, including development of WSPs and WRPs by DPIE – Water
- identifying opportunities for more strategic river operations as well as strengthening collaboration between holders of environmental water
- helping target investment priorities for complementary actions that will effectively contribute to progressing the outcomes sought by this LTWP
- building broad community understanding of river and wetland health issues.

1.4 The Long Term Water Plan document structure

The Intersecting Streams LTWP is presented in seven chapters with accompanying appendices. It is divided into Part A (catchment scale information) and Part B (planning unit scale information).

Part A

- **Chapter 1** explains the background and purpose of the LTWP.
- **Chapters 2** and **3** identify the Intersecting Streams water-dependent environmental assets and ecosystem functions and articulate the environmental outcomes that are expected from implementation of the LTWP through ecological objectives and targets.
- **Chapter 4** describes the environmental water requirements (EWRs) needed to achieve the ecological objectives over the next five, 10 and 20 years.
- **Chapter 5** describes the risks and constraints that may limit water managers' capacity to achieve the ecological objectives in the Intersecting Streams and outlines potential strategies.
- **Chapter 6** outlines the workplan going forward to progress towards the objectives. This includes potential cooperative arrangements between government agencies.
- **Appendix A** provides detail on the ecological objectives relevant to each planning unit (PU).

Part B

- **Chapter 7** introduces Part B of the LTWP and information specific to individual planning units (PUs).
- **Appendix B** details the assets in each PU.
- **Appendix C** details the PU scale EWRs.

1.5 Planning units

Figure 3 shows the Intersecting Streams WRPA and PUs covered in this LTWP. The Intersecting Streams WSP is for reaches along the river and not a catchment or floodplain boundary. To identify the floodplain boundary for the LTWP, a combination of data sources and evidence has been used. This includes Healthy Floodplain mapping in the north and TVD Floodplain modelling in the south. Planning Unit boundaries align with the management zones defined by the Intersecting Streams WSP.

An additional PU was introduced around Toorale at the junction of the Warrego and Darling Rivers to reflect that the area can receive water from both these sources. Consequently, this LTWP has 8 PUs.

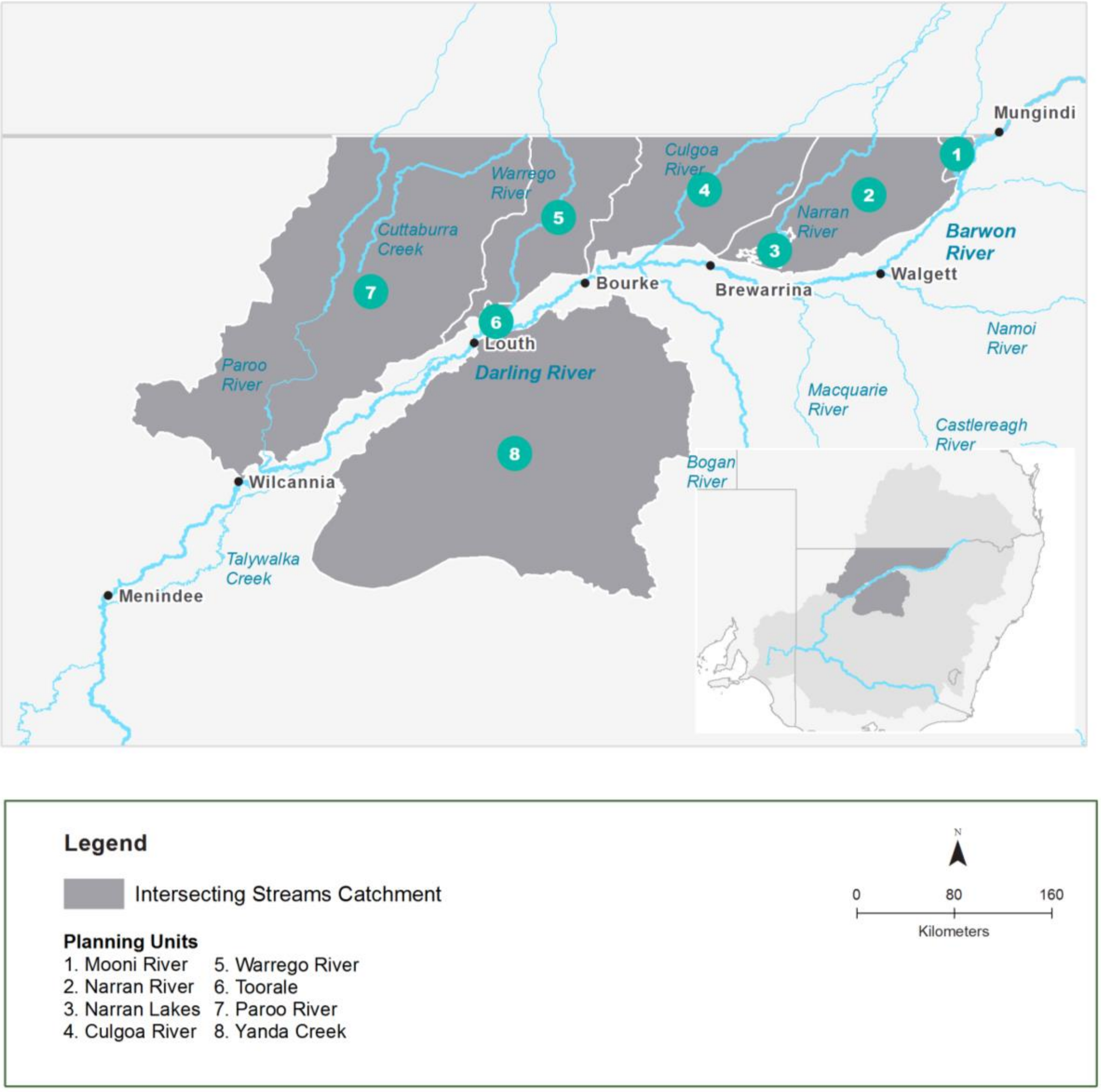


Figure 3 **The Intersecting Streams WRPA showing the planning unit divisions**

2. Environmental assets of the Intersecting Streams

The Intersecting Streams supports a variety of water-dependent ecosystems, including instream aquatic habitats, riparian vegetation, and floodplain woodlands and wetlands. These ecosystems are located along the river system and each has its own water requirements depending on the plants, animals and ecosystem functions they perform.

2.1 Priority environmental assets in the Intersecting Streams

In addition to the targets in the BWS, Schedule 8 of the Basin Plan outlines criteria for identifying water-dependent ecosystems as environmental assets. The criteria are designed to identify water-dependent ecosystems that are internationally important, natural or near-natural, provide vital habitat for native water-dependent biota, and/or can support threatened species, threatened ecological communities or significant biodiversity.

The water-dependent ecosystems of the Intersecting Streams were assessed against the Schedule 8 criteria. Significant Aboriginal cultural water-dependent sites, such as Aboriginal ceremony and dreaming sites, fish traps, scar trees, and waterholes that are registered in the AHIMS were also included as water-dependent assets in the LTWP.

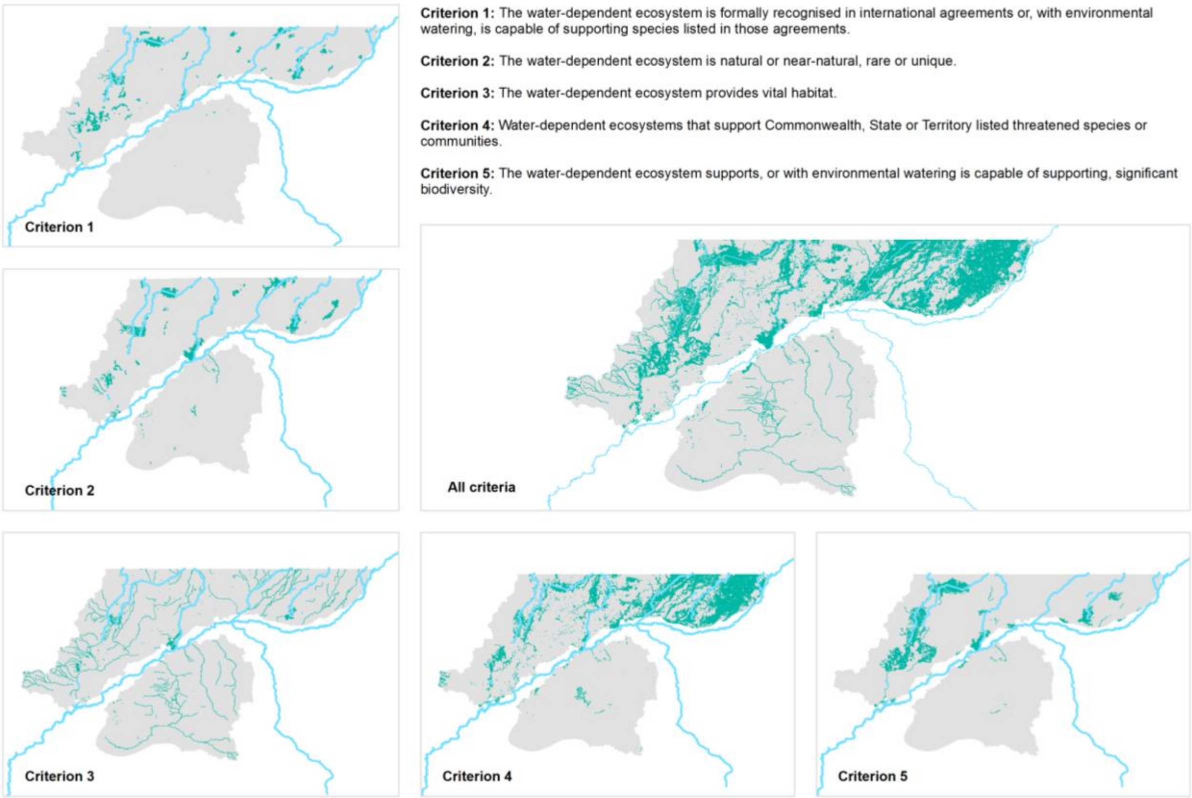


Figure 4 Five criteria for identification of environmental assets applied to Intersecting Streams

3. Ecological objectives and targets

Ecological objectives and targets have been established for priority environmental assets and values in the Intersecting Streams (sections 3.1–3.4). Consistent with the BWS, the objectives are grouped into four themes: native fish, native vegetation, waterbirds and ecosystem functions (MDBA 2014). Collectively, these themes provide an overall indication of ecosystem health and are responsive to flow. Achievement of the objectives will contribute to the landscape and Basin-scale environmental outcomes sought by the BWS and benefit other water-dependent species.

The five, ten and 20-year targets for each ecological objective provide a transparent means of evaluating progress towards their achievement and the long-term success of the LTWP's management strategies and their implementation. If met, the targets will indicate that the environment is responding positively to water management. Prevailing conditions, such as drought and floods, will influence our capacity to meet ecological targets, and so these climatic shifts will need to be considered when analysing and interpreting outcomes. Failure to meet targets should trigger re-assessment of the related flow regime and whether the LTWP is being implemented as intended to determine if changes are needed. It is important to note that the 20-year targets in the LTWP assume the removal of constraints to allow more flexibility in water delivery.

The ecological objectives for the Intersecting Streams LTWP as they relate to individual planning units are listed in Appendix A. The ecological objectives recognise environmental assets (e.g. native fish species, native vegetation communities, waterbirds) or the ecosystem functions (e.g. provides vital instream habitat) align to the BWS targets.

3.1 Native fish objectives

There are 11 native fish species that have been recorded or are expected to occur in the NSW Intersecting Streams WRPA (NSW DPI 2015). These species include freshwater catfish (eel-tailed catfish; MDB population) and the olive perchlet (western population), which are listed as endangered under the *Fisheries Management Act 1994* (FM Act), while silver perch and Murray cod are listed as vulnerable under the FM Act 1994 and *environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), respectively (NSW DPI 2015). Additionally, there are several species that only occur in the northern Basin, including Rendahl's tandan and Hyrtl's tandan, as well as important remnant populations of olive perchlet that are less prevalent or no longer present in the southern Basin.

The condition of fish communities in NSW reaches of the Intersecting Stream varies within and among catchments. In 2015, NSW DPI (2015) rated fish community status in the Paroo River as moderate–excellent¸ the Moonie River as good, the Culgoa and Narran Rivers as moderate–good and the Warrego River as poor–good. The Fisheries Scientific Committee has made a recommendation to list the Aquatic Ecological Community in the Natural Drainage System of the Lowland Catchment of the Darling River as an endangered ecological community (EEC), which includes the Warrego, Culgoa and Narran Rivers and their tributaries south of the Queensland border. The associated aquatic biota from these systems, including all native fish and aquatic invertebrates within all natural creeks, rivers, streams and associated lagoons, billabongs, lakes, anabranches, flow diversions to anabranches and floodplains are listed under the Fisheries Management Act as part of the Lowland Darling River EEC (EEC Primefacts).

Connectivity between the Barwon–Darling and the Intersecting Streams is particularly important for regional communities of native fish and other aquatic species. The Barwon–Darling River channel connects all the rivers, lakes and wetlands in the northern Murray–Darling Basin, providing a critical dry period refuge and movement corridor for fish and waterbirds, as well as habitats for other aquatic species including turtles, mussels, and shrimp. There are a number of man-made structures located across the Intersecting Streams WRPA (both in NSW and Queensland). Individually they have limited impact, but cumulatively they are significant in impeding natural flows and connectivity, affecting the condition of fish habitat upstream and downstream.

Identified priority drought refuge sites include the system of weirs on the river, pools, floodplain and wetlands known to support golden perch and Murray cod (McNeil, Gehrig & Cheshire 2013). In addition, the MDBA's BWS (MDBA 2014) has identified as important environmental assets for native fish:

- Warrego River (Darling to Ward Rivers)
- Anabranches laterally connecting the Paroo and Warrego Rivers (including Bow, Gumholes and Cuttaburra Creeks)
- Culgoa junction to St George (including lateral connectivity to the floodplain)
- Paroo River

Native fish species in the Murray–Darling Basin have a range of spawning and recruitment behaviours that have evolved with a variable flow regime. A range of flows is required to meet the diverse needs of the fish community of a system (Baumgartner et al. 2013; NSW DPI 2015). An effective approach is to identify functional groups of fishes based on certain flow-related attributes (Lloyd, Walker & Hillman 1991; Humphries, King & Koehn 1999; Baumgartner 2011; Baumgartner et al. 2013; NSW DPI 2015; Mallen-Cooper & Zampatti 2015). Functional groups can then be used to simplify flow requirements, maximising the efficiency of water use and environmental benefits (Humphries, King & Koehn 1999; Growns 2004; NSW DPI 2015; Mallen-Cooper & Zampatti 2015). The effective and efficient management of water is even more pertinent in systems of the Northern Basin where water availability is limited and exacerbated by competing needs (Thoms et al. 2004; NSW DPI 2015).

The functional groups formed were based around specific flow related attributes for spawning, recruitment, movement, maintenance, and condition (NSW DPI 2015). This included consideration of:

- cues for migration, dispersal and spawning (temperature and/or flow)
- scale of spawning migration (from metres to kilometres)
- whether a nesting species or not
- spawning in still/slow-flowing water or in fast-flowing habitats
- egg hatch time (days to weeks) and egg morphology
- temporal and spatial scales of larval drift and recruitment.

Figure 5 Freshwater catfish
Photo: G. Schmida

Table 2 Native fish ecological objectives

Objective		Target fish species	Targets[1]		
			5 years (2024)	10 years (2029)	20 years (2039)
NF1	No loss of native fish species	All recorded native fish species	All known species detected annually		
				Fish community status improved by one category compared to 2014 assessment	
NF2	Increase the distribution & abundance of short to moderate-lived generalist native fish species	Murray–Darling rainbowfish Bony bream Carp gudgeon Australian smelt	Increased distribution & abundance of short to moderate-lived species compared to 2014 assessment No more than one year without detection of immature fish (short-lived) No more than two years without detection of immature fish (moderate-lived species)		
NF3	Increase the distribution & abundance of short to moderate-lived floodplain specialist native fish species	Olive perchlet [2,3]			
NF4	Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species	Golden perch Hyrtl's Tandan Spangled perch Silver perch	Juvenile & adult fish detected annually No more than two consecutive years without recruitment in moderate-lived species No more than four consecutive years without recruitment in long-lived species		
NF5	Improve native fish population structure for moderate to long-lived riverine specialist native fish species	Murray cod Olive perchlet [2, 3]	Minimum of 1 significant recruitment event in 5 years	Minimum of 2 significant recruitment events in 10 years	Minimum of 4 significant recruitment events in 20 years
NF6	A 25% increase in abundance of mature (harvestable sized) golden perch & Murray cod	Golden perch Murray cod	Length-frequency distributions include size classes of legal take size for golden perch & Murray cod 25% increase in abundance of mature golden perch & Murray cod		

[1] The intermittent nature of flows in the Intersecting Streams WRPA may affect ability to collect consistent annual data.

[2] Olive perchlet may be considered either floodplain specialist or riverine species depending on geographical location.

[3] Olive perchlet has only been observed in the Narran River but is predicted to occur in several other locations.

3.2 Native vegetation objectives

The water-dependent native vegetation species and communities identified by the BWS are river red gum, black box, coolibah, lignum and non-woody vegetation closely fringing or within the main river corridors and floodplain. Native vegetation in the Intersecting Streams includes important riparian and floodplain communities in the dryland catchment areas such as lignum, river red gum, river cooba, black box and coolibah. There is a high proportion of remnant vegetation in good condition in some areas including the floodplains of the Warrego and Culgoa rivers.

There are a number of significant Ramsar and DIWA-listed wetlands located within the Intersecting Streams WRPA. Ramsar sites are located in the Paroo and Narran River water sources. The Narran Lake Nature Reserve (8447 ha), located at the terminus of the Narran River in the Lower Balonne, supports some of the largest undisturbed lignum shrubland communities in NSW (NPWS 2000). The floodplains of the Narran Lake Nature Reserve also support 1000 ha of herblands, sedgelands and grasslands that develop on lakebeds during the dry phase (NPWS 2000). Narran Lakes also supports the endangered (listed under the *Environmental Protection and Biodiversity Conservation* (EPBC) *Act 1999 [Clth]*) winged peppercress (*Lepidium monoplocoides*).

The Peery section of the Paroo River Wetlands Ramsar site supports the threatened Artesian Springs Ecological Community (Kingsford and Lee 2010). It is listed as endangered under both the EPBC Act 1999 and the *NSW Biodiversity Conservation Act 2016* due to the unique community of native species dependent on the natural discharge of groundwater from the Great Artesian Basin and the rarity of the mound spring landform in Australia. There are two distinct sets of artesian mound springs on the eastern and western sides of Peery Lake. The dominant vegetation community of the mound springs is sedgelands (*Eleocharis* spp. or *Cyperus* spp.) and glassworts, with the threatened salt pipewort a key component of the ecological community.

Over 300 plant species have been recorded in Nocoleche Nature Reserve (71,000 ha) alone (Kingsford and Porter 1999), including large stands of yapunyah (*Eucalyptus ochrophloia)* which mainly grows in floodplain areas close to the main river channel. Nocoleche Nature Reserve also supports starfruit (*Dentella minutissima*) and the charophyte algal species *Nitella partita*, and has the only known NSW record for the aquatic plant *Aponogeton queenslandicus* (listed under the NSW Biodiversity Conservation Act).

The Lower Balonne River floodplain, covering two million hectares in Queensland and NSW, supports the largest area of wetland of any catchment in the Murray–Darling Basin. Native grasslands and coolibah woodlands on the floodplain are some of the most extensive in Australia and are considered to be in near natural condition. Threatened plant species include the endangered aquatic plants *Nocoleche goodenia* and *Nitella partita*.

The NSW Scientific Committee have determined the Coolibah–Black Box Woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain and Mulga Lands Bioregion as an Endangered Ecological Community (EEC) (Keith et al. 2009). The vegetation identified by the EEC is generally found on the grey, self-mulching clays of periodically waterlogged floodplains, swamp margins, ephemeral wetlands, and stream levees. The structure of the community may vary from tall riparian woodlands to very open 'savanna like' grassy woodlands with a sparse mid-story of shrubs and saplings.

The availability of water across the landscape affects plant germination, establishment and growth, survival and reproduction, and ultimately influences the position of species in the landscape (Casanova 2015). The native vegetation species and communities identified by the BWS have been grouped into objectives that reflect similar watering requirements and the variable extent of flooding across the floodplain. In the Intersecting Streams, river red gum is predominantly found in riparian zones and requires more frequent watering. Coolibah and black box remnants can be found on the floodplain and require less frequent surface water to maintain condition and extent (Roberts & Marston 2011; Casanova 2015). Flooding is often required for recruitment (Roberts & Marston 2011; Casanova 2015).

It may not be possible to increase the extent of woody vegetation due to agricultural land development. The objectives and targets of this plan aim to maintain the current extent. This requires native vegetation of good condition to limit tree mortality and recruitment to replace any losses. Objectives and targets for within channel vegetation, lignum shrublands and non-woody wetland recognise the ongoing need for vegetative growth and regular seed setting to ensure ongoing population viability of these species (Roberts & Marston 2011; Casanova 2015).

Table 3 Native vegetation ecological objectives

<table>
<tr><th colspan="2" rowspan="2">Objective[4]</th><th colspan="3">Targets</th></tr>
<tr><th>5 years (2024)</th><th>10 years (2029)</th><th>20 years (2039)</th></tr>
<tr><td rowspan="2">NV1</td><td rowspan="2">Maintain the extent of non-woody vegetation communities occurring within or closely fringing channels</td><td colspan="3">Lower Balonne & Narran Lakes
Increase the cover of non-woody, flood-dependent vegetation within or closely fringing river channels following flood events</td></tr>
<tr><td colspan="3">Paroo, Warrego, Moonie & Yanda Creek
Maintain the cover of non-woody, flood dependent vegetation within or closely fringing river channels following flood events</td></tr>
<tr><td>NV2</td><td>Maintain or increase the extent & maintain the viability of non-woody vegetation communities occurring in wetlands & on floodplains</td><td colspan="3">Maintain the OEH (2017) mapped extent of non-woody, flood dependent vegetation [5]</td></tr>
<tr><td rowspan="3">NV3</td><td rowspan="3">Maintain the extent & improve the condition of river red gum communities closely fringing river channels</td><td colspan="3">Maintain the 2016 extent of river red gum woodland communities closely fringing river channels</td></tr>
<tr><td colspan="3">Lower Balonne & Narran Lakes</td></tr>
<tr><td colspan="2">Over a 5-year rolling period:
• maintain the proportion of river red gum communities closely fringing river channels that are in moderate or good condition
• no further decline in the condition of river red gum communities closely fringing river channels that are in poor condition</td><td>Over a 5-year rolling period:
• increase the proportion of river red gum communities closely fringing river channels that are in moderate or good condition
• improve the condition score of river red gum communities closely fringing river channels that are in condition by at least one condition score</td></tr>
</table>

[4] NV4a refers to river red gum forest and does not occur within the Intersecting Streams WRPA.

[5] Measured over a 5-year rolling period to account for variation between naturally dry and wet times.

<table>
<tr><th colspan="3" rowspan="2">Objective[4]</th><th colspan="3">Targets</th></tr>
<tr><th>5 years (2024)</th><th>10 years (2029)</th><th>20 years (2039)</th></tr>
<tr><td></td><td colspan="2"></td><td colspan="3">Paroo, Warrego, Moonie & Yanda Creek
Over a 5-year rolling period, maintain the proportion of river red gum communities closely fringing river channels that are in moderate or good condition[6]
Over a 5-year rolling period, no further decline in the condition of river red gum communities closely fringing river channels that are in poor or degraded condition</td></tr>
<tr><td>NV4b</td><td rowspan="4">Maintain or increase the extent & maintain or improve the condition of native woodland & shrubland communities on floodplains</td><td>River red gum woodland</td><td colspan="3" rowspan="2">Maintain the OEH (2017) amalgamated mapped extent of woodland & lignum shrubland communities
Over a 5-year rolling period, no further decline in the condition of woodland & shrubland communities in condition
Maintain or improve the age class structure of river red gum, black box & coolibah communities (measured in selected sites only)</td></tr>
<tr><td>NV4c</td><td>Black box woodland</td></tr>
<tr><td>NV4d</td><td>Coolibah woodland</td><td colspan="2" rowspan="2">Over a 5-year rolling period, maintain the proportion of woodland & shrubland communities in moderate or good condition</td><td rowspan="2">Over a 5-year rolling period, maintain or increase the proportion of woodland & shrubland communities in moderate or good condition</td></tr>
<tr><td>NV4e</td><td>Lignum shrublands</td></tr>
</table>

3.3 Waterbird objectives

Waterbirds are useful indicators of the health of water-dependent ecosystems (Amat & Green 2010). In the 30 years to 2012, annual waterbird surveys revealed a 72% decline in average waterbird abundance in the Murray–Darling Basin (MDBA 2014). This is a critical observation because waterbirds are an important indicator of wetland health as their abundance and diversity are related to the total area of wetland available, the health of wetland vegetation and the abundance of food resources, e.g. microcrustacea, fish and aquatic vegetation (Kingsford 1999). This means that wetlands in good condition, which have vegetation in good health and a variety of habitats with varying water depths, tend to support the greatest diversity and types of waterbird species, and highest waterbird abundance (Kingsford & Norman 2002).

Waterbirds are a group of highly mobile species and can respond to flows over large spatial scales (Kingsford & Norman 2002; Amat & Green 2010). Improvements in waterbird populations across the Murray–Darling Basin is one of the main ecological objectives of the Basin Plan. With more water available for delivery to the environment through the Basin Plan, increases in frequency, duration and extent of inundation of wetland areas are expected to provide more habitat for waterbirds and other water-dependent species (MDBA 2014).

[6] Measured by MDBA Stand Condition tool.

Waterbirds can be classified into functional groups (guilds) based on their feeding behaviours and foraging habitat requirements. The five common waterbird functional groups include: ducks and grebes, herbivores, piscivores (fish-eating waterbirds), large waders, and shorebirds (or small waders). In total 78 waterbird species representing all functional groups have been recorded in the Intersecting Streams.

The Intersecting Streams support a significant number of migratory bird species including 15 species listed under international migratory species treaties (JAMBA, CAMBA and RoKAMBA) and ten threatened waterbird species including the Australasian bittern (*Botaurus poiciloptilus*), Australian painted snipe (*Rostratula australis*), black-necked stork (*Ephippiorhynchus asiaticus*), black-tailed godwit (*Limosa limosa*), brolga (*Grus rubicunda*), blue-billed duck (*Oxyura australis*), freckled duck (*Stictonetta naevosa*), curlew sandpiper (*Calidris ferruginea*), bar-tailed Godwit (*Limosa lapponica*) and magpie goose (*Itim warrego*) have been observed.

Significant breeding populations of colonial breeding species including straw-necked ibis (*Threskiornis spinicollis*), eastern great egret (*Ardea modesta*), glossy ibis (*Plegadis falcinellus*), Australian white ibis (*T. molucca*), and royal spoonbill (*Platalea regia*) are supported at sites across the WRPA, most significantly at Narran Lakes and Yantabulla Swamp. The Narran Lake Nature Reserve is one of the most important areas for birds in NSW, ranked among the highest for species richness, number of breeding species and total abundance (MDBA 2012, Brandis et al. 2018). The wetlands of the Warrego and adjacent Paroo rivers are also considered significant for waterbirds in the Murray Darling Basin (MDBA 2016). When the rivers are not flowing they form chains of permanent waterholes providing critical refuge for waterbird populations (MDBA 2016).

Other key wetland sites within the Intersecting Streams for waterbirds include the Paroo River wetlands, the Western Floodplain on Toorale National Park, and the Darling-Warrego confluence floodplain. These sites provide substantial suitable foraging habitat for waterbirds and further breeding habitat for species such as cormorants and egrets. The sites are dependent on overbank flows to receive water by floodplain inundation (Brandis and Bino 2016).

Table 4 Vulnerable, endangered and migratory waterbird species grouped by the five functional waterbird groups

Functional waterbird groups	Species & status[7]
Ducks	Blue-billed duck (v), Freckled duck (v)
Herbivores	Magpie goose (v),
Large waders	Brolga (v), Australasian bittern (E,e), Black-necked stork (e)
Piscivores	Caspian tern (J)
Shorebirds	Common greenshank (C, J, K), Latham's snipe (J, K), Marsh sandpiper (C, J, K), Sharp-tailed sandpiper (C, J, K), Australian painted snipe (E,e), Oriental pratincole (C, J, K), Common sandpiper (C, J, K), Curlew sandpiper (J,C,K,CE, e), Black-tailed godwit (J,C,K, v), Bar-tailed godwit (J.C,K, CE, v)

Knowledge of the water requirements of different waterbird species informs watering strategies and can be used to evaluate whether these strategies have met the timing, duration and frequency requirements for different waterbird groups. The waterbird functional

[7] v = listed as vulnerable e= endangered on NSW threatened species list (BC Act), E = endangered in EPBC Act, CE = critically endangered in EPBC Act, C = CAMBA listed, J = JAMBA listed, K = RoKAMBA listed

groups in section 3.3 are reflected in the objectives and targets in this LTWP. In addition, the objectives recognise the differences between colonial and non-colonial waterbirds. Colonially breeding waterbirds gather in large numbers when their nesting habitats are inundated and conditions for breeding are suitable.

The total number of waterbird species and total number of individuals can change rapidly in response to flows, specifically increases in total wetland area and the diversity of wetland habitats inundated. When inundated, floodplain habitats can provide feeding and breeding habitat for a range of waterbird species. Waterbird species richness is greatest when there are varying water depths across a range of wetland types (Taft et al. 2002). This is because there is a mosaic of wetland types with varying water depths this can provide deeper wetlands for fish-eating waterbirds and diving ducks, and vegetated shallower wetlands that provide feeding habitat for dabbling ducks and large waders. Emergent aquatic vegetation on the edge of waterbodies also provides habitat for cryptic species e.g. crakes, rails and bitterns. As wetlands dry, exposed mudflats can form providing feeding habitat for resident and migratory shorebird species.

Table 5 Waterbird ecological objectives

<table>
<tr><th colspan="2" rowspan="2">Ecological objectives</th><th colspan="3">Targets</th></tr>
<tr><th>5 years (2024)</th><th>10 years (2029)</th><th>20 years[8] (2039)</th></tr>
<tr><td rowspan="2">WB1</td><td rowspan="2">Maintain the number & type of waterbird species</td><td colspan="3">Maintain a five-year rolling average of 21 or more waterbird species across the five functional groups in the identified key waterbird habitats (Narran lakes, Yantabulla Swamp, Cuttaburra Channels, Paroo River Overflow Lakes – within the Intersecting Streams</td></tr>
<tr><td></td><td>Identify at least 43 waterbird species in a ten-year period</td><td>At least 60 waterbird species observed in a 20-year period</td></tr>
<tr><td>WB2</td><td>Increase total waterbird abundance across all functional groups</td><td>Total abundance of the five functional groups maintained compared to the five-year 2012–16 period</td><td>Total waterbird abundance increased by 20–25% compared to the five year 2012–16 period, with increases in all functional groups</td><td>Maintain or increase total waterbird abundance compared to the 10-year target, with increases in all functional groups</td></tr>
<tr><td>WB3</td><td>Increase opportunities for non-colonial waterbird breeding</td><td>Total abundance of non-colonial waterbirds maintained & breeding recorded in at least 2 non-colonial waterbird species compared to the five-year 2012–16 baseline period</td><td>Total abundance of non-colonial waterbirds increased by 20–25% with breeding detected in at least 2 non-colonial waterbird species compared to the five-year 2012–16 baseline</td><td>Maintain or increase total abundance of non-colonial waterbirds compared to the 10-year target, with breeding detected in at least 2 non-colonial waterbird species</td></tr>
</table>

[8] 20-year targets will be further refined following additional data collection.

Ecological objectives		Targets		
		5 years (2024)	10 years (2029)	20 years[8] (2039)
WB4	Increase opportunities for colonial waterbird breeding	Support active waterbird colonies in the Intersecting Streams by maintaining the water depth & duration of flooding (as required) to support breeding through to completion (from egg laying through to fledging including post-fledgling care) & maintain duration of flooding in key foraging habitats to enhance breeding success & the survival of young		
WB5	Maintain the extent & improve condition of waterbird habitats	Maintain or increase extent & improve condition of waterbird foraging & breeding locations in the Intersecting Streams (to be evaluated under targets set for native vegetation)		

3.4 Ecosystem function objectives

Ecosystem functions have been broadly defined as natural processes or structures that provide goods and services for humans (De Groot 1992). They include the maintenance of vital habitats such as refugia during drought, the transportation of nutrients and organic matter to provide food and resources, the movement of sediment for the maintenance of riparian channels, movement of water dependent species, and maintenance of water quality suitable for the persistence of flora and fauna (see Schedule 9, Basin Plan, 2012).

The Intersecting Streams is comprised of rivers, anabranches with semi-permanent lagoons and wetlands, and floodplain features (NSW DPI 2015). Within these broad habitat types, niche habitats such as deep channels, pools and riffles, gravel beds, instream benches, snags, aquatic vegetation and riparian vegetation are available to the catchment's aquatic species. Flows that connect within and between these niche habitats can enable biological, geochemical and physical processes that provide ecosystem function, as needed to support healthy ecosystems (Bunn & Arthington 2002).

Ecosystem functions have been grouped into objectives based on the processes involved. Collectively, the objectives require variable flows, with periods of low flows alongside a range of flooding flows to maintain ecosystem functions such as in-channel complexity (e.g. benches) (Boulton et al. 2000; Thoms & Sheldon 2002).

Drought refugia

Refugia can occur within the main river channels, as instream pools, or in off-channel habitat where water persists after disconnection from the channel, such as in billabongs and anabranches. The refugia can contain different types of habitat, such as logs, wet undercut banks, riffles, sub-surface stream sediments and riparian vegetation. The range of habitat available can inform assessment of the quality of the refugia.

Refugia is critical to the survival of many aquatic species during dry spells and drought, and act as source populations for subsequent recolonisation and population growth (Adams & Warren 2005; Arthington et al. 2010). Water quality of pools is also considered under this objective.

Quality instream habitat (geomorphic processes)

Processes grouped in this objective include water quality, flow variability, appropriate wetting and drying cycles, geomorphic processes that create and maintain diverse physical habitat, large woody debris and rates of rise and fall that limit bank erosion. The physical form of instream habitats, including the location of riparian and instream vegetation, channel shape and bed sediment, is influenced by river flow (Bunn & Arthington 2002). For example, fresh and bankfull flows with sufficient velocity are required to maintain pool depth and riffles by scouring out bed material and initiating material transportation downstream (Davie & Mitrovoc 2014). Changes to the rates of rise and fall of river levels can also impact on the quality of instream habitat.

Movement and dispersal opportunities for aquatic biota

Longitudinal and lateral connectivity allows organisms to move and disperse within and between environments. It can be essential for maintaining population viability (Amtstaetter et al. 2016) by allowing individuals to move to different habitat types for breeding and conditioning, and recolonisation following disturbances like flood and drought. Flow pulses can promote dispersal of early life stages for a range of species from the breeding site and promote genetic diversity among catchments (Humphries & King 2004).

Instream and floodplain productivity

All plants and animals require energy to carry out basic functions including growth, movement and reproduction. With a few exceptions, the underlying source of all energy in ecosystems is photosynthesis, a process where energy from the sun is stored as plant biomass (organic matter). Organic matter in aquatic ecosystems is provided from either terrestrial plants or trees or by aquatic plants and algae. The sources of organic material, the timing of its delivery and how long it remains in a section of river depends on the flow regime and the nature of the riparian vegetation.

Groundwater-dependent biota

While this LTWP is primarily focused on the management of surface water, there are interactions with groundwater and groundwater-dependent ecosystems (GDEs). There are two alluvial aquifer systems within the NSW Intersecting Streams WRPA, namely the Paroo alluvial and the Warrego alluvial groundwater sources. Although no high priority GDEs have been identified within the Intersecting Streams alluvial groundwater sources, there are many significant plant communities identified on the surrounding floodplains that are likely to be dependent on groundwater. Many of these plant communities occur on in filled paleo-channels that still have some longitudinal connectivity with the river. More research is required to quantify their degree of dependence on the groundwater sources (NOW 2011). For this reason recharge to groundwater is considered under this objective.

Sediment, carbon and nutrient exchange

This objective addresses the processes of sediment delivery to downstream reaches and the mobilisation of carbon and nutrients to and from anabranches, floodplains and wetlands. The flows, and processes, required to meet this objective overlap with those required for instream and floodplain productivity and quality instream habitat.

Inter-catchment flow contributions

Biological connectivity between Intersecting Streams and the Barwon–Darling during critical spawning periods will support native fish outcomes and contribute to improved outcomes in the Intersecting Streams and northern basin catchments. Hydrological connectivity is required at a planning unit scale throughout the catchment to contribute to end of system flows.

Table 6 Priority ecosystem function ecological objectives

Objective			Targets[1] 5 years (2024)	Targets[1] 10 years (2029)	Targets[1] 20 years (2039)
EF1	Provide & protect a diversity of refugia across the landscape		Maintain dissolved oxygen & salinity levels in key refuge pools at ecologically tolerable levels		
EF2	Create quality instream, floodplain & wetland habitat		Rates of rise & fall do not exceed the 5th & 95th percentiles (respectively) of natural rates in areas of high hydrological stress Rates of rise & fall do not exceed the 5th & 95th percentiles (respectively) of natural rates during regulated water deliveries		
EF3	Provide movement & dispersal opportunities within, & between, catchments for water-dependent biota to complete lifecycles & disperse into new habitats	a. within catchments b. between catchments	Maintain frequency of events that allow fish passage in target PUs & gauges Annual detection of species & life stages representative of the whole fish community through key fish passages in specified PUs Increase in passage of key moderate to long-lived riverine & flow-pulse specialist native fish through key fish passages in the Intersecting Streams compared to passage rates detected in 2014–2019		
EF4	Support instream & floodplain productivity		Maintain soil nitrogen, phosphorus & carbon levels at long-term natural levels		
EF5	Support nutrient, carbon & sediment transport along channels, & exchange between channels & floodplains/wetlands		Maintain nutrient & carbon (DOC) pulses at multiple locations along a channel during freshes, bankfull & overbank events Maintain extent & condition of floodplain vegetation Maintain soil nitrogen, phosphorus & carbon levels at long-term natural levels		
			No decline in key native fish species condition metrics (e.g. weight: length ratio)	Improve key native fish species metrics (e.g. weight: length ratio)	
EF6	Support groundwater conditions to sustain groundwater-dependent biota		Maintain the 2016 mapped extent of groundwater-dependent vegetation communities Maintain groundwater levels within the natural range of variability over the long-term		
EF7	Increase contribution from Intersecting Streams to Barwon–Darling		No reduction in rolling 5-year average flows at each end of PU gauge & end of catchment gauge. No increase in the long-term average number of days of cease-to-flow conditions.		

4. Environmental water requirements

A river's flow or inundation regime influences the ecological characteristics of that river's ecosystems (Poff & Zimmermann 2010). A flow regime is the totality of patterns of flows of different volumes, durations and timings. Flow regimes shape river channels, provide cues for key biological processes such as breeding or migration, support dispersal of plants and animals and shape how a river links with its floodplain.

Flow regimes can be partitioned into flow components, such as cease to flow, base flows, freshes and overbank flows, which describe the height or level of the flow within a river channel or its extent across a floodplain (see Figure 6 and Table 7). Flow components can be defined hydrologically and ecologically, with each providing for a range of ecological functions. For example, a small fresh might inundate river benches that provide access to food for native fish and support in-channel vegetation. Similarly, an overbank flow may support carbon exchange between the river and its floodplain and improve river red gum condition and provide feeding and breeding habitat for waterbird species. The volumes that define each of the flow components in the Intersecting Streams are shown in Table 9.

An EWR is the flow needed for a species, or group of species to ensure its survival and persistence. EWRs are based on current knowledge of a species' biological and ecological needs, such as what it needs to feed, breed, migrate and disperse. EWRs are defined based on the volume of flow required, as generalised to a flow component (e.g. baseflow, small fresh) as well as specific flow criteria such as timing, duration and inter-event period. The LTWP applies a flow event method that is based on ecological processes rather than hydrological statistics (Stewardson & Gippel 2003).

Meeting the full life-history needs of an aquatic organism (plant or animal) might require a combination of several different EWRs over time. For example, a native fish species may require a 'small fresh' as a 10-day pulse in late winter to cue spawning, followed by a relatively stable flow for 2–4 weeks in early spring to support nesting. Once the fish reaches maturity (1–3 years) it may require a 'bankfull' fast-flowing river in combination with 'overbank' flows to trigger dispersal and migration. The EWRs collectively represent an ideal flow regime.

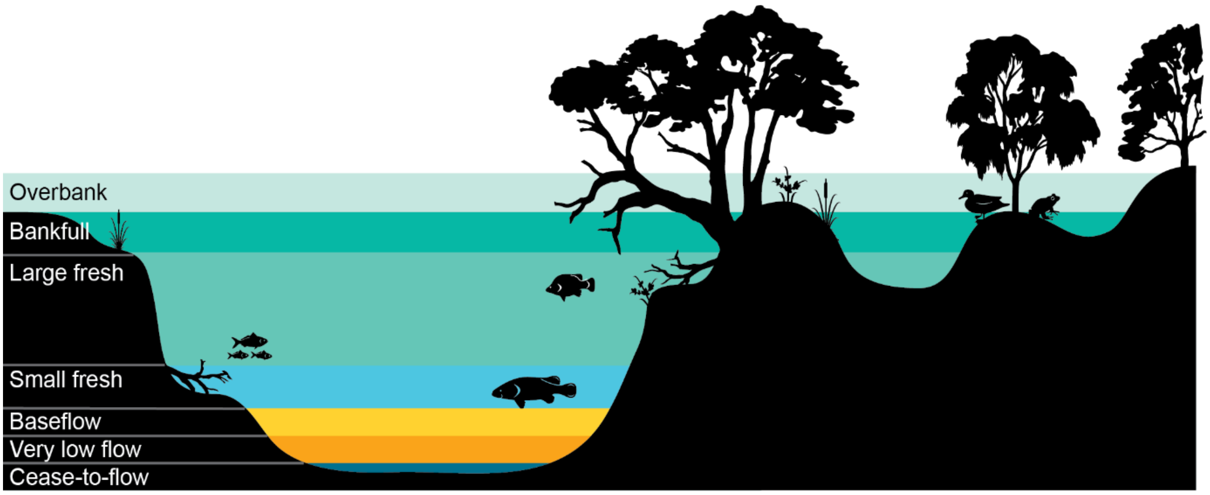


Figure 6 A simplified conceptual model of the role of each flow regime component

4.1 Developing environmental water requirements

Development of EWRs for LTWPs draw on the best available information from water managers, ecologists, scientific publications and analysis of gauged and modelled flows. The process started with an assessment of the water requirements of individual species, then of guilds or functional groups. Where EWRs overlapped between species or groups, the EWRs were combined to provide a single EWR for a flow category.

At the Planning Unit (PU), EWRs were informed by an understanding of the channel morphology and hydrology. This included an analysis of channel cross-sections, floodplain inundation data, observed flow data, modelled flow data and operational experience.

Important flow regime characteristics to meet each of the LTWP objectives are described within the following tables in this chapter. The combined EWRs, grouped by flow component for all biota and functions in the Intersecting Streams are presented in Table 10. Each EWR is named as the flow component it sits within, and then assigned a number reflective of specific details such as ideal timing, duration and frequency based on the suite of plants, animals and functions it supports.

Specific EWRs at each PU in Intersecting Streams, including flow rates and total volumes, can be found in Appendix C.

Table 7 Description of the role provided by each flow component

Flow component	Description
Overbank (OB) / wetland inundating (WL) flow	Both overbank & wetland inundation flows provide broad scale lateral connectivity between channels, wetlands & floodplains. Supports nutrient, carbon & sediment cycling. Promotes large-scale productivity. Overbank flows are used to describe flows above bankfull that results in the inundation of floodplain or disconnected wetlands. Wetland inundation flows are used to describe: • flows that are required to inundate terminal wetlands or off-river lakes • flows that fill wetlands via regulating structures below bankfull over weeks or sometimes months (i.e. longer than a typical fresh/pulse).
Bankfull flow (BK)	Inundates all in-channel habitats & connects many low-lying wetlands connected to the river. Partial or full longitudinal connectivity.
Large fresh (pulse) (LF)	Inundates benches, snags & inundation-tolerant vegetation higher in the channel. Supports productivity & transfer of nutrients, carbon & sediment. Provides fast-flowing habitat. May connect wetlands & anabranches with low commence-to-flow thresholds.
Small fresh (pulse) (SF)	Improves longitudinal connectivity. Inundates lower banks, bars, snags & in-channel vegetation. Trigger for aquatic animal movement & breeding. Flushes pools. May stimulate productivity/food webs.
Baseflow (BF)	Provides connectivity between pools & riffles & along channels. Provides sufficient depth for fish movement along reaches.
Very low flow (VF)	Minimum flow in a channel that prevents a cease-to-flow. Provides connectivity between some pools.
Cease-to-flow (CF)	Partial or total drying of the channel. Stream contracts to a series of disconnected pools. No surface flows.

Table 8 EWR terms and definitions

Term	Definition
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 & EWRs.
Ecological Objectives	The LTWP ecological objectives supported by the EWR. Includes reference to codes of all LTWP Objectives supported (e.g. NF1 = Objective 1 for Native Fish), & a short description of key objectives & life stages being targeted (e.g. spawning or recruitment). Bold text indicates the primary objectives of each EWR. See Tables 1, 2, 4 & 5 for full objectives.
Gauge	The flow gauging station that best represents the flow within the planning unit, for the purpose of the respective EWR & 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 & delivering environmental water, the preferred timing should be used to give greater confidence in achieving ecological objectives. Natural events may occur at other times & 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 & deliver better ecological outcomes. Some species may suffer from extended durations of inundation, & where relevant a maximum duration may also be specified. Flows may persist on floodplains & 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 & 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. For native fish in ephemeral systems, the frequency and duration of events may be less than those stated by DPI (2017). 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, & variability in response during different climate sequences (e.g. maintenance of populations during dry climate sequences

Term	Definition
	at the lower end of the range, & population improvement & 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 & 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, DPIE recommend that the average of the frequency range is used as the minimum long-term target frequency.
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 & comments	Other conditions that should occur to assist ecological objectives to be met – for example rates of rise & fall in flows. Also comments regarding limitations on delivering environmental flows & achieving the EWR.

4.2 Environmental water requirements for the Intersecting Streams

Table 9 Flow threshold estimates for flow components in the Intersection Streams WRPA[9]

Planning unit	Gauge	Low flows (ML/day)		Freshes (ML/day)		Overbank / wetland inundation[10]
		Very low flow[11]	Baseflow	Small	Large	
Moonie River						
Moonie @ Gundablourie	417001	30	NA	314	3909 5100	18,700
Narran River						
Narran @ New Angledool 2	422030	NA	NA	NA	NA	500 GL (volume)
Narran @ Wilby Wilby	422016	126	NA	233	1629	6300 9000
Narran Lakes						
Narran @ Wilby Wilby	422016					25 GL 50 GL 154 GL 250 GL (volumes)
Culgoa River & Lower Balonne Floodplain						
Culgoa @Brenda	422015	50	NA	183 1000	3500	9200 15,000 24,500

[9] These minimums are where the benefits of flow category are likely to begin manifesting. Further substantial benefits occur, particularly for wetland connecting large freshes and overbanks, as flows increase in size.

[10] Values are minimum discharge rate estimates (ML/day) unless indicated as a volume delivered over a set period.

[11] Thresholds for very low flows in this LTWP are provisional estimates of discharges required that enable any flow to reach the Barwon-Darling River.

Planning unit	Gauge	Low flows (ML/day)		Freshes (ML/day)		Overbank / wetland inundation[10]
		Very low flow[11]	Baseflow	Small	Large	
						38,000
Bokhara @ Bokhara (Goodwins)	422032	30	NA	89	913	
Birrie @ Goodooga	422013	30	NA	84	1160	
Warrego River						
Warrego @ Barringun	423004	TBD	NA	217	2242	9597
Paroo River						
Yantabulla: Cuttaburra @ Tura	423005	NA	NA	Any flow < 1000	1000	83 GL 166 GL 724 GL 1,786 GL (volumes)
Toorale						
Warrego @ Fords Bridge Warrego @ Fords Bridge Bywash	423001 + 423002					7 GL 16 GL 33 GL 75 GL (volumes)
Warrego @ Boera	423008	TBD	TBD	TBD	TBD	TBD

Table 10 Summary of catchment-scale EWRs for the Intersecting Streams

Flow category & EWR code		Ecological objectives	Timing	Duration[12]	Frequency (LTA frequency)	Maximum inter-event period	Additional requirements & comments
Cease-to-flow	CF1	Native Fish: NF1 – Survival & condition (all native species) Ecosystem Functions: EF1, 2 – refuge habitat; EF4 – support in-stream productivity	In line with historical low season flow	Consistent with historical low-flow season	No greater than natural	N/A	Many of the waterways in the Intersecting Streams WRPA are ephemeral. CF are expected under natural flows. When restarting flows avoid harmful water quality impacts, such as de-oxygenating refuge pools
Very-low flow	VF1	Native Fish: NF1 – Survival & condition (all species) Ecosystem Functions: EF1, 2 – refuge habitat	Any time	No less than natural	Annual	No greater than natural	Flows that provide replenishment volumes to refuge pools. Waterhole persistence can also be supported by groundwater discharge
Baseflow	BF1	Native Fish: NF1–NF6 – condition & movement (all species) Native Vegetation: NV1 – in-channel non-woody vegetation Ecosystem Functions: EF1, 2, 3a	Any time	No less than natural	No less than natural	No greater than natural	Minimum depth of 0.3 m to allow fish passage
	BF2	Native Fish: NF1, 2, 5, 6 – recruitment (river specialists, generalists)	Sep to Mar	In line with natural	5–10 years in 10 (*75%*)	2 years	

[12] Flow durations may vary depending on the size of large wetland complexes and the morphology of inlet infrastructure.

Flow category & EWR code		Ecological objectives	Timing	Duration[12]	Frequency (LTA frequency)	Maximum inter-event period	Additional requirements & comments
Small fresh	SF1	Native Fish: NF1 to NF6 – dispersal/condition (all native species) Native Vegetation: NV1 (in-channel non-woody native vegetation) Waterbirds: WB5 – habitat Ecosystem Functions: EF1–EF5, EF3b (for some planning units only)	Oct to Apr (or any time)	10 days min.	10 years in 10 (100%) or in ephemeral systems in line with historic	1 year	Minimum depth of 0.5 m allows movement of large-bodied fish
	SF2	Native Fish: NF1, 2, 5, 6 – **Spawning (river specialists, generalists)** Native Vegetation: NV1 (in-channel non-woody native vegetation) Ecosystem Functions: EF1–EF5	Sep to Apr	14 days min.	5–10 years in 10 (*75%*) or in ephemeral systems in line with historic	2 years	Minimum depth of 0.5 m allows movement of large-bodied fish Some fish have temperature-specific spawning requirements
Large fresh	LF1	Native Fish: NF1 to NF6 – **dispersal / condition (all native species)** Native Vegetation: NV1, 3 Ecosystem Functions: EF1 to EF7	Jul to Sep (or any time)	5 days min.	5–10 years in 10 (*75%*) or in ephemeral systems in line with historic	2 years	This flow in Jul to Sep will improve pre-spawning fish condition) Minimum depth of 2m to inundate channel features & trigger fish movement Flow ideally reaches an average velocity of 0.3 to 0.4 m/s (depending on channel morphology)

Flow category & EWR code		Ecological objectives	Timing	Duration[12]	Frequency (LTA frequency)	Maximum inter-event period	Additional requirements & comments
	LF2	Native Fish: NF1, 4, 6 – **spawning (flow pulse specialists)** Native Vegetation: NV1, 3 – in-channel Ecosystem Functions: EF1 to EF7	Oct to Apr	5 days min.	3–5 years in 10 (*40%*) or in ephemeral systems in line with historic	4 years	Rate of flow rise should be consistent with natural rates Minimum depth of 2 m to inundate channel features & trigger fish response Flow ideally reaches an average velocity of 0.3 to 0.4 m/s (depending on channel morphology)
	LF3	Native Vegetation: NV3 – riparian **river red gum**.	Aug to Feb (or any time)	In line with historic (habitat inundation for 1-4 months)	In line with historic	5 years	Supports in-channel river red gum below bankfull height.
Small wetland inundation	WL1	Native Fish: NF1 (all species) Native Vegetation: NV 2, 3 Waterbirds: WB5 Ecosystem Functions: EF3a, 4, 6 – productivity	Any time	In line with specific wetland requirements	In line with specific wetland requirements	2 years	Frequencies may vary among specific wetlands.
	WL2	Native Fish: NF1, 3 – **Dispersal / condition (all native species)** Native Vegetation: NV2, 3 – non-woody wetland maintenance & regeneration Waterbirds: WB1, 2, 5 – survival & habitat Ecosystem Functions: EF3a, 4, 6 – productivity	Any time	In line with specific wetland requirements	In line with specific wetland requirements	4 years	For enhanced productivity & movement opportunities for fish

<table>
<tr><th colspan="2">Flow category & EWR code</th><th>Ecological objectives</th><th>Timing</th><th>Duration[12]</th><th>Frequency (LTA frequency)</th><th>Maximum inter-event period</th><th>Additional requirements & comments</th></tr>
<tr><td rowspan="2">Large wetland inundation</td><td>WL3</td><td>Native Fish: NF1, 3, 7 – Spawning (floodplain specialist fish)
Native Vegetation: NV2 – NV4 – lignum regeneration, coolabah wetland regeneration
Waterbirds: WB1 to WB5 – waterbird breeding
Ecosystem functions: EF3a, 4, 6 – productivity</td><td>Any time</td><td>In line with specific wetland requirements</td><td>In line with specific wetland requirements</td><td>5 years</td><td>Max interevent may change depending on antecedent conditions.</td></tr>
<tr><td>WL4 (boom)</td><td>Native Fish: NF1, 3, 7 – dispersal & condition (all species)
Native Vegetation: NV1, 2, 4b, 4e – lignum maintenance, coolabah wetland maintenance
Waterbirds: WB1 to WB5 – waterbird breeding
Ecosystem functions: EF3a, 4, 6 – productivity</td><td>Any time</td><td>In line with specific wetland requirements</td><td>In line with specific wetland requirements</td><td>10 years</td><td></td></tr>
<tr><td>Small overbank inundation</td><td>OB1</td><td>Native Fish: NF1 (all species)
Native Vegetation: NV1, 2, 3
Waterbirds: WB5
Ecosystem Functions: EF3, 4, 6, 7 – productivity</td><td>Oct to Apr</td><td>In line with historic</td><td>5 years in 10 (50%)</td><td>4 years</td><td>>22°C
Ideally, recruitment flow 2–4 weeks after spawning flow
In ephemeral systems floodplain specialists can spawn & survive in-channel. Overbank events expand available habitat, support movement & increase productivity.</td></tr>
</table>

Flow category & EWR code		Ecological objectives	Timing	Duration[12]	Frequency (LTA frequency)	Maximum inter-event period	Additional requirements & comments
	OB2	Native Fish: NF1, 3 – **Dispersal / condition (all native species)** Native Vegetation: NV1, 2, 3 – non-woody wetland maintenance & regeneration Waterbirds: WB1, 2, 5 – survival & habitat Ecosystem Functions: EF3, 4, 6, 7 – productivity	Ideally Sep to Apr but can occur any time	In line with historic	2–3 years in 10 (25%)	5 years	In ephemeral systems floodplain specialists can spawn & survive in-channel. Overbank events expand available habitat, support movement & increase productivity.
Large overbank inundation	OB3	Native Fish: NF1, 3, 7 – Spawning (floodplain specialist fish) Native Vegetation: NV1, 2, 4b, 4e – **lignum regeneration, coolabah wetland regeneration** Waterbirds: WB1 to WB5 – **waterbird breeding** Ecosystem Functions: EF3, 4, 6, 7 – productivity	Any time	In line with historic	1–2 years in 10 (*15%*)	No more than natural	In ephemeral systems floodplain specialists can spawn & survive in-channel. Overbank events expand available habitat, support movement & increase productivity.

Flow category & EWR code		Ecological objectives	Timing	Duration[12]	Frequency (LTA frequency)	Maximum inter-event period	Additional requirements & comments
	OB4	Native Fish: NF1, 3, 7 – **dispersal & condition (all species)** Native Vegetation: NV1, 2, 4b, 4e – **lignum maintenance, coolabah wetland maintenance** Waterbirds: WB1 to WB5 – **waterbird breeding** Ecosystem Functions: EF3, 4, 6, 7 – productivity	Any time	In line with historic	0.5 to 1 year 10 (*7.5%*)	No more than natural	In ephemeral systems floodplain specialists can spawn & survive in-channel. Overbank events expand available habitat, support movement & increase productivity.

4.3 Changes to the flow regime

Hydrological variability is a feature of the rivers in the Intersecting Streams WRPA. There are long periods of low to zero flow, punctuated with episodic flooding events. For example, the Lower Balonne, Moonie, Warrego, Nebine and Paroo systems experience no flow for 50% or more of the time on a long-term basis. Flows in the Darling and Warrego Rivers are also highly variable and are strongly correlated with the Southern Oscillation Index (MDBA 2018).

While seasonal flow patterns have largely been preserved in the Intersecting Streams, diversions during unregulated flow events have reduced the volume of water remaining in the system, reducing end of system flows. These flow changes, which are associated with small public regulated water schemes (such as the Condamine–Balonne) and in-stream weirs with diversions to private infrastructure have not only reduced the volume, but also the duration and frequency of flows that support in-stream and floodplain communities, and terminal wetlands in some areas. Low flow regimes have also been affected in some areas, including an increase in the percentage of time with no flow and the maximum period between events that refill waterholes and re-establish hydrological connectivity throughout the system.

Water diversions present a key threat to the ecological character of water sources within the Intersecting Streams WRPA, with potential impacts such as reduced vegetation health and loss of habitat for waterbird breeding, reduced value as drought refugia and support of critical life stages. Other reported ecological impacts from these changes to the flow regime include increased risk of thermal stratification in weir pools and waterholes from extended no flows. Thermal stratification can contribute to increased incidence of potentially toxic blue green algal blooms and reduce oxygen levels within pools, reducing available aquatic habitat and in severe cases cause fish deaths.

The hydrology of the lower Warrego River, and receiving Darling River, has been heavily modified. For example, although the Warrego catchment is still relatively unregulated upstream, several dams associated with Toorale National Park partly control in-channel flows to the lower Warrego River. The Toorale Infrastructure Project is now looking to modify these structures to improve environmental outcomes and provide greater flows to the Darling River.

These weir pools form important in-channel refugia during no-flow periods (Capon 2009). In some cases their presence has also significantly changed the inundation frequency of the surrounding floodplain (Cox et al. 2012).

The *Water Sharing Plan for the Intersecting Streams Unregulated and Alluvial Water Sources 2011* (WSP, NOW 2011) aims to provide a legislative basis for sharing water between the environment and consumptive purposes. It includes six unregulated water sources that are managed under a long-term average annual extraction limit (LTAAEL) (NOW 2011). The LTAAEL for each unregulated water source is equal to the total of the estimated annual extraction of water averaged over the period from July 1993 to June 1999 for those entitlements issued under Part 2 of the *Water Act 1912* prior to the commencement of the WSP; plus an estimate of annual extraction of water under domestic and stock rights and native title rights at the commencement of the plan.

CSIRO (2008) calculated that for the Darling Basin the average long term water availability (under historical climate conditions) is around 3515 GL/y (at Bourke). Average surface water availability for the Condamine–Balonne under the historical climate is 1363 GL/year, with average surface water use at the current level of development is 722 GL/year or 53% of the available water, and is considered an extremely high level of use (CSIRO 2008). Current monitored groundwater extraction is 160 GL/year (CSIRO 2008). Current average surface water availability in the Paroo is 445 GL/year and less than 0.1% is currently diverted for use. Groundwater use in the Paroo is also low and does not impact on streamflow (CSIRO 2008).

Small freshes or greater are needed to reconnect the weir pools, promote mixing, and minimise the occurrence of these algal blooms (Mitrovic et al 2003, 2006 in MDBA 2016b). The first flow after a dry spell is important to maintain habitats and refresh pools, improve water quality, provide conditions for fish and other animals to access key habitats and water riparian vegetation (MDBA 2018).

In-channel freshes that promote fish spawning, recruitment and dispersal have been significantly reduced in number and size (NSW DPI 2015 in CSIRO 2016b). The increased spell duration between larger events that drown out weirs, has reduced the frequency of fish passage (CSIRO 2008). Migration of fish along through the northern Basin is only possible when flows are high enough to drown out existing weirs. The frequency of these critical drown outs has generally been reduced due to water use (CSIRO 2008, MDBC 2007, NSW DPI 2015*,* MDBA 2016).

The reduction in flow events that inundate in-channel features and the floodplain has also reduced the cycling of nutrients and organic material (Southwell 2008) and the access to habitat for aquatic animals such as fish (Boys and Thoms 2006; NSW DPI 2015, MDBA 2016). The reduction in peaks has reduced lateral connectivity between the main-channel and other assets (riparian channels, wetland habitat and floodplain). The number of days when wetlands along the Intersecting Streams are receiving water has also declined.

4.4 Environmental water in the Intersecting Streams

Water for the environment is classified as either planned or Held environmental water (HEW). Planned environmental water (PEW) is water that is committed by management plans for fundamental ecosystem health or other specified environmental purposes, either generally or at specified times or in specified circumstances, and that cannot, to the extent committed, be taken or used for any other purpose.

In the Intersecting Streams WSP, water is identified as PEW by its physical presence, commitment to a long term average annual or as ‘water that is not committed after the commitments to basic landholder rights and for sharing and extraction under any other rights have been met’ (WSP 15(2) c). Access is restricted through licence conditions, including approved pump capacities or daily extraction rates, account limits and commence to pump flow thresholds. The combination of these restrictions limit extraction and protect a portion of flows for the environment and downstream users. Any change to the rules that results in increasing access to flows, is a loss of PEW.

HEW is the water that is committed by the conditions of access licences for specified environmental purposes. The Australian Government has purchased water access licences:

- 5671 ML in the Moonie catchment with a long term average annual yield of 2523 ML
- 17,826 ML in the NSW Warrego catchment (Toorale CEWO holdings) with a long term average annual yield of 13,733 ML

These entitlements allow water that could previously have been pumped before government acquisition to be left in the river to support natural flows. However, there are currently no mechanisms to protect this water from being extracted by other licence holders in both the Intersecting Streams WRPA and Barwon–Darling and beyond.

Environmental water holdings are being used to address changes in flow volumes that have occurred as a result of diversions during unregulated flow events. These diversions have reduced the volume, duration and frequency of flows that support instream and floodplain ecological communities.

This LTWP aims to guide the management of both PEW and HEW, in partnership with the CEWH and DPIE–Water.

4.5 The Water Sharing Plan for the Intersecting Streams Unregulated and Alluvial Water Sources

The Intersecting Streams water resource is managed by the *Water Sharing Plan for the Intersecting Streams Unregulated and Alluvial Water Sources 2011* (WSP, NOW 2011). The WSP divides the river reach into four sections to assist in mitigating the effects of water trade.

The WSP determines how river flows are shared between the environment and consumptive users. The health of the river depends on floods, freshes and low flows (DoI-W 2017). Environmental flow rules are designed to address all these requirements (DoI-W 2017). Provisions for the environment in the unregulated WSP include:

- Extraction limits: six unregulated water sources are to be individually managed under a long-term average annual extraction limit (LTAAEL). The LTAAEL for each unregulated water source is equal to the total of the estimated annual extraction of water averaged over the period from July 1993 to June 1999 for those entitlements issued under Part 2 of the *Water Act 1912*. It also includes an estimate of annual extraction of water under domestic and stock rights and native title rights at the commencement of the plan.
- Available water determination (AWD): AWDs are to be made annually defining how much of the share component will be available under each category of licence. Specific purpose access licences such as domestic and stock or local water utility access licences, generally receive 100% of their share component, although in years of exceptional drought the daily access rules may limit extraction to the extent that annual entitlement cannot be fully realised.
- Water accounts: a water allocation account is established for each water access licence. Water is credited to the account when an AWD is made, and debited when water is extracted.
- Water interception: floodplain harvesting in unregulated water sources has generally already been recognised and licensed as part of the process that converted area based water licences to volume based licences. However, further volumetric entitlements for floodplain harvesting may be established through the development of a NSW Floodplain Harvesting Policy. As a result, the WSP may be amended at a later date to deal with the management of floodplain harvesting.
- Access rules: for the majority of water sources no access rules, other than a cease to pump when there is no visible flow in the vicinity of the pump site, could be recommended due to many existing licences having no existing access rules. This access rule provides, at a minimum, protection of natural pools, which are important for drought refuge, as well as domestic and stock water supplies. Those activities that are considered critical human needs or animal health requirements are permitted to access the very low flow, i.e. below the ‘cease-to-pump’ defined in the access rules. An important exception is the provision of WSP rules that maintain low-flow connectivity to the Narran Lakes.
- Trading rules: trading within each water source is permitted. No trading is permitted into any of the water sources to minimise potential competition for extraction in ephemeral stream systems, and to protect environmental values.

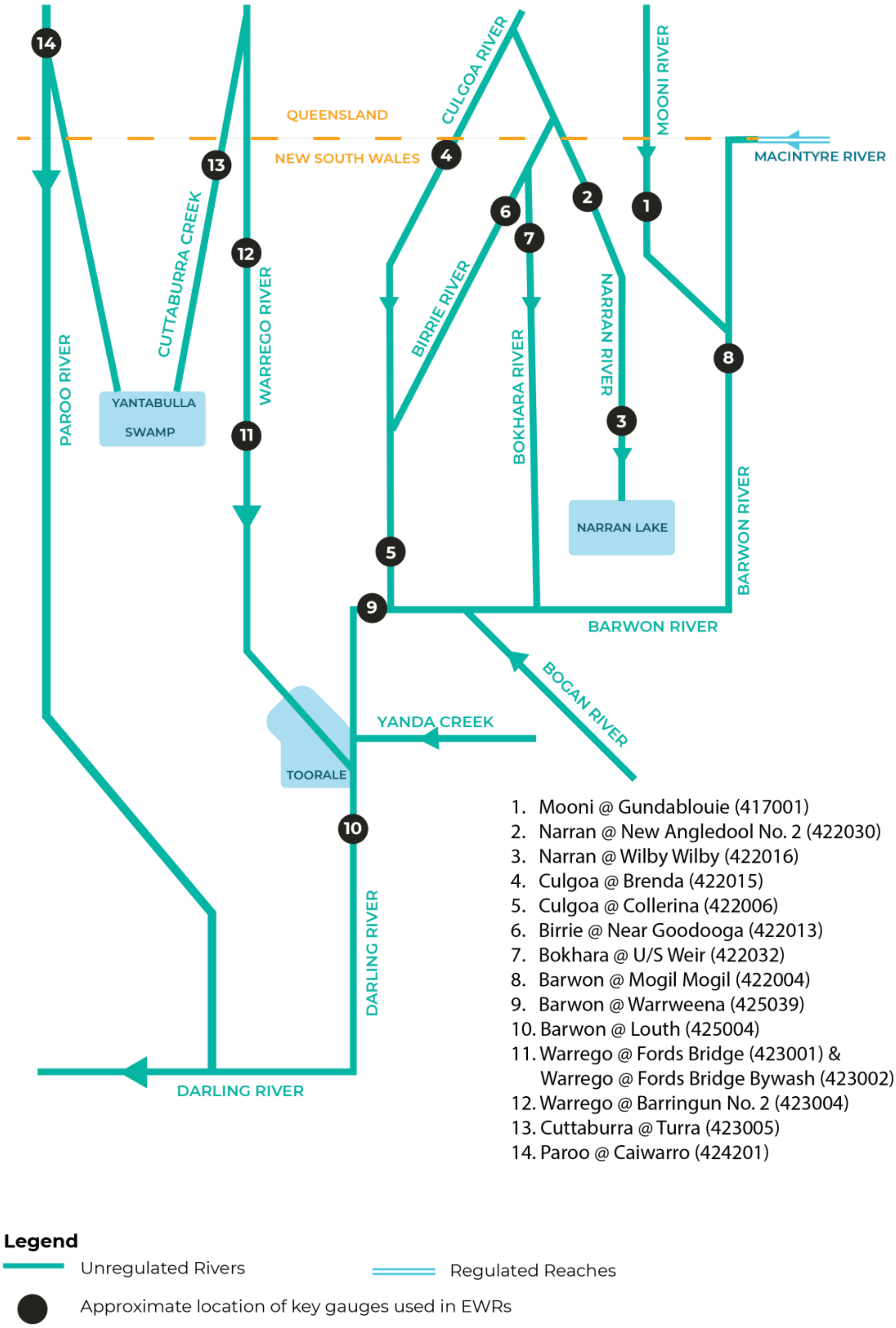


Figure 7 A schematic diagram of the main watercourses and key gauges referred to in the Intersecting Streams Long Term Water Plan

5. Risks, constraints and strategies

This LTWP focuses on actions to deliver environmental outcomes for water-dependent environmental assets in a highly variable climatic zone. There are many factors that could potentially impact on how the plan is implemented and the outcomes achieved.

The *Intersecting Streams Water Resource Plan Risk Assessment* (DPIE–Water in prep) was undertaken to inform water resource planning in the Intersecting Streams WRPA. It identifies risks to areas of conservation value based on hydrological change within sub-catchments and describes how the WRP may mitigate those risks. This chapter of the Intersecting Streams LTWP complements the risk assessment, addressing the specific risks and constraints related to delivering water for the environment.

The risks and constraints outlined in the LTWP are those that affect our capacity to:

- meet the EWRs of environmental assets and functions
- achieve the environmental objectives of the LTWP.

All EWRs assessed as significantly changed between without development and current conditions model scenarios, and EWRs that have not been sufficiently occurring in recent times are at high risk of not being met in the future.

This risk assessment has assisted with identification of appropriate investment opportunities for improving the likelihood that and EWR can be achieved in the short and long term (Part B).

There is also risk to the EWRs from potential further development of the tributaries and unregulated water sources and new in-stream and floodplain water infrastructure. This could include activation of ‘sleeper’ licences, or new water storage and floodplain harvesting infrastructure.

Figure 8 **The Warrego River at Brooka Dam**
Photo: Joanne Ocock.

Table 11 Water management-based risks to meeting EWRs that may be present in the NSW Intersecting Streams

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Responsible organisation(s)
Insufficient water for the environment available within the WRPA	There is a relatively small volume of HEW in the NSW Intersecting Streams. However, large volumes of the Australian Government's environmental water entitlements have been recovered upstream in QLD water sources connected to NSW Intersecting Streams (in the QLD Condamine–Lower Balonne, Warrego & Moonie catchments). Development of sleeper licences (including by trade upstream into connected QLD water sources) & any further development of water storages & weirs along the Intersecting Streams is likely to exacerbate any current shortage of environmental water.	All EWRs assessed as significantly changed between without development & current conditions model scenarios, & EWRs that have not been sufficiently occurring in recent times are at high risk of not being met in the future. Associated ecological objectives are unlikely to be achieved.	Implement SDL & Water Resource plan compliance including Growth-in-use provisions. Active management to protect the passage of residual flows of HEW (that is not 'used' by upstream wetlands, refuges) through the Intersecting Streams may contribute to achievement of some EWRs. Implementation of event-based mechanisms & other Northern Basin Toolkit measures.	DPIE, MDBA, DPIE–Water & CEWO

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Responsible organisation(s)
	Extraction rules in unregulated systems do not protect the 'first flush' event.	The first flow after a period of no flow is ecologically critical. Loss of the first flow, or delay in timing of the first flow can stress ecological thresholds & limit the ecological effectiveness of the flow.	Consider mechanisms to protect the first significant flow event following a cease to flow period using active management (e.g. event based mechanisms).	DPIE–Water
	Inadequate commence & cease to pump rules can place pools at risk & limit or prevent flows reaching the end of system & replenishing all waterholes.	Existing & changed extraction rules may have an impact on the volume, timing & flow rate of PEW & subsequently impact on EWRs. Pumping from natural waterholes & weir pools can impact on ecosystem functions objectives, & also fish objectives including those pertaining to threatened species. Pumping under low & nil flow conditions reduces habitat quality & ability of waterholes to provide refuge for aquatic life during cease to flow periods, & restock the system when it is next connected	Ensure any changes to WSP rules are not detrimental to the EWRs. Where evidence suggests extraction is impacting EWRs, investigate options to mitigate this impact via new WSP rules. Maintain protection of pools – implement no visible flow commence-to-flow conditions at a minimum.	DPIE & DPIE–Water
	Increased capture of unregulated flows through floodplain harvesting Insufficient environmental, stock & domestic flows from upstream WRP areas (Beardmore Dam) Further development of the tributaries Drying out of the tributaries – so	This would prevent achievement of certain EWRs. Cease to flow periods extending beyond persistence times of key refugia waterholes, particularly in the Culgoa & Narran rivers. The ecological character of Narran Lakes is not maintained, particularly core lignum rookery habitat & opportunities for large-scale waterbird breeding.	Coordinate dam releases with unregulated tributary flows to promote higher peaking events. Ensure no further development of unregulated tributaries, including no further construction of dams Quantify, licence & set limits on floodplain harvesting in the Intersecting Streams. Initiate interjurisdictional working group to collaboratively manage environmental flows	DPIE, CEWO & DPIE–Water

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Responsible organisation(s)
	sequential flooding no longer occurs.			
Unsuitable water quality	Water quality affects the ecology & survival of aquatic organisms. Natural processes can cause unfavourable water quality, such as during blackwater events after dry or low-flow periods. This occurs from the build-up of organic material in channels & on floodplains & leads to low dissolved oxygen levels & potential fish kills. Insert risk assessment results for salinity & blue-green algae. Also note thermal stratification & how this effectively reduces the habitat area of the weir pool.	Poor water quality may reduce ecosystem resilience to disturbances & reduce the extent of ecological response from watering. Potential direct & indirect impacts on the objectives. Recovery may require increased frequency of environmental flows to encourage species recruitment & a return to stable populations.	Implement the recommendations detailed in the Water Quality Salinity Management Plan to improve overall water quality. Monitor water quality. Coordinate algal response and contingencies via Regional Algal Coordinating Committee (RACC) also monitoring and reporting of toxic BGA blooms	DPIE–Water, WaterNSW (RACC)
Take of environmental water	In the absence of active management to protect additional inflows to the Intersecting Streams	This may prevent flows from reaching the flow thresholds & event duration required by EWRs, & subsequently prevent objectives from being achieved.	Refer to the NRAR water compliance policy & strategy Active management where appropriate (as above)	NRAR & DPIE–Water

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Responsible organisation(s)
	any environmental water that increases flows above commence to pump thresholds could be at risk of being taken.		Improved transparency in water harvesting announcements & flow event reporting in upstream WRP areas	
Altered system inflows & seasonal flows due to climate change	Increased extremes of temperature & rainfall may increase the flashiness of flows & reduce the persistence of waterholes. Changing the seasonality of inflows may also have effects on environmental values. Longer & more frequent cease-to-flow periods, coupled with increased dry sequences may increase average & maximum interflow periods experienced, & increase demand for environmental water.	It may become more difficult to meet the minimum durations of EWRs, particularly in unregulated streams.	Monitor changes & adjust use of HEW & PEW in response	DPIE & CEWO
Knowledge gaps & uncertainties	There are significant knowledge gaps about EWRs in the Intersecting Streams. These include:	Some EWRs may be insufficient to achieve the environmental objectives.	As regionally specific knowledge is gained, revision to the objectives & EWRs will be required.	DPIE, DPIF, DPIE–Water, CEWO & MDBA

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Responsible organisation(s)
	• relationship between ground & surface water • location of high quality habitat drought refugia • location & watering needs of cultural assets • ongoing fish tagging to monitor movement of species & populations • flows required for recovery of golden perch (as opposed to maintenance). • Impact of climate change on various components of the hydrograph in respective streams in the IS (maybe also implications for biota)		As funding permits, undertake research activities such as habitat mapping & monitoring of LTWP outcomes.	
Social willingness & adequacy of governance structures	There may be resistance within the community to take actions to meet the	A lack of social willingness for environmental protection may increase the need for compliance actions.	Establish mechanism for gaining regional input to environmental water decisions to build knowledge & understanding & foster ownership. Grow community understanding & acceptance of environmental water.	DPIE, CEWO & MDBA, Local Government

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Responsible organisation(s)
	objectives stated in this LTWP.	Local knowledge may improve development of appropriate management strategies to achieve the EWRs & associated objectives.		
New floodplain structures & barriers	Construction (e.g. levees, diversion channels, sediment blockage of culverts) may create barriers to delivering water to wetland & floodplain areas.	New structures could change floodplain flows, directing water away from environmental assets. This may limit achievement of native vegetation, waterbird & functions objectives associated with overbank EWRs.	Develop and implement a floodplain management plan for the Intersecting Streams WRPA & undertake priority remedial works.	DPIE–Water & DPIE
Existing & new instream barriers & structures	Three weirs have been identified as high priority for remediation to improve fish passage on the Warrego & Condamine Rivers in Queensland. There are also numerous smaller instream weirs on all channels in the Intersecting Streams. Fish movement is significantly limited by in-stream structures & sections are only connected during flows that drown out structures. In some cases the structures provide important refugia during periods of no flow.	This directly impacts on achievement of the objective “Dispersal of fish across the whole of the Intersecting Streams after major breeding events & dry spells.” Remediation to add suitable fish ways would enable this objective to be achieved at lower flow rates.	Refer to NSW DPIF *Fish for the Future: Action in the Northern Basin-NSW proposal for Northern Basin Toolkit*. Seek funding to remove barriers.	DPIF
			Remove priority illegal barriers Ensure compliance on any new in-stream works.	NRAR & DPIF

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Responsible organisation(s)
Fish entrainment	Native fish can be removed, injured or killed when sucked into irrigation pumps.	This directly impacts on native fish objectives. Mortality or removal of native fish due to entrainment places additional pressure on successful spawning & recruitment events to maintain populations.	Refer to DPI Fisheries fish screening criteria (Boys et al. 2012).	DPIF & DPIE–Water

5.1 Non-flow related risks and constraints to meeting LTWP objectives

The risks and constraints to meeting the ecological objectives include non-flow-related external factors that could potentially impact on achieving the objectives outlined in this plan (Table 12). While managing these risks and constraints is outside the scope of this LTWP, they have been included to draw attention to their influence on river and wetland health, and to highlight the importance of linking this LTWP with broader natural resource management.

Figure 9 Lignum (*Muehlenbeckia florulental*) in flower at Toorale
Photo: Joanne Ocock.

Table 12 Non-flow management related risks and constraints to meeting LTWP ecological objectives

Risk	Description	Potential management strategies	Responsible organisations
Poor water quality including salinity & elevated turbidity, affecting LTWP fish & functions objectives	Water quality affects the ecology & survival of aquatic organisms Elevated salinity has been reported to occur intermittently in the Intersecting Streams WRPA (Narran & Culgoa Rivers) Algal blooms are known to occur within weirs & pools of the Intersecting Streams WRPA. Hypolimnetic hypoxia & destratification can cause adverse water quality events in refuge & weirpools of the Intersecting Streams WRPA (N. Foster, pers. com). However, the remoteness of the region may mean many events go unrecognised. Elevated water column turbidity can affect fish feeding behaviour & ecosystem functions	Implement recommendations detailed in the *Water Quality Salinity Management Plan* (DPIEI–Water, in prep)	DPIE–Water
		Manage salinity in accordance with the *Basin Salinity Management 2030 Strategy* (MDB Ministerial Council 2015)	DPIE–Water
		Implement land management strategies to improve water quality	LLS with Landholders, Landcare, DPIE, WaterNSW, DoI–W & other community groups
Native vegetation clearing impacting on LTWP vegetation & waterbird habitat objectives	Native vegetation clearing has direct impacts on LTWP vegetation objectives & the availability of waterbird habitat. Changes to riparian vegetation can impact on water quality, stream erosion & instream habitat.	Work with relevant departments & organisations to identify & protect core wetland vegetation communities using legislation & native vegetation planning processes	DPIE & LLS, DoI (Crown Lands)
		Map & identify riparian & aquatic habitat condition to inform development of formal agreements in a unified strategy Prioritise reaches for management in partnership with LLS & landholders	DPIE, DPIF & LLS

Risk	Description	Potential management strategies	Responsible organisations
Impacts of unmanaged total grazing pressure & stock access to waterways impacting on water quality & LTWP vegetation targets	If not managed carefully, grazing pressure from domestic & native herbivores, & access of stock to riverbanks, can: • reduce native vegetation cover which allows weeds to establish • reduce streambank stability • damage important instream habitat • reduce water quality	Map & identify riparian & aquatic habitat condition to inform development of formal agreements in a unified strategy. Prioritise reaches for management in partnership with LLS & landholders.	DPIE, DPIF & LLS
		Support implementation of grazing strategies that are sympathetic to wetland vegetation as per Holmes *et al.* (2009) www.dpi.nsw.gov.au/agriculture/pastures-and-rangelands/establishment-mgmt/grazing-management2/guidelines-gwydir-macquarie.	LLS & landholders, DPIE (Crown Lands)
		Investigate incentives to achieve sympathetic management of wetlands on private land to meet ecological objectives.	LLS & BCT
		Manage the abundance the abundance of native herbivores to control total grazing pressure.	NPWS & Kangaroo Management, landholders & LLS
Lakebed cropping	Cropping of dry lakebeds & wetlands can have adverse impacts on ecological communities & ecosystem functions when sites are inundated. Cropping lakebeds can increase fine sediment load when wet, increasing turbidity.	Map & identify lakebed & floodplain condition to inform development of formal agreements in a unified strategy. Prioritise areas for management in partnership with LLS & landholders.	DPIE, DPIE (Crown Lands), DPIF & LLS
Spread of pest plant species impacting on achieving LTWP vegetation objectives	There is potential for environmental water to promote the growth & spread of aquatic & terrestrial weed species including lippia, Noogoora burr & tobacco weed.	Map & identify riparian & aquatic habitat condition to inform development of formal agreements in a unified strategy. Prioritise reaches for management in partnership with LLS & landholders.	DPIE & LLS
		Maintain existing weed control programs.	NPWS, LLS & local government, landholders
		Inundate wetlands for enough time to favour native wetland species growth & reduce the extent of terrestrial weed species like lippia.	DPIE & CEWO

Risk	Description	Potential management strategies	Responsible organisations
		Monitor for pest species, including for potential new pests.	DPI, DPIE (including NPWS), LLS, landholders & local government
Spread of pest animal species impacting on achieving LTWP vegetation, fish, frog & waterbird objectives	The current flow regime, including environmental water supports populations of invasive animals. These populations reduce the benefit of environmental water on native species.	Support recommendations in pest species management plans, with implementation of control programs such as those for: • carp (see NSW I&I 2010), including the cyprinid herpesvirus-3 if recommended by the National Carp Control Program • other invasive fish such as redfin & gambusia (competition with native fish & predation) • pigs (vegetation, predation impacts) • goats (vegetation impacts) • foxes & cats (predation impacts)	DPIF, WaterNSW, DPIE & NPWS
		Implement proposals in *Fish for the Future: Action in the Northern Basin—NSW proposal for Northern Basin Toolkit measures to promote native fish health*. (NSW Fisheries, 2017)	DPIF
		Monitor for pest species, including for potential new pests (e.g. Tilapia).	DPIF, DPIE (including NPWS), LLS, landholders & local government
Problematic erosion & sedimentation may impact upon various LTWP objectives	Erosion (both natural & accelerated) & sedimentation may result in a variety of changes that affect the LTWP targets, including: • vegetation (inundation extent change, changes in streams) • waterbird habitats • water quality • longitudinal & lateral connections	Support variable flows & ecologically desirable flow recession rates in river operations to reduce bank slumping.	DPIE & WaterNSW
		Map & prioritise riparian habitat & erosion points for rehabilitation at the catchment scale, with a commitment to manage risk & monitor outcomes.	DPIE, DPIF, LLS & WaterNSW
		Manage environmental waters to mimic pre-development flow patterns & variability (where possible).	DPIE, DPIE–Water, WaterNSW & CEWO
		Investigate ongoing erosion control works in high-risk areas	DPIE, WaterNSW, DPIE–W

Risk	Description	Potential management strategies	Responsible organisations
		Identify and treat erosion risk areas	LLS, DPIE–Water, local government, DPIE & landholders
Current & future instream barriers & structures impacting connectivity related LTWP objectives	There are several major barriers including weirs, regulators, & road crossings identified in the *Intersecting Streams Water Resource Plan Risk Assessment* (DPIE-Water in prep). These impede natural flow & connectivity, significantly impacting fish populations.	Remove priority illegal & unauthorised barriers.	DPIE–W & DPIF
		Implement NSW Department of Primary Industries, Fisheries (2017): *Fish for the Future: Action in the Northern Basin – NSW proposal for Northern Basin Toolkit measures to promote native fish health* measures to overcome priority fish barriers	DPIF
		Implement the *Fisheries Management Act 1994*	DPIF
		Implement works required under Toorale Infrastructure Project	DPIE–Water & DPIE
		Seek funding opportunities to identify & potentially modify existing structures e.g. levees, town weirs, privately owned weirs & regulators	WaterNSW, local government, landholders, DPIF, DPIE & LLS
Pumps & other water offtakes impacting on LTWP fish objectives	There are over multiple pump offtakes with a diameter greater than 200 mm located across the Intersecting Streams WRPA.	Implement NSW Department of Primary Industries, Fisheries (2017): *Fish for the Future: Action in the Northern Basin – NSW proposal for Northern Basin Toolkit measures to promote native fish health* measures for fish-friendly water extraction	DPIF, LLS & industry groups
No protection of environmental flows to connect with the Barwon-Darling River impacting on LTWP fish, connectivity & flow contribution targets.	Current unregulated WSP end of system access rules do not ensure a minimum flow rate from the Intersecting Streams into the Barwon-Darling River Additional end of system flows that could be provided by HEW are not protected from extraction. The actual contribution of Intersecting Streams flows to the Barwon-Darling River cannot currently be accurately determined & managed.	Consider mechanisms to protect HEW through unregulated areas downstream of the regulated system. This could be done to meet in-system or connection outcomes.	DPIE–Water
		Improve gauging of flows & providing event-based management for events in unregulated areas where HEW will be used	DPIE–Water & WaterNSW
		Upgrade the capability of end of system gauges, in combination with event-based metering of unregulated water users, to enable measurement of actual end of system flows & contributions to the Barwon-Darling River.	DPIE–Water & WaterNSW

5.2 Climate change

Climate change is a key long-term risk to river, wetland and floodplain health. Climate modelling indicates it is likely to exacerbate seasonal variability, making it more difficult to manage our landscapes and ecosystems and the human activities that depend on them.

The Murray–Darling Basin Sustainable Yields project investigated the potential impacts of climate change on water resources and flows to key environmental sites across the Basin, including the Paroo, Warrego and Condamine–Balonne regions, all of which contain the water sources of the Intersecting Streams (CSIRO 2008). The best estimates for 2030[13] predicts a reduction in surface water availability by:

- 3% in the Paroo River water source
- 6.5% in the Warrego River water source
- 8.5% in the Culgoa River water source
- 11% in the Moonie River water source.

Best available climate change predictions for the Intersecting Streams indicate a significant change to climatic patterns in the future. According to the NARCLiM model[14] (scenario 2), the changes in Table 13 are predicted by 2030 and 2070.

There are uncertainties with these climate change predictions, and the predicted changes will not occur in isolation. Rather, the predicted changes will occur alongside other changes owing to water resource development, land use, and environmental water management. Accordingly, it is currently unclear what impacts these changes will have on the environmental assets in the Intersecting Streams WRPA.

In addition, climate change may impact on the achievement of EWRs. The CSIRO Murray–Darling Basin Sustainable Yields Project assessment was undertaken for 18 regions including the Paroo, Warrego and Condamine–Balonne all of which contain the water sources of the Intersecting Streams (CSIRO 2008). CSIRO concluded that, by 2030, climate change is likely to result in a 3% reduction in surface water availability in the Paroo River water source, a 6.5% reduction in the Warrego River water source, an 8.5% reduction in the Culgoa River and Narran River water sources, and an 11% reduction in the Moonie River water source. However, CSIRO also reports that the hydrological impacts of climate change in the Murray–Darling Basin remain very uncertain.

---

[13] Assuming the current levels of development within the catchment.

[14] The NARCliM projections have been generated from four global climate models (GCMs) dynamically downscaled by three regional climate models (RCMs). http://climatechange.environment.nsw.gov.au/Climate-projections-for-NSW/About-NARCliM.

Table 13 Potential climate-related risks in the Intersecting Streams WRPA

Potential climate change risk	Description of risk	NARCliM projection (scenario 2)				
			2020–39		2060–79	
			East[15]	West[16]	East	West
Change in rainfall	Rainfall is projected to vary across the region, with the greatest increases predicted to occur during summer & autumn. Winter & spring rainfall is primarily decreasing across the region.	Summer	-3.3%	+3.1%	+9.8%	+12.6%
		Autumn	+14.9%	+14.1%	+16.8%	+13.7%
		Winter	-7.6%	-7.2%	-0.7%	+4.1%
		Spring	+2.6%	-10.3%	-0.7%	-5.4%
Change in average temperature	Mean temperatures are projected to rise by 0.7 ºC by 2030. The increases are occurring across the region, with the greatest increase during summer. All models show there are no declines in mean temperatures across the Intersecting Streams region.	Summer	+0.89°C	+0.90°C	+2.4°C	+2.49°C
		Autumn	+0.75°C	+0.59°C	+2.16°C	+2.05°C
		Winter	+0.48°C	+0.41°C	+1.92°C	+1.64°C
		Spring	+0.80°C	+0.80°C	+2.33°C	+2.31°C
Change in number of hot days (maximum temperature >35°C)	Hots days are projected to increase across the region by an average of 7–12 or more days per year by 2030. Parts of the regions are projected to experience an additional 10–20 days per year, particularly in the summer months.	Annual number of days	+7.1	+11.5	+23.4	+17.7
Change in number of cold nights (minimum temperature <2°C)	Cold nights are projected to decrease across the region by an average of 9 fewer nights below 2°C per year by 2030 in the eastern region. Changes in cold nights can have considerable impacts on native ecosystems.	Annual number of days	-8.8	-3.2	-26.1	-9.5
Bushfires Changes in number of days a year FFDI>50[17]	Severe fire weather is projected to increase across the region by 2030 during summer & spring. Declines are projected	Annual number of days	+0.2	+1.3	+0.9	+3.2

[15] East refers to the New England and North West region in the NARCLiM and includes (the Moonie River) planning unit

[16] West refers to the Far West region in the NARCLiM and includes the Narran, Narran Lakes, Culgoa, Warrego, Paroo and Yanda planning units

[17] Forest Fire Danger Index (FFDI) is used in NSW to quantify fire weather. The FFDI combines observations of temperature, humidity and wind speed. Fire weather is classified as severe when the FFDI is above 50.

Potential climate change risk	Description of risk	NARCliM projection (scenario 2)				
			2020–39		2060–79	
			East[15]	West[16]	East	West
	during autumn due to increases in rainfall. There is little change during winter. These increases are being seen during the peak prescribed burning season (spring) & peak fire risk season (summer). Overall severe fire weather is projected to have a small increase across the region by 2030. However increased severed fire weather is during spring (the prescribed burning season) & summer (peak fire risk season).					
Hill slope erosion	Changes in erosion can have significant implications for natural assets & water quality. Removal of groundcover will increase the risk of erosion significantly. Significant increases in hill slope erosion are predicted to occur in the western region (Yang 2015).	Mean percent change	4.3%	10.92%	17.4%	29.1%
Biodiversity	Rising temperature, increased fire frequency & changing fire regimes, storm damage & potentially drought will all affect species composition					

6. Going forward

6.1 Potential further actions for water management

Cooperative water management

All water, including natural events and consumptive water can contribute to the ecological condition of rivers, wetlands and floodplains (MDBA 2014). The combination of a highly variable climate, low rainfall and extensive water resource development across many systems in the Intersecting Streams WRPA places an increased emphasis on the need to collectively manage all water sources to achieve the objectives in the LTWP.

The risks and constraints to achieving EWRs (Table 11) described in this LTWP include some river management practices that are currently limiting or impacting on the capacity to meet ecological requirements of the Intersecting Streams. The LTWP identifies the following strategies to maximise the benefit of all water in the system:

- establish a multi-agency, interjurisdictional working group to collaboratively scope and to develop an ongoing program to implement the LTWP
- identify and, where possible, modify water resource infrastructure to ensure adequate flows are provided to ecological assets
- develop policy options to protect environmental flows (shepherding) to enable increased longitudinal connectivity in this WRPA and to increase flows to the Barwon– Darling River.

In the Intersecting Streams WRPA, the reliance on water management practice in Queensland increases the responsibility of NSW to implement an on environmentally effective WSP rules to maximise the achievement of EWRs. The ability of these rules to support ecological outcomes may be limited, and this should be reflected in ongoing reporting and assessment against objectives.

6.2 Complementary actions

Cooperative natural resources management for environmental outcomes

Complementary land management of flow-dependent environmental assets is vital to the success of this LTWP. Degradation of assets through unsympathetic land management practices and inadequate legislative protection or compliance may undermine efforts to meet the environment objectives of this plan.

Cooperative arrangements between government agencies, private industry groups, individual landholders and community groups that support the sympathetic stewardship of environmental assets are required to meet the objectives of this LTWP. A priority recommendation from this LTWP is to support efforts to strengthen partnerships and cooperation between water and broader NRM agencies.

Fish entrainment

Large numbers of fish can be lost from rivers due to water diversions and pumping (Baumgartner et al. 2009). Guidelines to minimise losses to native fish populations are outlined in Boys et al. (2012), and include the use of screens that limit approach velocities to less than 0.1 m/sec. Complementary programs that ensure all diversion infrastructure complies with these requirements is expected to improve outcomes for native fish.

Pest control

There are six alien fish species known to occur in the northern basin catchments, including common carp, goldfish, gambusia and redfin perch (NSW DPI 2015). Mozambique tilapia are an alien fish species known to occur in tropical and sub-tropical streams Australian streams that have not yet been recorded in waterways of the Murray-Darling Basin (MDBA 2011). By occupying critical habitat, competing with native species for food, predating on native flora and fauna and causing adverse water quality, these widespread invasive species can exacerbate the impacts of water abstraction and catchment disturbance on native fish populations. Complementary programs aimed at reducing populations of exotic species (e.g. the National Carp Control Plan) or limiting their dispersal are likely to enhance ecological outcomes associated with the EWRs stated in this LTWP.

Small breeding events may occur that sustain waterbird populations in periods of drought. Birds may abandon nests if water drops too quickly or if pig damage occurs (McCann & Brandis, pers. com.).

Identifying and addressing knowledge gaps

There is growing information on the characteristics of water-dependent ecosystems in the Intersecting Streams WRPA. Recent and ongoing research, monitoring and modelling projects have made an important contribution to the EWRs developed under the current LTWP.

This includes work recently or currently being undertaken through:

- the Northern Basin Review, which provided additional data and analysis of the social, economic and ecological requirements of the northern basin including detailed assessment of the environmental water requirements of the Narran Lakes and Lower Balonne River and floodplain (MDBA 2016)
- the determination of watering requirements of water-dependent ecosystems in the Toorale Western Floodplain and the Warrego River Channel between Boera Dam and the Barwon River under the Toorale Infrastructure Project
- ecological research and monitoring by university, government and private groups under the Australian Government’s Long Term Intervention Monitoring Program at Toorale
- the Fish and Flows monitoring project, which has made a significant contribution to informing the objectives and EWRs for the Condamine–Balonne in this plan.

Despite recent investment, there are considerable knowledge gaps in the Intersecting Streams that require further research and monitoring to fully understand the value, condition and watering requirements of key wetland and channel assets. Such understanding will broaden the number and effectiveness of EWRs identified by this LTWP. Key work areas include:

- extending remote-sensed inundation mapping
- identifying high quality habitat drought refugia
- expanding habitat mapping
- identifying the location and watering needs of cultural assets
- hydrological analysis and modelling to determine the underlying reasons for some EWRs that are unlikely to occur in the future
- Predicted impacts of climate change on current and future water availability in the WRPA
- Identifying water-dependent communities that are supported by groundwater

As regionally specific information grows, revision of the objectives, targets and/or EWRs will be required.

6.3 Measuring progress

Monitoring, evaluating and reporting (MER) are integral components of the adaptive management of environmental water. Monitoring how water moves through the landscape and how the environment responds informs ongoing improvements to planning and operational decisions. This information will also assist in determining whether the LTWP is meeting its objectives and targets, and will inform revisions of this LTWP.

The majority of NSW Government monitoring and evaluation activities in the Intersecting Streams catchment have traditionally been associated with river health-related responses to WSP implementation. Currently there is limited funding available for direct measurement of waterbird, vegetation, processes or native fish so it is likely that DPIE will be unable to track progress towards these objectives directly, relying instead on the status of EWRs.

The development and further testing of EWRs in terms of flow-response and relationship to LTWP objectives in this WRPA is identified as a major research need for the future. Some data suitable for tracking progress towards the Intersecting Streams LTWP objectives may be serviced by data collected and information products produced by NSW DPIE–Water as part of assessment of WSP objectives. Other sources of information which will inform management and future revisions include work undertaken by universities or other government organisations.

After the purchase of water access licences and Basin Plan implementation, monitoring and evaluation activities have expanded and now include contributions from a broader suite of NSW agencies as well as from the Australian Government. Vegetation, fish and waterbirds are monitored at Toorale under the Long-Term Intervention Monitoring Program.

6.4 Review and update

This LTWP brings together the best available information from a range of community, traditional and scientific sources. To keep information relevant and up-to-date, this LTWP will be reviewed and updated no later than five years after it is implemented. Additional reviews may also be triggered by:

- accreditation or amendment to the WSP or WRP
- revision of the BWS that materially affects this LTWP
- a sustainable diversion limit adjustment
- new information arising from evaluating responses to environmental watering
- new ecological knowledge that is relevant to environmental watering
- improved understanding of the effects of climate change and its impacts on the objectives and EWRs
- changes to the river operating environment or the removal of constraints that affect watering strategies
- material changes to river and wetland health, not considered within this LTWP.

7. References

Adams SB & Warren LM 2005, Recolonization by warmwater fishes and crayfishes after severe drought in upper Coastal Plain hill streams, *Transactions of the American Fisheries Society,* 134, pp. 1173–1192.

Amat J & Green A 2010, Waterbirds as bioindicators of environmental conditions, in C Hurford, M Schneider and I Cowx (eds), *Conservation Monitoring in Freshwater Habitats: A Practical Guide and Case Studies*, Springer, Netherlands, pp.45–52.

Amtstaetter F, O'Connor J and Pickworth A 2016, Environmental flow releases trigger spawning migrations by Australian grayling Prototroctes maraena, a threatened, diadromous fish, *Aquatic Conservation: Marine and Freshwater Ecosystems*, 26, pp.35–43.

Arthington A, Olden J, Balcombe S and Thoms M 2010, Multi-scale environmental factors explain fish losses and refuge quality in drying waterholes of Cooper Creek, an Australian arid-zone river, *Marine and Freshwater Research*, 61(8), pp.842–856.

ABS 2011, *Census Community Profile*. Australian Bureau of Statistics http://www.abs.gov.au/websitedbs/censushome.nsf/home/communityprofiles?opendocument&navpos=230 accessed 11 Oct 2016.

Balcombe S, Arthington A, Foster N, Thoms M, Wilson G & Bunn S 2006, Fish assemblages of an Australian dryland river: abundance, assemblage structure and recruitment patterns in the Warrego River, Murray–Darling Basin Marine and Freshwater Research 57(6) 619-633

Basin Plan 2012, Amendment to the *Water Act 2007*, Commonwealth.

Baumgartner L, Reynoldson NK, Cameron L, Stanger JG 2009, Effects of irrigation pumps on riverine fish, *FisheriesManagement and Ecology*, 16(6), pp429-437.

Baumgartner L 2011, *Establishment of a long term environmental watering and monitoring regime to improve ecological condition in the Wakool–Yallakool River system.* Special project proposal prepared by NSW Department of Primary Industries and Murray Catchment Management Authority. NSW Department of Primary Industries, Narrandera.

Baumgartner L, Conallin J, Campbell B, Gee R, Robinson W and Mallen-Cooper M 2013, Using flow guilds of freshwater fish in an adaptive management framework to simplify environmental flow delivery for semi-arid riverine systems, *Fish and Fisheries,* 15, pp.410-427.

BOM 2019, Beaureau of Meteorology climate data online. http://www.bom.gov.au/climate/data/, accessed: 20/6/2010

Boulton AJ, Sheldon F, Thoms MC, Stanley EH 2000, Problems and constraints in managing rivers with variable flow regimes, in PJ Boon, BR Davies and GE Petts (eds), *Global Perspectives on River Conservation: Science, Policy and Practice*, Wiley, Chichester, pp. 431– 444.

Boys C 2007, *Fish habitat association in a large dryland river of the Murray-Darling basin Australia*. Thesis submitted in fulfilment of the requirements of the Degree of Doctor of Philosophy. Canberra University Water Resource Centre, University of Canberra.

Boys C, Baumgartner L, Rampano B, Robinson W, Alexander T, Reilly G, Roswell M, Fowler T, Lowry M, 2012, Development of fish screening criteria for water diversions in the Murray-Darling Basin, NSW Department of Primary Industries.

Brandis KJ & Bino G 2016, *A review of relationships between flow and waterbird ecology in the Condamine-Balonne and Barwon-Darling River systems*. Murray-Darling Basin Authority, Canberra.

Brandis KJ, Bino G, Spencer JA, Ramp D, Kingsford RT 2018, Decline in colonial waterbird breeding highlights loss of Ramsar wetland function, *Biological Conservation*, 225, pp. 22-30.

Bunn SE & Arthington AH 2002, Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity*, Environmental Management*, 30(4), pp. 492–507.

Capon S 2009, *Flow-dependent Ecosystems of Toorale Station: Ecological character, condition and issues associated with decommissioning water resources infrastructure.* Australian Rivers Institute, Griffith University.

Casanova MT 2015, *Review of Water Requirements for Key Floodplain Vegetation for the Northern Basin: Literature review and expert knowledge assessment*. Report to the Murray–Darling Basin Authority, Charophyte Services, Lake Bolac.

CEWO 2014, *Commonwealth Environmental Water Office Long Term Intervention Monitoring Project Junction of the Warrego and Darling rivers Selected Area*, Commonwealth of Australia 2014.

Cox SJ, Thomas RF & Lu Y 2012*, Flooding patterns of Toorale: the confluence of the Warrego and Darling rivers,* Office of Environment and Heritage, Sydney, Unpublished report.

CSIRO 2008, *Water availability in the Murray-Darling Basin, A report from CSIRO to the Australian Government*, CSIRO Australia.

Davie AW & Mitrovic SM 2014, Benthic algal biomass and assemblage changes following environmental flow releases and unregulated tributary flows downstream of a major storage, *Marine and Freshwater Research,* 65, pp.1059-1097.

De Groot R, Wilson, MA & Boumans RMJ 2001, A typology for the classification, description and valuation of ecosystem functions, goods and services, *Ecological Economics*, 41(3), pp393-408.

DEWHA 2001, *A directory of important wetlands in Australia*, Australian wetlands database — spatial data, viewed November 2008, <asdd.ga.gov.au/asdd>.

Environment Australia 2001, *A Directory of Important Wetlands in Australia*, 3rd edition, Environment Australia, Canberra. http://www.environment.gov.au/resource/directory-important-wetlands-australia-third-edition

Growns I 2004, A numerical classification of reproductive guilds of the freshwater fishes of southeastern Australia and their application to river management, *Fisheries Management and Ecology*, 11, pp.369-377.

Humphries P, King A & Koehn J 1999, Fish, flows and flood plains: links between freshwater fishes and their environment in the Murray-Darling River system, Australia. *Environmental Biology of Fishes*, 56, pp.129–151.

Humphries P & King AJ 2004, Drifting fish larvae in Murray – Darling Basin rivers: composition, spatial and temporal patterns and distance drifted*,* in M Lintermans & B Phillips (eds), *Downstream Movement of Fish in the Murray – Darling Basin. Statement, Recommendations and Supporting Papers from a Workshop held in Canberra 3–4 June 2003,* Murray – Darling Basin Commission, Canberra, Australia, pp.51–58.

Keenan, C, Watts, R & Serafini, L 1998, *Population genetics of golden perch (Macquaria ambigua), silver perch (Bidyanus bidyanus) and eel-tailed catfish (*Tandanus *tandanus) within the Murray–Darling Basin*. Final report on NRMS Project M262 to the Murray-Darling Basin Commission, Southern Fisheries Centre, Department of Primary Industries, Brisbane.

Keith D A, Orscheg C, Simpson CC, Clarke P J, Hughes L, Kennelly SJ, Major R E, Soderquist T R, Wilson A L & Bedward M 2009. A new approach and case study for estimating extent and rates of habitat loss for ecological communities. *Biological Conservation* 142, 1469-1479.

Kingsford RT 1999, Aerial survey of waterbirds on wetlands as a measure of river and floodplain health, *Freshwater Biology*, 41, pp.425–438.

Kingsford RT & Auld KM 2005, Waterbird breeding and environmental flow management in the Macquarie Marshes, arid Australia, *River Research and Applications*, 21, pp.187–200.

Kingsford RT & Norman FI 2002, Australian waterbirds – products of the continent's ecology, *Emu*, 102, pp.47–69.

Kingsford RT & Porter J 1999. Wetlands and waterbirds of the Paroo and Warrego Rivers, in *A free flowing river: The ecology of the Paroo River*, R.T. Kingsford (ed.), pp. 23–50, NSW National Parks and Wildlife Service, Sydney

Kingsford RT, Lee E, 2010, Ecological character description of the Paroo River Wetlands Ramsar site, Department of Environment, Climate Change and Water, NSW, Sydney.

Lloyd L, Walker K & Hillman T 1991, *Environmental significance of snags in the River Murray.* Department of Primary Industries and Energy, Land and Water Resources Research and Development Corporation, Canberra.

McNeil D, Gehrig S and Cheshire K 2013, *The protection of drought refuges for native fish in the Murray-Darling Basin*. South Australian Research and Development Institute, South Australia.

Mallen-Cooper M & Zampatti B 2015, Background paper: use of life history conceptual models of fish in flow management in the Murray-Darling Basin. Murray-Darling Basin Authority, Canberra.

MDBA 2010, *Guide to the proposed Basin Plan: Technical background*, Murray–Darling Basin Authority, Canberra.

MDBA 2011, The potential for Mozambique tilapia to invade the Murray-Darling Basin and the likely impacts: a review of existing information, Murray-Darling Basin Authority (MDBA), Canberra.

MDBA 2012, *Assessment of environmental water requirements for the proposed Basin Plan: Narran Lakes*. Murray Darling Basin Authority (MDBA), Canberra.

MDBA 2003, Intergovernment agreement for the Paroo River between New South Wales and Queensland, https://www.mdba.gov.au/sites/default/files/pubs/26-Intergovernmental-Agreement-Paroo-River-NSW-QLD-D16-40857.pdf

MDBA 2014, *Basin-wide environmental watering strategy*. MDBA Publication No 20/14. Murray-Darling Basin Authority for and on behalf of the Commonwealth of Australia, 2014.

MDBA 2016, The Northern Basin Review, Understanding the economic, social and environmental outcomes from water recovery in the northern BasinLicensed from the Murray–Darling Basin Authority under a Creative Commons Attribution 4.0 Licence

MDBA 2018, Observed flows in the Barwon-Darlin 1990-2017: A hydrologica investigation, Murray-Darling Basin Authority (MDBA), Canberra.

MDBC 2007, State of the Darling Hydrology Report. Prepared by Webb, McKeown & Associates Pty Ltd for the Murray–Darling Basin Commission. MDBC Publication No. 07/07

Mitrovic SM, Oliver RL, Rees C, Bowling LC & Buckney RT 2003, Critical flow velocities for the growth and dominance of *Anabaena circinalis* in some turbid freshwater rivers, *Freshwater Biology*, vol 48 p 164–174

NOW 2011, *Water Sharing Plan for the Intersecting Streams, Unregulated and Alluvial Water Sources – background documen*t, NSW Office of Water, Sydney.

NPWS 2000, Narran Lake Plan of Management, NSW National Parks and Wildlife Service.

NSW DPIE–Water in prep., Risk assessment for the Intersecting Streams Water Resource Plan Area (SW13), NSW DPIE - Water

NSW DPI 2015, *Fish and Flows in the Northern Basin: responses of fish to changes in flow in the Northern Murray-Darling Basin – Valley Scale Report*, Final report prepared for the Murray–Darling Basin Authority, NSW Department of Primary Industries, Tamworth.

NSW National Parks and Wildlife Service (NSW NPWS) 2000, Narran Lake Nature Reserve Plan of Management, NSW National Parks and Wildlife Service.

Poff N, Allan J, Bain M, Karr J, Prestegaard K, Richter B, Sparks R & Stromberg J 1997, The natural flow regime: a paradigm for river conservation and restoration, *Bioscience* 47, pp.769-784.

Poff NL & Zimmerman JKH 2010, Ecological responses to altered flow regimes: a literature review to inform the science and management of environmental flows, *Freshwater Biology*, 55(1), pp.194-205.

Queensland Government 2016, Warrego-Paroo-Nebine water resource plan.

Roberts J & Marston F 2011, *Water regime for wetland & floodplain plants: a source book for the Murray–Darling Basin: A source book of ecological knowledge,* Canberra: CSIRO Land and Water.

Sims N 2004, The landscape-scale structure and functioning of floodplains, Honours Thesis, University of Canberra, ACT.

SMEC 2006, *Lower Balonne Scoping Study – Hydrology Review*. Final report to the Western Catchment Management Authority, North Sydney.

Southwell M 2008, *Floodplains as dynamic mosaics: sediment and nutrient patches in a large lowland riverine landscape*, PhD Thesis, University of Canberra.

Stewardson MJ & Gippel CJ 2003, Incorporating flow variability into environmental flow regimes using the flow events method, *River Research and Applications*, 19, pp.459-472.

Taft OW, Colwell MA, Isola CR & Safran RJ 2002, Waterbird responses to experimental drawdown: implications for the multispecies management of wetland mosaics, *Journal of Applied Ecology,* 39, pp.987–1001.

Thomas RF, Karunaratne S, Heath J & Kuo W 2016, Assessment of Site-specific Flow Indicator inundation in the vegetation of Narran Lakes. Summary report to the MDBA. NSW Office of Environment and Heritage.

Thoms MC & Sheldon F 2002, An ecosystem approach for determining environmental water allocations in Australian dryland river systems: the role of geomorphology, *Geomorphology*, 47, pp.153-168.

Thoms M, Maher S, Terrill P, Crabb P, Harris J & Sheldon F 2004, Environmental flows in the Darling River, in R Breckwoldt, R Boden, and J Andrew (eds), *The Darling*, Murray-Darling Basin Commission, Canberra, pp.350 – 373.

Thoms MC, Southwell M and McGinness, HM 2005, Floodplain-river ecosystems: Fragmentation and water resources development, *Geomorphology*, 71, pp.126–138.

Thoms M, Capon S, James C, Padgham M and Rayburg S 2007, *The Narran Ecosystem Project: the response of a terminal wetland system to variable wetting and drying*. Final report to the Murray-Darling Basin Commission. Murray-Darling Basin Commission, Canberra.

Appendix A Ecological objectives relevant to each planning unit

Table 12 Ecological objectives for each planning unit in the Intersecting Streams

Code	Ecological objective	Paroo River	Yanda Creek	Warrego River	Toorale	Culgoa River	Narran River	Narran Lakes	Moonie River
Native fish									
NF1	No loss of native fish species	X	X	X	X	X	X	X	X
NF2	Increase the distribution & abundance of short to moderate-lived generalist native fish species	X		X	X	X	X	X	X
NF3	Increase the distribution & abundance of short to moderate-lived floodplain specialist native fish species	X			X	X	X		
NF4	Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species	X	X	X	X	X	X	X	X
NF5	Improve native fish population structure for moderate to long-lived riverine specialist native fish species	X			X	X	X		X
NF6	A 25% increase in abundance of mature (harvestable sized) golden perch & Murray cod	X		X		X	X	X	X
Native vegetation									
NV1	Maintain the extent & viability of non-woody vegetation communities occurring within channels	X	X	X	X	X	X	X	X
NV2	Maintain or increase the extent & maintain the viability of non-woody vegetation communities occurring in wetlands & on floodplains	X	X	X	X	X	X	X	X
NV3	Maintain the extent & improve the condition of river red gum communities closely fringing river channels	X	X	X	X	X	X	X	X
NV4b	Maintain or increase the extent & maintain or improve the condition of native woodland & shrubland communities on floodplains – River red gum woodland	X	X	X	X	X	X	X	X
NV4c	Maintain or increase the extent & maintain or improve the condition of native woodland & shrubland communities on floodplains – Black box woodland	X	X	X	X	X	X	X	
NV4e	Maintain or increase the extent & maintain or improve the condition of native woodland & shrubland communities on floodplains – Lignum shrublands	X	X	X	X	X	X	X	X
NV4d	Maintain or increase the extent & maintain or improve the condition of native woodland & shrubland communities on floodplains – Coolibah woodland	X	X	X	X	X	X	X	X
Waterbirds									
WB1	Maintain the number & type of waterbird species	X	X	X	X	X	X	X	X

Code	Ecological objective	Paroo River	Yanda Creek	Warrego River	Toorale	Culgoa River	Narran River	Narran Lakes	Moonie River
WB2	Increase total waterbird abundance across all functional groups	X	X	X	X	X	X	X	X
WB3	Increase opportunities for non-colonial waterbird breeding	X	X	X	X	X	X	X	X
WB5	Maintain the extent & improve condition of waterbird habitats	X	X	X	X	X	X	X	X
Ecological functions									
EF1	Provide & protect a diversity of refugia across the landscape	X	X	X	X	X	X	X	X
EF2	Create quality instream, floodplain & wetland habitat	X	X	X	X	X	X	X	X
EF3a	Provide movement & dispersal opportunities for water-dependent biota to complete lifecycles & disperse into new habitats – within catchments	X	X	X	X	X	X	X	X
EF3b	Provide movement & dispersal opportunities catchments for water-dependent biota to complete lifecycles & disperse into new habitats – between catchments	X	X	X	X	X	X	X	X
EF4	Support instream & floodplain productivity	X	X	X	X	X	X	X	X
EF5	Support nutrient, carbon & sediment transport along channels, & exchange between channels & floodplains/wetlands	X	X	X	X	X	X	X	X
EF6	Support groundwater conditions to sustain groundwater-dependent biota	X	X	X	X	X	X	X	X
EF7	Increase the contribution of flows into the Murray & Barwon–Darling from tributaries	X	X	X	X	X			X

Intersecting Streams Long Term Water Plan Part B

Figure 10 Yantabulla Swamp
Photo: Justin McCann.

8. Planning units

This section of the LTWP provides further detail of the environmental assets and values at a planning unit scale. It also specifies any planning unit-scale tailoring of the catchment scale EWRs. Objectives for native fish and other biota are outlined in Part A of the LTWP (Appendix A). However, native fish objectives have been reiterated in Part B as these objectives are highly species-specific.

All of the planning units in the Intersecting Streams WRPA are unregulated. Information is presented on the hydrology and degree of hydrological alteration, as determined by DPIE–Water in the *Intersecting Streams 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. The risk assessment references key gauges located in some, but not all, planning units used in the Intersecting Streams LTWP.

Table 14 describes how the hydrology changes are presented for each planning unit.

Table 14 Key to hydrological alteration used in this document

Key from NSW DPIE–Water, in prep.		
L = Low: less than 20% departure (+/-) from the base case for each hydrological metric		
M = Medium: 20–50% departure (+/-); from the base case for each hydrologic metric		
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

8.1 Definitions and explanatory text for EWRs

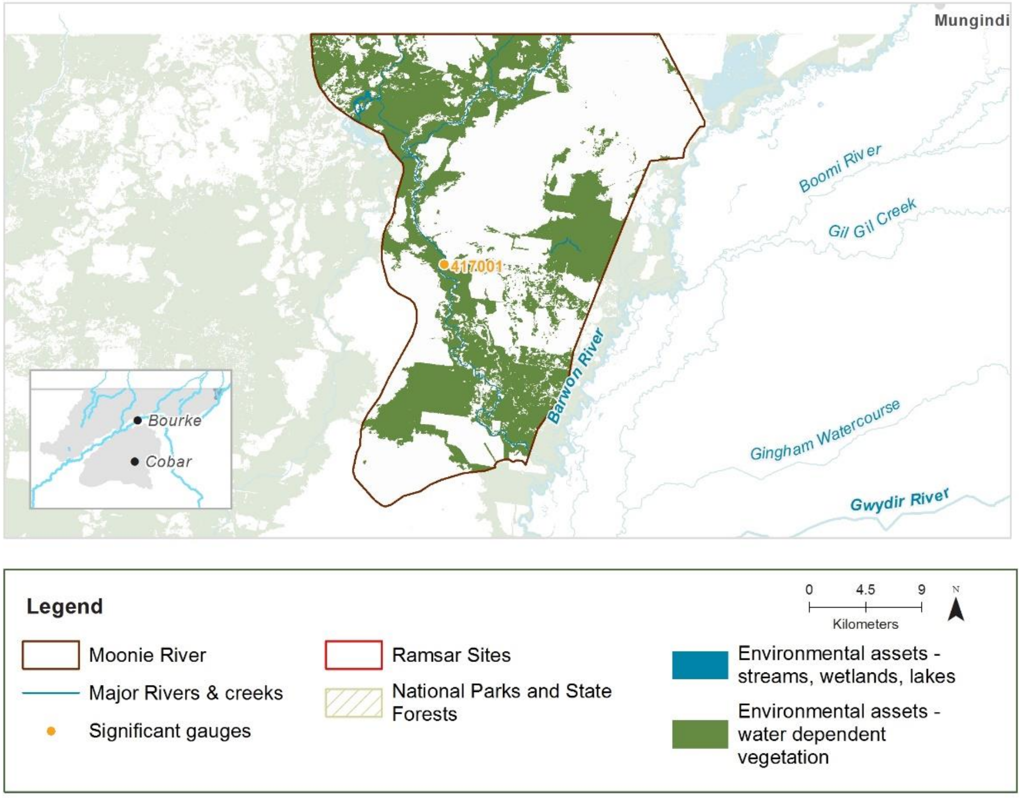
Term	Definition
Flow category	Flows in rivers vary over time in response to rainfall, river regulation, extractions & other factors. The sequence of flows over time can be considered as a series of discrete events. These events can be placed into different flow categories (e.g. baseflows, freshes, bankfull, overbank & wetland flows) according to the magnitude of flow discharge or height within a watercourse, & 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 & defined 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, & 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 & in-channel vegetation). There may be multiple EWRs defined within a flow category, & 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.

Term	Definition
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 & EWRs.
Gauge	The flow gauging station that best represents the flow within the planning unit, for the purpose of the respective EWR & 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 & delivering environmental water, the preferred timing should be used to give greater confidence in achieving ecological objectives. Natural events may occur at other times & 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 & deliver better ecological outcomes. Some species may suffer from extended durations of inundation, & where relevant a maximum duration may also be specified. Flows may persist on floodplains & 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 & 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, & variability in response during different climate sequences (e.g. maintenance of populations during dry climate sequences at the lower end of the range,

Term	Definition
	& population improvement & 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 & 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, DPIE recommend that the average of the frequency range is used as the minimum long term target frequency.
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 & comments	Other conditions that should occur to assist ecological objectives to be met – for example rates of rise & fall in flows. Also comments regarding limitations on delivering environmental flows & achieving the EWR.

8.2 Moonie River

The Moonie River flows south from Queensland, crossing the state border into NSW approximately 25km west of Mungindi. Only 2% of the total Moonie River catchment occurs within NSW. The river is unregulated, with no large impoundments, although in some areas overbank flows are harvested and stored in floodplain storages for later use by irrigated agriculture. The NSW-section of the Moonie River flows mostly through coolibah open woodlands, with open river red gum woodlands growing adjacent to the stream. The Mungaroo Warrambool is an overflow channel that splits from the Moonie River within the NSW-section of the intersecting streams, flowing south-west across the Narran Planning unit with flows that occasionally connect with the Barwon River.



Named priority environmental assets	
Moonie River channel, riparian zone and floodplain	
Key ecological values (CE = Critically Endangered, E = Endangered, V= vulnerable, C = CAMBA, J = JAMBA, R = RoKAMBA)	
Native fish	Bony herring, golden perch, spangled perch, Murray cod (V)
Waterbirds	38 species including: Black-necked stork (E), Brolga (V), Eastern Great Egret (J), Latham's Snipe (J, R), Sharp-tailed sandpiper (C, J, R)
Native vegetation	27,184 ha of water-dependent vegetation communities including: coolabah (23,138), river red gum (1,083 ha) and non-woody wetland vegetation (500 ha)
Registered water-dependent cultural assets	Burials, Ceremonial Rings, modified trees

Native fish objectives
NF1 No loss of native species: bony herring, golden perch, spangled perch, Murray cod
NF2 Increase the distribution and abundance of short to moderate-lived generalist native fish species: bony herring
NF4 Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species: golden perch, spangled perch
NF5 Improve native fish population structure for moderate to long-lived riverine specialist native fish species: Murray cod (V)
NF6 A 25%^ increase in abundance of mature (harvestable sized) golden perch and Murray cod (V)
EF3 Provide movement and dispersal opportunities within and between catchments for water-dependent biota to complete lifecycles: golden perch, spangled perch, Murray cod (V)

Hydrology (DPIE-Water in prep.)

The NSW Moonie River Water Source Area

Hydrological alteration	CTF	Low flow & baseflow	Freshes	High & infrequent flows		
				1.5ARI	2.5 ARI	5ARI
Moonie River	L^{+}	H^{-}	M^{-}	M^{-}	M^{-}	L^{-}
Relevant rules from WSP	**Trading rules:** **Trade INTO water source**: not permitted **Trade WITHIN water source**: permitted (subject to assessment) **INTERSTATE trades:** The plan may be amended to allow interstate trading in line with an Inter Governmental Agreement should such an agreement be negotiated during the life of the plan. **Cease to pump**: pumping only permitted when flow is visible (at water supply work)					

Table 15: LTWP EWRs for the NSW section of the Moonie River at Gundablouie (417001)

Flow Component		Flow volume	Timing	Minimum duration	Frequency (LTA)[18]	Maximum interflow period	Additional requirements & comments
Cease-to-flow	CF	0 ML/d	In line with natural (any time)	Maximum duration: Typically persist for 32 days & should not persist for longer than 278 days[18]			
Very low flow	VF	Any flow at the end of the system (30 ML/day[20])	In line with natural (any time)	Minimum duration: typically 60 days/yr exceed VF threshold but not less than 9 days/yr[18]	At least 96% of years	70 days (but not more than 283 days)	Very low flows are minimum flows that reach the end of the system
Small fresh	SF1	>314 ML/d	Any time (ideally Oct-Apr)	10 days	3-8 years in 10 (*55%*)[19]	4.5 years	
	SF2	>314 ML/d	Sep-Apr	14 days	2-6 years in 10 (*40%*)[19]	6.5 years	
Large fresh	LF1	>3909 ML/d	Any time	5 days	2-6 years in 10 (*45%*)[19]	6.5 years	
	LF2	>3909 ML/d	Oct-Apr	5 days	2-5 years in 10 (*35%*)[19]	6.5 years	

[18] Based on 1945–1990 observations. Where calculated, maximum durations (for CTF), maximum interflow periods and minimum durations (for other flows) are based on 95th percentiles.

[19] The frequency and maximum interflow period of some flow components may differ from the frequencies identified by NSW DPI (2017). For highly ephemeral systems, the pre-1990 historical frequency and maximum interflow period for that flow component has been adopted to describe the EWR.

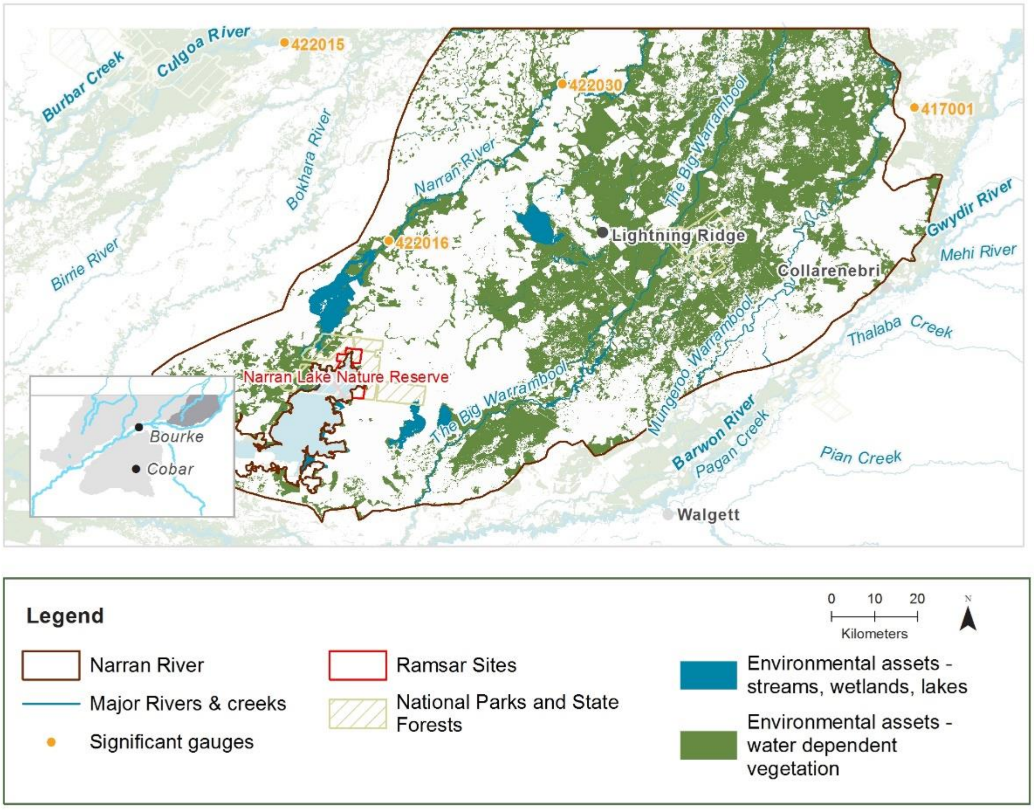
Flow Component		Flow volume	Timing	Minimum duration	Frequency (LTA)[18]	Maximum interflow period	Additional requirements & comments
	LF3	>5100-18,787 ML/d[20]	Any time	7 days[21]	2-5 years in 10 (*40%*)	6.5 years	For riparian river red gum.
Overbank	OB3	>18,787 ML/d	Any time	1 day	0-3 years in 10 (*15%*)	20 years	

[20] Provisional estimate based on available data. Further analysis required.

[21] Based on median flow duration of pre-1990 observed data.

8.3 Narran River

The Narran River flows south from Queensland, crossing the state border into NSW approximately 17km north of the NSW town of Angledool. The Narran River splits from the Culgoa River downstream of the Balonne River Floodplain in Queensland, carrying 28% of the long-term mean annual flow of the Condamine-Balonne River (at St George, QLD). Flows down the NSW-section of the Narran River terminate at Narran Lake (described in this LTWP as a separate planning unit). The NSW-section of the Narran River flows mostly through coolabah/lignum open woodlands and lignum shrublands. Overbank flow events in Narran River inundate large areas of floodplain east of Angledool, moving south to inundate Angledool and Coocoran Lakes and the Grawin Creek floodplain. These lake and floodplain areas are thought to be important supporting habitat waterbirds breeding at Narran Lakes (Brandis and Bino 2015). Large areas of the Narran River planning unit are drained by two large, ephemeral distributary systems – The Big Warrambool and the Mungaroo Warrambool. These systems are not gauged and typically fed by local rainfall rather than surface water flows.



Named priority environmental assets
Narran River channel, riparian zone and floodplain
Coocoran Lake
Angledool Lake
Grawin Creek floodplain

Key ecological values (CE = Critically Endangered, E = Endangered, V= vulnerable, C = CAMBA, J = JAMBA, R = RoKAMBA)	
Native fish	Carp gudgeon, Murray-Darling rainbowfish, bony herring, Australian smelt, golden perch, spangled perch, silver perch (V), olive perchlet
Waterbirds	66 species including: Australasian bittern (E), Black-necked stork (E), black-tailed gotwit (V,C,J,R), blue-billed duck (V), Brolga (V), common greenshank (C,J,K),

	common sandpiper (C,J), Eastern Great Egret (J), freckled duck (V), Latham's Snipe (J, R), marsh sandpiper (C,J,R), red-necked stint (C,J,R), Sharp-tailed sandpiper (C, J, R), white-winged black tern (C,J)
Native vegetation	663,841 ha of water-dependent vegetation communities including: coolabah (386,243 ha), black box (69,336 ha), non-woody wetland vegetation (8,380 ha), river red gum (2,460 ha)
Registered water-dependent cultural assets	Sites, burials, artefacts, modified trees and waterholes of Aboriginal ceremony and dreaming, Artefacts, hearth and modified trees associated with Aboriginal resource and gathering Earth-mound and shell artefacts Grinding grooves, modified trees, hearths, stone quarry, waterholes, fish trap

Native fish objectives
NF1 No loss of native species: Carp gudgeon, Murray-Darling rainbowfish, bony herring, Australian smelt, golden perch, spangled perch, silver perch, olive perchlet
NF2 Increase the distribution and abundance of short to moderate-lived generalist native fish species: carp gudgeon, Murray-Darling rainbowfish, bony herring, Australian smelt
NF3 Increase the distribution and abundance of short to moderate-lived generalist native fish species: olive perchlet
NF4 Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species: golden perch, spangled perch, silver perch
NF5 Improve native fish population structure for moderate to long-lived riverine specialist native fish species: olive perchlet
NF6 A 25%^ increase in abundance of mature (harvestable sized) golden perch
EF3 Provide movement and dispersal opportunities within and between catchments for water-dependent biota to complete lifecycles: golden perch, spangled perch, silver perch

Hydrology (DPIE-Water in prep.)						
The NSW Narran River Water Source Area						
Hydrological alteration	CTF	Low flow & baseflow	Freshes	High & infrequent flows		
				1.5 ARI	2.5ARI	5ARI
Narran River @ Wilby	M^{+}	H^{-}	M^{-}	L^{-}	L^{-}	L^{-}
Relevant rules from WSP	**Trading rules:** **INTO water source**: not permitted **WITHIN water source**: permitted (subject to assessment) **INTERSTATE trades:** The plan may be amended to allow interstate trading in line with an Inter Governmental Agreement should such an agreement be negotiated during the life of the plan. **Cease to pump**: QLD border – New Angledool: pumping permitted at or above 0.45m / 170 ML/day at New Angledool New Angledool – Wilby Wilby: pumping permitted at or above 1.18m / 80 ML/day at Wilby Wilby Wilby Wilby – Narran Park: pumping only permitted when flow is visible					

Table 16 LTWP EWRs for the NSW section of the Narran River @ Wilby Wilby (422016)

Flow Component		Flow volume	Timing	Minimum duration	Frequency (LTA)[22]	Maximum interflow period	Additional requirements & comments
Cease-to-flow	CF	0 ML/d	In line with natural (any time)	Maximum duration: Typically persist for 55 days & should not persist for longer than 276 days[22]			
Very low flow	VF	Any flow at the end of the system (126 ML/day @ Wilby Wilby)	In line with natural (any time)	Minimum duration: typically 85 days/yr. In very dry years at least 6 days/yr[22]	Occur in 100% of years	85 days (but not more than 278 days)	VF are minimum flows that reach the end of the system
Small fresh	SF1	>233 ML/d	Any time (ideally Oct-Apr)	10 days	4-9 years in 10 (*65%*)[19]	3.5 years	
	SF2	>233 ML/d	Sep-Apr	14 days	2-6 years in 10 (*45%*)[19]	6 years	
Large fresh	LF1	>1629 ML/d	Any time	5 days	2-8 years in 10 (*55%*)[19]	6.5 years	
	LF2	>1629 ML/d	Oct-Apr	5 days	2-6 years in 10 (*45%*)[19]	6.5 years	
Overbank	OB2	>6300 ML/day	Any time	1 day	2-6 years in 10 (*43%*)	6.5 years	
	OB3	>9000 ML/day	Any time	1 day	1-5 years in 10 (*35%*)	7.5 years	
Wetland inundation	WL3	Any flow with a cumulative volume of 500GL within 80 days[23]	Any time		0.5 years in 10 (*5%*)	18 years	Inundates Angledool/ Coocoran lakes & the Grawin floodplain

[22] Based on 1964–1990 observations. Maximum durations (for CTF), maximum interflow periods and minimum durations (for other flows) are based on 95th percentiles.

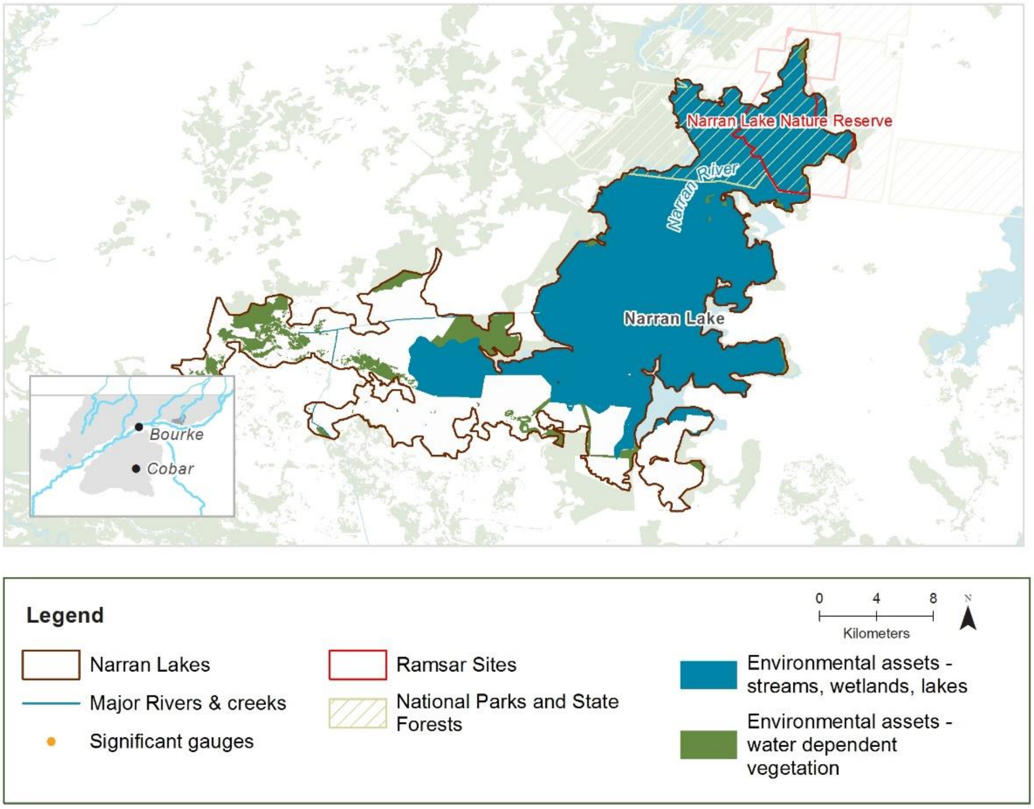
[23] Provisional estimate, requires further analysis (Brandis and Bino 2015). Measured at the New Angledool gauge (422030).

8.4 Narran Lakes

Narran Lakes are a complex of terminal wetlands located at the end of the Narran River. The lakes receive inflows from the Condamine-Balonne Catchment via the Narran River. A portion of the Narran Lakes is listed as a RAMSAR site due to the unique and diverse habitat it provides to threatened species and breeding migratory bird species. Narran Lakes also provide an important refuge site for many species during drought and harbours some of the largest expanses of lignum in NSW.

The lower Balonne floodplain has been used for cattle and sheep grazing since the 1840s, Since the 1990s, there has been a shift towards irrigated agriculture, mainly cotton.

The Lakes’ vegetation includes river red gum, lignum, coolibah, black box and river cooba, which are all water-dependent species with varying inundation requirements (Thomas et al. 2016).



Named priority environmental assets	
Narran Lakes	
Narran Lakes nature reserve	
Narran Lakes RAMSAR site, which includes Clear Lake, Back Lake and Long Arm Lake	
Narran floodplains	
Key ecological values (CE = Critically Endangered, E = Endangered, V= vulnerable, C = CAMBA, J = JAMBA, R = RoKAMBA)	
Native fish	Bony herring, golden perch
Waterbirds	63 species including: Australasian bittern (E), bar-tailed gotwit (V,C,J,K), Black-necked stork (E), black-tailed gotwit (V,C,J,R), blue-billed duck (V), Brolga (V), Caspian tern (J), cattle egret (J), common greenshank (C,J,K), curlew sandpiper

	(CE,C,J,K), Eastern Great Egret (J), freckled duck (V), Latham's Snipe (J, R), magpie goose (V), marsh sandpiper (C,J,R), sharp-tailed sandpiper (C,J,R), white-winged black tern (C,J), wood sandpiper (C,J,K)
Native vegetation	24,866 ha of water-dependent vegetation communities including: coolabah (2,754 ha), black box (894 ha), non-woody wetland vegetation (9,221 ha), river red gum (235 ha)
Registered water-dependent cultural assets	Shell artefacts, modified trees
Native fish objectives	
NF1 No loss of native species: bony herring, golden perch	
NF2 Increase the distribution and abundance of short to moderate-lived generalist native fish species: bony herring	
NF4 Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species: golden perch	
NF6 A 25%^ increase in abundance of mature (harvestable sized) golden perch	
EF3 Provide movement and dispersal opportunities within and between catchments for water-dependent biota to complete lifecycles: golden perch	

Table 17 LTWP EWRs for Narran Lakes[24] measured at Wilby Wilby (422016)

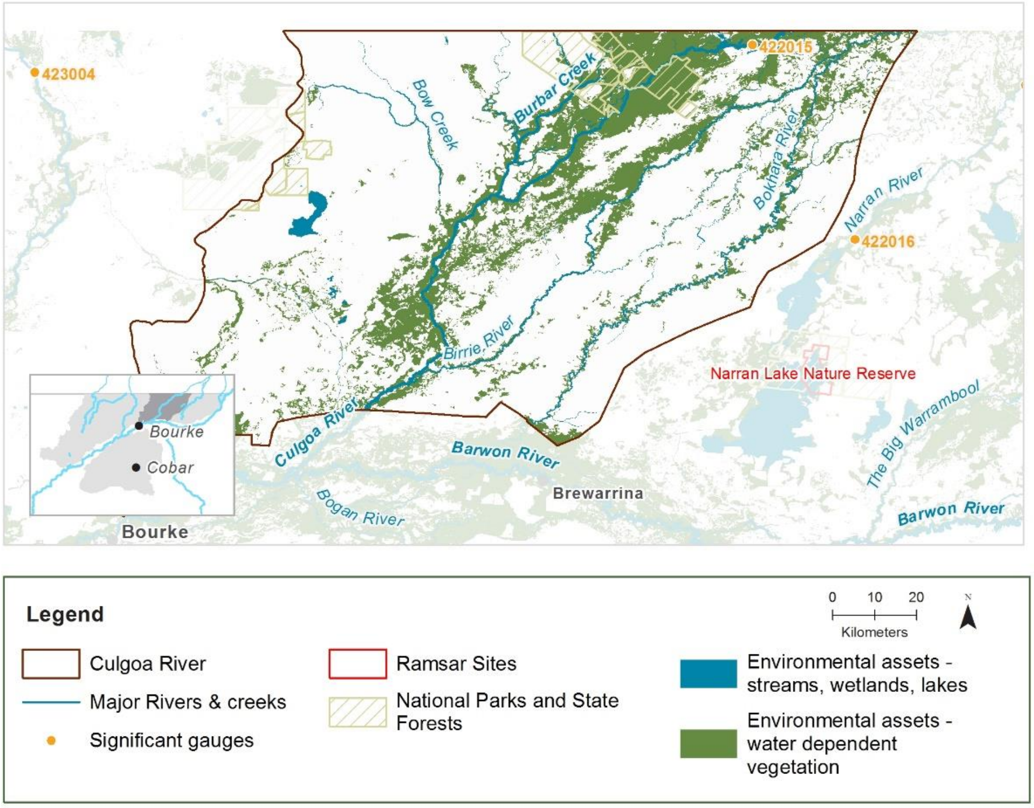
Flow Component		Flow volume	Timing	Minimum duration	Frequency (LTA)	Maximum interflow period[25]	Additional requirements & comments
Wetland inundation	WL1	Cumulative volume of 25GL within 60 days	In line with natural (any time)	Inundation durations vary among target wetlands	7-10 years in 10 (*85%*)	2 years	Flows at Wilby Wilby should exceed 126 ML/day
	WL2	Cumulative volume of 50GL within 60 days	In line with natural (any time)		5-8 years in 10 (*65%*)	2 years	
	WL3	Cumulative volume of 154GL within 60 days	In line with natural (any time)		2-3 years in 10 (*25%*)	6 years	
	WL4	Cumulative volume of 250GL within 180 days	In line with natural (any time)		1 year in 10 (*10%*)	6 years	

[24] The Narran Lakes EWRs described here have been adopted from the *Environmental outcomes of the Northern Basin Review (MDBA 2016)*.

[25] Maximum interflow periods determined as the 95th percentile of interflow periods observed at the Wilby Wilby gauge for 1964-1990.

8.5 Culgoa River

The Culgoa River flows south from Queensland, crossing into NSW approximately 15km north-west of Goodooga (NSW). The NSW-section of the Culgoa River receives inflows from the Condamine-Balonne catchment, with additional surface inflows from the Birrie River (a distributary of the Narran River) near Collerina, NSW and from several ephemeral tributaries including Bow Creek and Burbar Creek. The Culgoa River floodplain supports vast areas of coolabah woodlands.



Named priority environmental assets	
Culgoa River channel, riparian zone and floodplain	
Key ecological values (CE = Critically Endangered, E = Endangered, V= vulnerable, C = CAMBA, J = JAMBA, R = RoKAMBA)	
Native fish	Murray-Darling rainbowfish, bony herring, golden perch, Hyrtl’s tandan, spangled perch, silver perch, Murray cod, olive perchlet (predicted)
Waterbirds	46 species including: Australasian Bittern (E), Black-necked stork (E), Brolga (V), Cattle Egret (J), Common Greenshank (C,J,K), Eastern Great Egret (J)
Native vegetation	289,627 ha of water-dependent vegetation communities including: coolibah (182,979 ha), black box (68,856 ha), lignum (24,772 ha), non-woody wetland vegetation (10,952 ha), river red gum (2,068 ha)
Registered water-dependent cultural assets	Aboriginal ceremony and dreaming places, artefacts of Aboriginal ceremony, Aboriginal resources and gathering, artefacts, burials, ceremonial ring, modified trees, waterholes, grinding grooves, hearth, health - shell, health – stone arrangement.

Native fish objectives
NF1 No loss of native species: Murray-Darling rainbowfish, bony herring, golden perch, Hyrtl's tandan, spangled perch, silver perch, Murray cod, olive perchlet (predicted)
NF2 Increase the distribution and abundance of short to moderate-lived generalist native fish species: Murray-Darling rainbowfish, bony herring
NF3 Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species: olive perchlet (predicted)
NF4 Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species: golden perch, spangled perch, Hyrtl's tandan, silver perch
NF5 Improve native fish population structure for moderate to long-lived riverine specialist native fish species: Murray cod (V) and oliver perchlet (predicted)
NF6 A 25%^ increase in abundance of mature (harvestable sized) golden perch and Murray cod (V)
EF3 Provide movement and dispersal opportunities within and between catchments for water-dependent biota to complete lifecycles: golden perch, spangled perch, Murray cod (V), Hyrtl's tandan, silver perch

Hydrology (DPIE-Water in prep.)

The NSW Culgoa River Water Source Area

Hydrological alteration	CTF	Low flow & baseflow	Freshes	High & infrequent flows		
				1.5ARI	2.5ARI	5ARI
Culgoa River	H^+	H^-	M^-	M^-	M^-	M^-
Birrie River	L^+	H^+	M^-	H^-	M^-	M^-
Bokhara River	L^+	H^+	M^-	H^-	M^-	M^-
Relevant rules from WSP	**Trading rules:** **INTO water source**: Not permitted **WITHIN water source**: Permitted, subject to assessment **Cease to pump:** Pumping is only permitted when a flow is visible.					

Table 18 LTWP EWRs for the NSW section of the Culgoa River at Brenda (422015)

Flow Component		Flow volume	Timing	Minimum duration	Frequency (LTA)	Maximum interflow period	Additional requirements & comments
Cease-to-flow	CF	0 ML/d	In line with natural (any time)	Maximum duration: Typically persist for 31 days and do not persist for longer than 210[26]			
Very low flow	VF	Any flow at the end of the system (50 ML/day[20])	In line with natural (any time)	Minimum duration: typically 223 days/yr. In very dry years at least 93 days/yr[26]	Occur in 100% of years	58 days (but not more than 193 days)	Very low flows are minimum flows that reach the end of the system
Small fresh	SF1	>183 ML/d	Any time (ideally Oct-Apr)	10 days	8-10 years in 10 (*95%*)[19]	2 years	
	SF2	>183 ML/d	Sep-Apr	14 days	5-10 years in 10 (*75%*)	2 years	
	SF3[28]	>1000 ML/day	Any time	7 days	8-9 years in 10 (*85%*)	3 years[27]	Connects fish habitat.
Large fresh	LF1	>3552 ML/d	Any time	5 days	5-10 years in 10 (*75%*)	2 years	
	LF2	>3552 ML/d	Oct-Apr	5 days	3-5 years in 10 (*40%*)	4 years)	
Overbank[28]	OB1	>9200 ML/d	Any time	12 days	3-5 years in 10 (*40%*)	9 years[27]	Inundates fringing vegetation and wetlands

[26] Based on 1960–1990 observations. Maximum durations (for CTF), maximum interflow periods and minimum durations (for other flows) are based on 95th percentiles.

[27] Maximum interflow periods determined as the 95th percentile of interflow periods observed at the Brenda gauge for 1960-1990.

[28] The Culgoa EWRs described here have been adopted from the *Environmental outcomes of the Northern Basin Review (MDBA 2016)*.

Flow Component		Flow volume	Timing	Minimum duration	Frequency (LTA)	Maximum interflow period	Additional requirements & comments
	OB2	>15,000 ML/day	Any time	10 days	2-4 years in 10 (*30%*)	11 years[27]	Inundates low-lying floodplain and wetlands
	OB3	>24,500 ML/day	Any time	7 days	1-2 years in 10 (*15%*)	11 years[27]	Increased area of inundated floodplain and wetlands
	OB4	>38,000 ML/day	Any time	6 days	0.5-1 years in 10 (*7.5%*)	23 years[27]	Large-scale inundation of floodplain and wetlands

Table 19 LTWP EWRs for the Birrie River at Googooga (422013)

Flow Component		Flow volume	Timing	Minimum duration	Frequency (LTA)	Maximum interflow period	Additional requirements & comments
Cease-to-flow	CF	0 ML/d	In line with natural (any time)	Maximum duration: Typically persist for 30 days and do not persist for longer than 276[29]			
Very low flow	VF	Any flow at the end of the system (estimated as 50 ML/day[20])	In line with natural (any time)	Minimum duration: typically 111 days/yr. In very dry years at least 6 days/yr[29]	Occur in 96% of years	83 days (but not more than 291 days)	Very low flows are minimum flows that reach the end of the system
Small fresh	SF1	>84 ML/d	Any time (ideally Oct-Apr)	10 days	6-10 years in 10 (*85%*)[19]	2 years	
	SF2	>84 ML/d	Sep-Apr	14 days	5-9 years in 10 (*60%*)[19]	4 years	
Large fresh	LF1	>1160 ML/d	Any time	5 days	4-8 years in 10 (*60%*)[19]	5 years	
	LF2	>1160 ML/d	Oct-Apr	5 days	3-6 years in 10 (*45%*)[19]	5 years	

[29] Based on 1968–1990 observations. Maximum durations (for CTF), maximum interflow periods and minimum durations (for other flows) are based on 95th percentiles.

Table 20 LTWP EWRs for the Bokhara River at Bokhara (Goodwins) (422005)

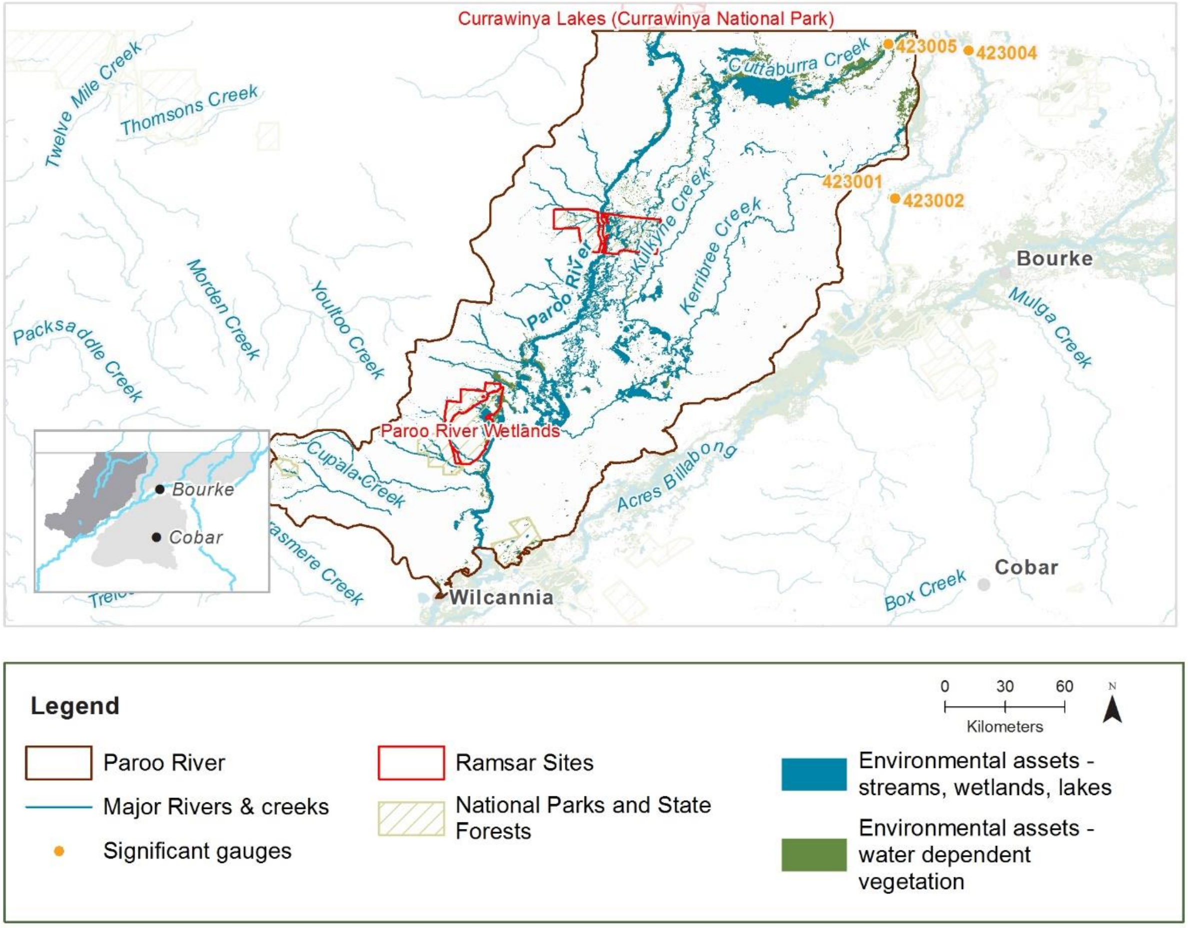
Flow Component		Flow volume	Timing	Minimum duration	Frequency (LTA)	Maximum interflow period	Additional requirements & comments
Cease-to-flow	CF	0 ML/d	In line with natural (any time)	Maximum duration: Typically persist for 70 days and do not persist for longer than 409[30]			
Very low flow	VF	Any flow at the end of the system (estimated as 30 ML/day[20])	In line with natural (any time)	Minimum duration: typically 101 days/yr. May not occur at all in very dry years[30]	Occur in 94% of years	113 days (but not more than 413 days)	Very low flows are minimum flows that reach the end of the system
Small fresh	SF1	>89 ML/d	Any time (ideally Oct-Apr)	10 days	7-10 years in 10 (*85%*)[19]	2 years	
	SF2	>89 ML/d	Sep-Apr	14 days	5-9 years in 10 (*70%*)[19]	3 years	
Large fresh	LF1	>913ML/d	Any time	5 days	3-8 years in 10 (*50%*)[19]	7 years	
	LF2	>913 ML/d	Oct-Apr	5 days	1-7 years in 10 (*40%*)[19]	5 years	

[30] Based on 1944–1990 observations. Maximum durations (for CTF), maximum interflow periods and minimum durations (for other flows) are based on 95th percentiles.

8.6 Paroo River

The Paroo River catchment begins in the Warrego range in Queensland and flows south into NSW. The Paroo River is part of the Mulga Lands biogeographic region and is comprised of many floodplains, lakes, wetlands and overflow channels which are significant both ecologically and culturally to Aboriginal people (MDBA 2003). The rivers in this catchment are mostly ephemeral, however some of the waterholes, wetlands and lakes remain permanently wet (for example King Charlie Waterhole in Nocoleche Nature Reserve) (MDBA 2019). Flora studies at Peery Lake have found that the only known population of *Schoenoplectus pungens* in far western NSW occurs at Peery Lakes Springs (Bowen and Pressey 1993). The endangered species of perennial forb, *Eriocaulon carsonii* (Salt Pipewort) has been recorded at several springs at Peery Lake. The Paroo River joins the Darling River at Wilcannia.

Although the Cuttaburra Channel and Yantabulla Swamp are listed as assets within the Paroo planning unit, these systems are mostly supported by surface flows from the Warrego River. Flows to Cuttaburra Creek and Yantabulla swamp are impacted by water extraction in the Warrego Catchment and are not protected under the Paroo River Agreement (2003).



Named priority environmental assets
Paroo River Wetlands Ramsar site – consists of the floodplains and channels of the Paroo River and Cuttaburra and Kulkyne creeks in Nocoleche Nature Reserve, and Peery and Poloko lakes in Paroo–Darling National Park
Yantabulla Swamp, on the Cuttaburra Creek, which is recognised as a highly important breeding area for waterbirds in the Paroo and Warrego catchments
Paroo River wetlands

Paroo River instream and fringing vegetation, and the important floodplain wetland adjacent to the river	
Peery Lake and Poloko Lake, which are also part of the Ramsar site; the artesian mound springs at Peery Lake are listed as an Artesian Springs Ecological Community (EPBC, 1999)	
Mullawoolka Basin and Blue, Gilpoko, Poloko, Peery, Tongo and Yantabangee lakes (are known as Paroo Overflow Lakes)	
Key ecological values (CE = Critically Endangered, E = Endangered, V= vulnerable, C = CAMBA, J = JAMBA, R = RoKAMBA)	
Native fish	Carp gudgeon, Murray-Darling rainbowfish, bony herring, Australian smelt, golden perch, Hyrtl's tandan, spangled perch, silver perch, olive perchlet (predicted)*
Waterbirds	84 species including: Australian painted snipe (CE), curlew sandpiper (CE, C, J, K), brolga (V), cattle egret (J), common greenshank (C,J,K), eastern great egret (J)
Native vegetation	687,806 ha of water-dependent vegetation communities including: coolibah (178,728 ha), black box (74,677 ha), lignum (78,967 ha), non-woody wetland vegetation (158,561 ha), river red gum (14,604 ha)
Registered water-dependent cultural assets	Modified trees, waterholes, hearths, habitation structures, earth mound hearths, artefacts, art, grinding grooves, Aboriginal resource and gathering areas, ceremonial rings, Aboriginal ceremony and dreaming artefacts

Native fish objectives
NF1 No loss of native species: bony herring, golden perch, spangled perch, Murray cod
NF2 Increase the distribution and abundance of short to moderate-lived generalist native fish species: bony herring
NF3 Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species
NF4 Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species: golden perch, spangled perch
NF5 Improve native fish population structure for moderate to long-lived riverine specialist native fish species: Murray cod (V)
NF6 A 25%^ increase in abundance of mature (harvestable sized) golden perch and Murray cod (V)
EF3 Provide movement and dispersal opportunities within and between catchments for water-dependent biota to complete lifecycles: golden perch, spangled perch, Murray cod (V)

Hydrology (DPIE-Water in prep.)

Hydrological alteration	CTF	Low flow & baseflow	Freshes	High & infrequent flows		
				1.5ARI	2.5ARI	5ARI
424002 - Paroo River @ Willara Crossing	L^+	M^-	L^0	L^0	L^0	L^0
424001 - Paroo River @ Wanaaring	L^+	L^0	L^0	L^0	L^0	L^0

Cuttaburra Creek[31]	N/A	N/A	N/A	L^-	L^-	L^-
Relevant rules from WSP	**Trading rules:** **INTO water source**: Not permitted **WITHIN water source**: Not permitted **INTERSTATE trades:** The plan may be amended to allow interstate trading in line with an Inter Governmental Agreement should such an agreement be negotiated during the life of the plan. **Cease to pump:** Pumping is only permitted when a flow is visible.					

[31] Flows in Cuttaburra Creek are typically provided by the Warrego River.

Table 21 LTWP EWRs for the Yantabulla Swamp/Wetland on the Cuttaburra Creek at Turra (423005)

Flow Component		Flow volume/day	Timing	Minimum duration	Frequency (LTA)	Maximum interflow period	Additional requirements & comments
Cease-to-flow	CF	0 ML/d	In line with natural (any time)	Maximum duration: Typically persist for 34 days and do not persist for longer than 291[32]		TBD	
Small fresh	SF1	<1000 ML	Any time	23 days	4 years in 10	TBD	Greater than 6m at the Cunnamulla gauge (leading to any flow at Turra), or local rainfall filling of waterholes. Generally under 1000ML/day at peak (McCann & Brandis, pers com.). Provides some connectivity of waterholes and can lead to fish breeding activity of some species.
Large fresh	LF1	1000-3000 ML	Any time	45 days	2.5 years in 10	TBD	Replenishes waterholes and will provide some feeding and foraging opportunities for waterbirds.
Wetland inundating flow - Minor inundation	WL1	Cumulative volume 82,548 ML[33]; Mean 2117 ML/day; Max 21,935 ML/day	Any time	2 weeks to 2 months	1.6 years in 10 (ARI 1 in 6 years)	3 years[34]	<20% wetland inundation Potential for small waterbird breeding events of non-colonial species - Important in drought (McCann & Brandis, in prep 2019).

[32] There is no pre-1990 gauge data or adequate modelled data for the Cuttaburra at Turra. CF durations and frequencies are based on observed 1993-2018 flow data and are indicative only.

[33] Occurred over 39 Days (McCann & Brandis, pers. com.)

[34] Lignum, which is important for waterbird breeding is unlikely to regenerate after a period of dormancy/no wetting of four years.

Flow Component		Flow volume/day	Timing	Minimum duration	Frequency (LTA)	Maximum interflow period	Additional requirements & comments
Wetland inundating flow - Half inundation	WL2	Cumulative volume 166,108 ML[35]; Mean 2158 ML/d; Max 21,880 ML/d	Any time	3-6 months (of drying back)	1.4 years in 10	TBD	50% wetland inundation (ARI 1 event every 7 years) Small breeding events may occur, but less than 1% of maximum observed waterbird abundance recorded at half inundation (McCann & Brandis, in prep 2019).
Wetland inundating flow - Full inundation	WL3	Cumulative volume 724,375 ML[36]; Mean 5030 ML/d; Max 46,230 ML/d	Any time	1 week (at full extent) to 6 months (of drying back)	1.4 years in 10	TBD	100% wetland inundation (ARI 1 in 7-8 years) Waterbird breeding events occur – waterbird abundance increases as wetland dries back (McCann & Brandis, in prep 2019). EWR will promote regeneration of overstorey species (inc black box, coolibah and poplar box)
Wetland inundating flow - Boom	WL4	Cumulative volume 1,785,870ML[37]; Mean 3069 ML/d; Max 50,830 ML/d	Any time	6 months of inundation, or more, with consecutive flood events	1 in 10 or more	TBD	100% wetland inundation early in flood period. ARI 10-12 years. EWR will promote regeneration of overstorey species (inc black box, coolibah and poplar box)

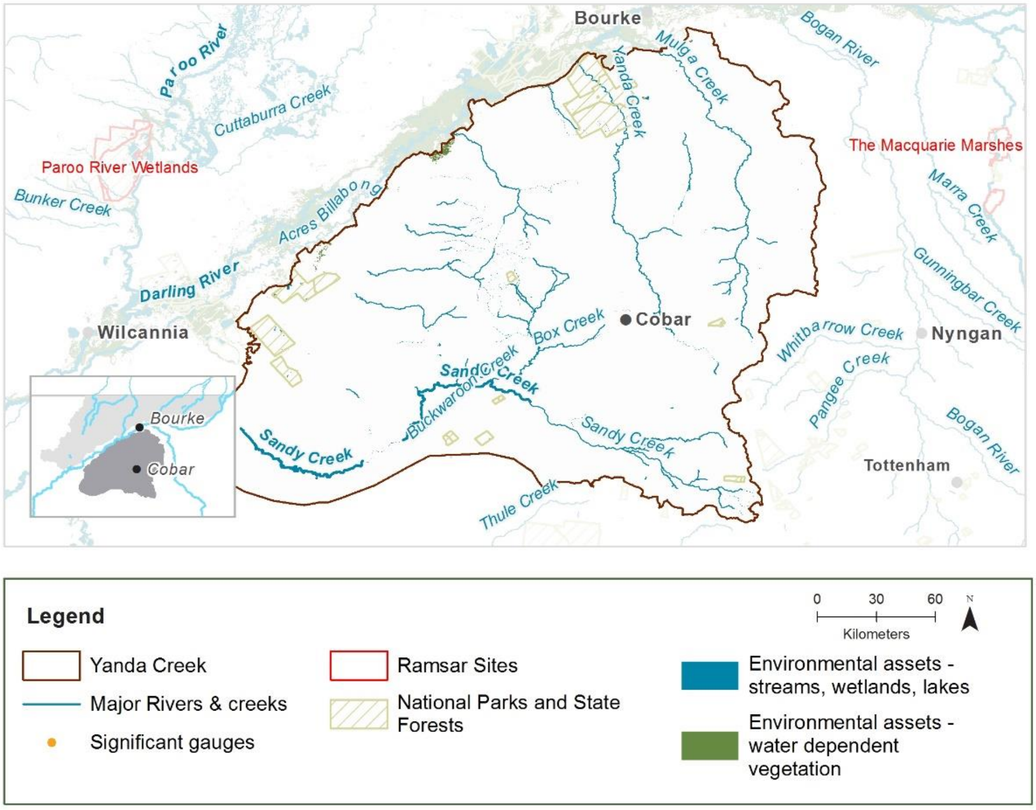
[35] Occurred over 77 Days (McCann & Brandis, pers. com.)

[36] Occurred over 144 Days (McCann & Brandis, pers. com.)

[37] Occurred over 582 Days (McCann & Brandis, pers. com.)

8.7 Yanda Creek

Yanda Creek planning unit is a sub-catchment on the Cobar Plain, which is southeast of the Darling River. It is entirely within NSW, unlike the other sub-catchments of Intersecting Streams. It provides inflows into the Darling River but is unregulated and does not currently have any gauges to measure streamflow.



Named priority environmental assets
Instream aquatic habitat in Yanda, Mulga, Sandy and Box Creeks
Yanda Creek in Gundabooka National Park is known as a bird hotspot
Tilpilly Lake
Unnamed ephemeral lakes between Louth and Tilpa

Key ecological values (CE = Critically Endangered, E = Endangered, V= vulnerable, C = CAMBA, J = JAMBA, R = RoKAMBA)	
Native fish	Silver perch
Waterbirds	63 species including: Australian painted snipe (CE), curlew sandpiper (CE, C, J, K), brolga (V), sharp-tailed sandpiper (C, J, K), common greenshank (C,J,K), red-necked stint (C, J, K)
Native vegetation	76,957 ha of water-dependent vegetation communities including: coolibah (3110 ha), black box (7375 ha), lignum (477 ha), non-woody wetland vegetation (4144 ha), river red gum (6494 ha)
Registered water-dependent cultural assets	Sites of Aboriginal Ceremony and Dreaming with art, artefacts, hearths, waterholes, Ceremonial Rings, Ochre quarry, grinding grooves. Aboriginal resource and gathering sites with art, hearths, and a potential archaeological deposit. Art and habitat structures, burials, earth mound Artefacts including hearths, modified trees, waterholes

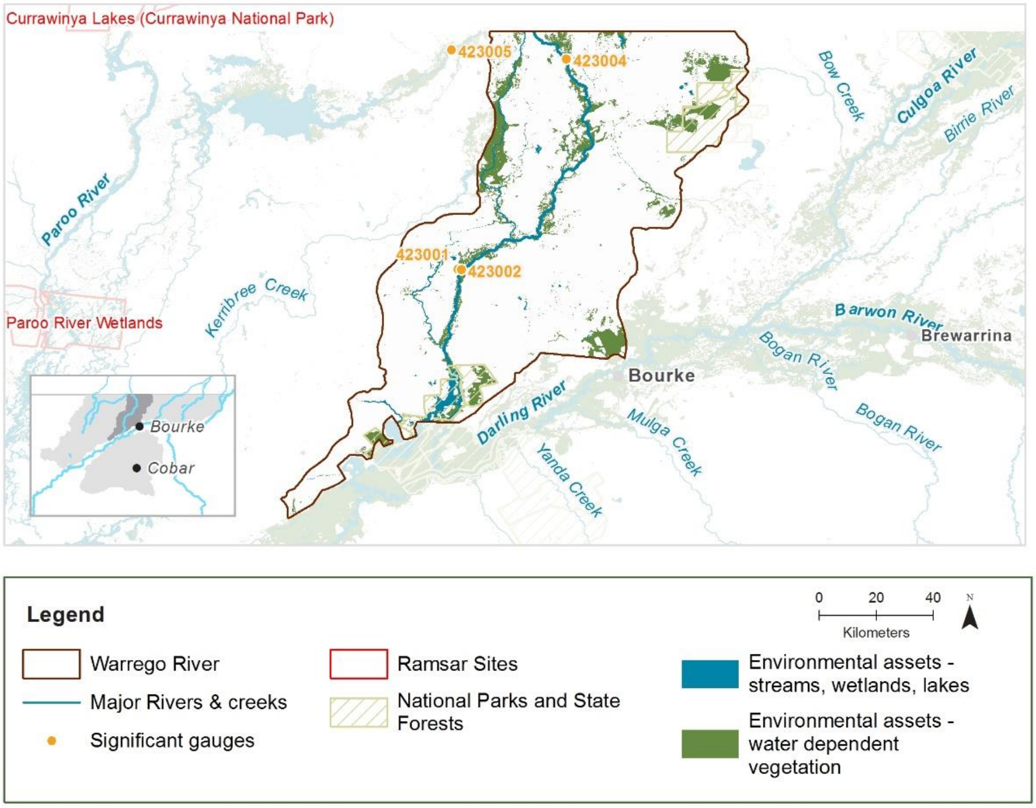
Native fish objectives
NF1 No loss of native species: bony herring, golden perch, spangled perch, Murray cod
NF4 Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species: golden perch, spangled perch
EF3 Provide movement and dispersal opportunities within and between catchments for water-dependent biota to complete lifecycles: silver perch

<table>
<tr><th colspan="7">Hydrology (DPIE-Water in prep.)</th></tr>
<tr><td rowspan="2">Hydrological alteration</td><td rowspan="2">CTF</td><td rowspan="2">Low flow & baseflow</td><td rowspan="2">Freshes</td><td colspan="3">High & infrequent flows</td></tr>
<tr><td>1.5ARI</td><td>2.5ARI</td><td>5ARI</td></tr>
<tr><td>Yanda Creek water source ephemeral streams</td><td>L^0</td><td>L^0</td><td>L^0</td><td>L^0</td><td>L^0</td><td>L^0</td></tr>
<tr><td>Relevant rules from WSP</td><td colspan="6">Trading rules:
INTO water source: Not permitted
WITHIN water source: Permitted, subject to assessment
INTERSTATE trades: The plan may be amended to allow interstate trading in line with an Inter Governmental Agreement should such an agreement be negotiated during the life of the plan.
Cease to pump:
Pumping is only permitted when a flow is visible.</td></tr>
</table>

8.8 Warrego River

The two major rivers in this catchment are the Warrego River and Irrara Creek, which start in Queensland and flow south, to where they join the Darling River south of Bourke, in NSW. The river splits at Cunamulla in Queensland with flows conveyed south down the Warrego River channel and west down Cuttaburra Creek towards Yantabulla Swamp. Much of the surface flow supporting water dependent assets at Yantabulla Swamp are provided via the Warrego River, however, in this LTWP Yantabulla Swamp EWRs are described under the Paroo River planning unit. Toorale National Park in the lower reaches of the Warrego River, is described under a separate planning unit.

South of Cunamulla, the Warrego River splits again, with flows leaving the mainstem and flowing down Irrara Creek before re-joining the Warrego River north of Fords Bridge. The Warrego River, and its effluent streams, flow through lignum and coolibah woodlands and canegrass swamps with sections of fringing river red gum forest.



Named priority environmental assets
Warrego River - aquatic habitat instream and important fringing vegetation
Irrara Creek and its large floodplain of vegetation
Green Creek and Green Creek Swamp
(Cuttaburra Creek and Yantabulla Swamp)
Racecourse Swamp
Tom's Lake

Key ecological values (CE = Critically Endangered, E = Endangered, V= vulnerable, C = CAMBA, J = JAMBA, R = RoKAMBA)	
Native fish	Carp gudgeon, Murray-Darling rainbowfish, bony herring, Australian smelt, golden perch, Hyrtl's Tandan, spangled perch, silver perch, freshwater catfish

Waterbirds	67 species including: Bar-tailed godwit (V, C, J, K), curlew sandpiper (CE, C, J, K), brolga (V), sharp-tailed sandpiper (C, J, K), common greenshank (C,J,K), red-necked stint (C, J, K)
Native vegetation	249,906 ha of water-dependent vegetation communities including: coolibah (56,166 ha), black box (32,713 ha), lignum (7346 ha), non-woody wetland vegetation (80,527 ha), river red gum (4434 ha)
Registered water-dependent cultural assets	Sites of Aboriginal Ceremony and Dreaming and resource gathering, modified trees and artefacts including Ceremonial Ring and hearth

Native fish objectives
NF1 No loss of native species: Carp gudgeon, Murray-Darling rainbowfish, bony herring, Australian smelt, golden perch, Hyrtl's Tandan, spangled perch, silver perch, freshwater catfish
NF2 Increase the distribution and abundance of short to moderate-lived generalist native fish species: carp gudgeon, Murray-Darling rainbowfish, bony herring, Australian smelt
NF4 Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species: golden perch, spangled perch, Hyrtl's tandan, silver perch
NF6 A 25%^ increase in abundance of mature (harvestable sized) golden perch
EF3 Provide movement and dispersal opportunities within and between catchments for water-dependent biota to complete lifecycles: golden perch, spangled perch, Hyrtl's tandan, silver perch, freshwater catfish

<table>
<tr><th colspan="7">Hydrology (DPIE-Water in prep.)</th></tr>
<tr><td rowspan="2">Hydrological alteration</td><td rowspan="2">CTF</td><td rowspan="2">Low flow & baseflow</td><td rowspan="2">Freshes</td><td colspan="3">High & infrequent flows</td></tr>
<tr><td>1.5ARI</td><td>2.5ARI</td><td>5ARI</td></tr>
<tr><td>423003 - Warrego River at Barringun No. 1</td><td>L^{+}</td><td>H^{-}</td><td>L^{-}</td><td>L^{-}</td><td>L^{-}</td><td>L^{-}</td></tr>
<tr><td>Relevant rules from WSP</td><td colspan="6">Trading rules:
INTO water source: Not permitted
WITHIN water source: Permitted, subject to assessment
INTERSTATE trades: The plan may be amended to allow interstate trading in line with an Inter Governmental Agreement should such an agreement be negotiated during the life of the plan.
Cease to pump:
Pumping is only permitted when a flow is visible.</td></tr>
</table>

Table 22 LTWP EWRs for the Warrego River planning unit at Barringun[38] (423004)

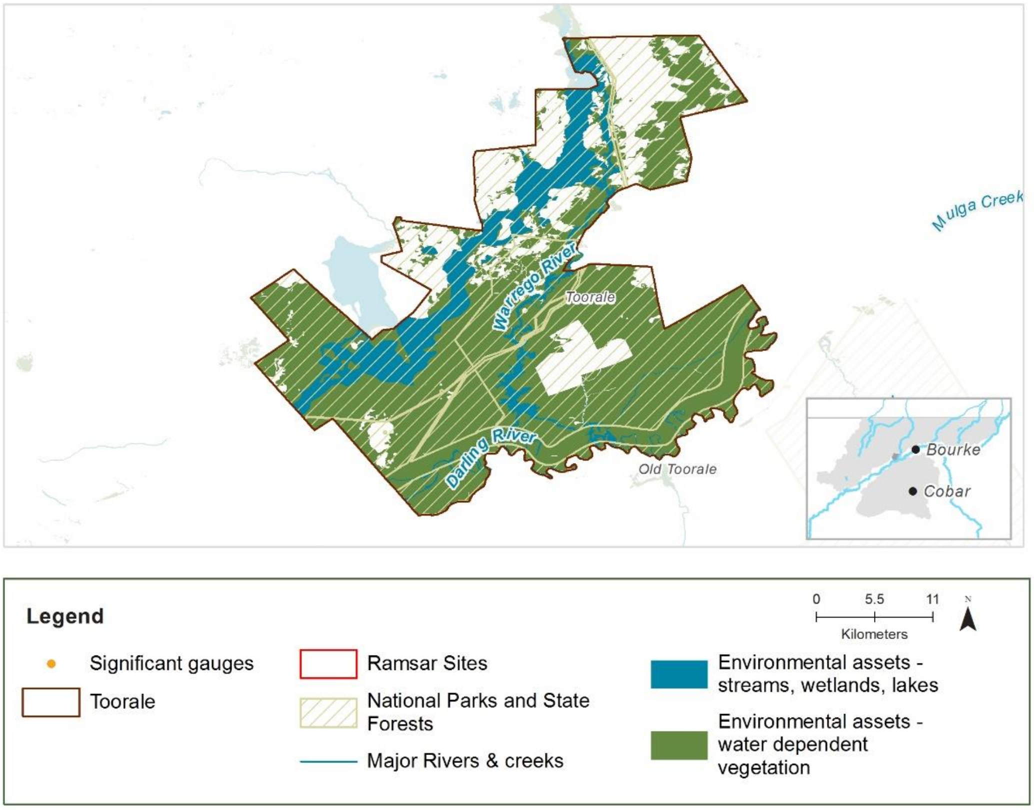
Flow Component		Flow volume	Timing	Minimum duration	Frequency (LTA)	Maximum interflow period	Additional requirements & comments
Cease-to-flow	CF	There is insufficient data to determine CF EWRs at Barringun.					
Very low flow	VF	End of system connecting flows are subject to changes under the Toorale Infrastructure Project and have not been determined for this LTWP					
Small fresh	SF1	>217 ML/d	Any time (ideally Oct-Apr)	10 days	10 years in 10 (100%)	1 year	
	SF2	>217 ML/d	Sep-Apr	14 days	5-10 years in 10 (*75%*)	2 years	
Large fresh	LF1	>2242 ML/d	Any time	5 days	5-10 years in 10 (*75%*)	2 years	
	LF2	>2242 ML/d	Oct-Apr	5 days	3-5 years in 10 (*40%*)	4 years	

[38] There is insufficient historic or modelled data for the Warrego River at Barringun to determine EWRs. Frequency and maximum interflow periods require further analysis.

8.9 Toorale

Located at the junction of the Warrego and Darling Rivers, Toorale National Park and State Conservation Area is a significant wetland site. This area is of very high cultural significance to the Kurnu-Baakandji People and the site is jointly managed by National Parks and Kurnu-Baakandji People. The site, which has an important historical heritage, was previously a significant pastoral station established in 1857 by Sir Samuel McCaughey. As a component of the property’s water management, a number of dams and associated floodplain works were constructed in 1892 on the Warrego river (which are culturally / socially significant) now hold and enable the management of water licences, including a number of environmental water licences held by the Commonwealth. and. The NSW and Commonwealth Governments jointly purchased the site in 2008.

At Toorale, the pattern of floodplain inundation has been altered by the development of infrastructure for more than 100 years. This has resulted in the establishment of water-dependent native communities on the western floodplain (NPWS 2018). Tiny teeth (*Dentella minutissima*), is listed as endangered under the Biodiversity Conservation Act. It is a small-leaved, inconspicuous, mat-forming plant that was found in Toorale in 2013. Tiny teeth is ephemeral and germinates on mud flats and grey cracking clays following receding floodwaters. Populations in Toorale occur on the bed and banks of the Warrego River, in particular on the drying beds of the artificial water storages Boera Dam, Homestead Dam, Dicks Dam and Ross Billabong (NPWS 2018).



Named priority environmental assets
Toorale Western Floodplain
Warrego River between Boera Dam and the Darling River
Toorale water storages

Key ecological values (CE = Critically Endangered, E = Endangered, V= vulnerable, C = CAMBA, J = JAMBA, R = RoKAMBA)	
Native fish	Bony herring, silver perch, olive perchlet (predicted)*
Waterbirds	50 species including: oriental pratincole (C, J, K), brolga (V), common greenshank (C,J,K)
Native vegetation	71,092 ha of water-dependent vegetation communities including: coolibah (18,677 ha), black box (5.2 ha), lignum (5831 ha), non-woody wetland vegetation (14 ha), river red gum (332 ha)
Registered water-dependent cultural assets	Sites of Aboriginal Ceremony and Dreaming with artefacts, stone quarry, hearths, and modified trees Aboriginal resource and gathering sites artefacts and a potential archaeological deposit. Artefacts including habitation structures, hearths, burials, shells, stone arrangements, modified trees, burials, waterholes

Native fish objectives
NF1 No loss of native species: bony herring, silver perch, olive perchlet (predicted)*
NF2 Increase the distribution and abundance of short to moderate-lived generalist native fish species: bony herring
NF3: Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species: olive perchlet (predicted)*
NF4 Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species: silver perch
NF5: Improve native fish population structure for moderate to long-lived riverine specialist native fish species: olive perchlet (predicted)*
EF3 Provide movement and dispersal opportunities within and between catchments for water-dependent biota to complete lifecycles: silver perch

Hydrology (DPIE-Water in prep.)						
Hydrological alteration	CTF	Low flow & baseflow	Freshes	High & infrequent flows		
				1.5ARI	2.5ARI	5ARI
423001 - Warrego River at Fords Bridge	H^+	H^-	L^-	L^-	L^-	L^-
Relevant rules from WSP	**Trading rules:** **INTO water source**: Not permitted **WITHIN water source**: Permitted, subject to assessment **Cease to pump:** Pumping is only permitted when a flow is visible.					

Table 23 LTWP EWRs for the Western Floodplain at Toorale at the combined Fords Bridge (423001) and Fords Bridge Bywash (423002) gauges

Flow Component		Flow volume/day[39]	Timing	Minimum duration	Frequency (LTA)[40]	Maximum interflow period[40]	Additional requirements & comments
Wetland inundating flow - Minor inundation	WL1	Cumulative volume 7000 ML within 30 days	Any time		5-10 years in 10 (90%)	2 years	Flows via Boera Dam.
Wetland inundating flow - Half inundation	WL2	Cumulative volume of 16,000 ML within 30 days	Any time		4-8 years in 10 (60%)	3 years	
Wetland inundating flow - Full inundation	WL3	Cumulative volume of 33,000 ML within 30 days	Any time		3-6 years in 10 (40%)	6 years	
Wetland inundating flow - Boom	WL4	Cumulative volume of 75,000 ML within 30 days	Any time		1-3 years in 10 (20%)	10 years	

[39] Volumetric thresholds for the Western Floodplain at Toorale EWRs are informed by Cox et al. (2011)

[40] Frequencies and maximum interflow periods for the Western Floodplain at Toorale were determined using the observed flow record at the combined Fords Bridge and Fords Bridge Bywash gauges for 1972-2018.