DEPARTMENT OF PLANNING, INDUSTRY & ENVIRONMENT

Barwon–Darling Long Term Water Plan Part A

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Acknowledgement of Traditional Owners

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

In relation to the Barwon–Darling river system, the NSW Department of Planning, Industry and Environment pays its respects to Barkindji, Murrawarri, Ngemba and Ngiyampaa Traditional Owners past, present and future, as well as those of other Nations for whom this river is significant. We look forward to building new and 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.

This Long Term Water Plan acknowledges that native title was determined for Barkandji traditional lands in 2015 and again in 2017, and includes reference to the associated native title rights.

Abbreviations

Basin Plan	Murray–Darling Basin Plan
BCT	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
DPIE-BC	NSW Department of Planning, Industry and Environment - Biodiversity and Conservation Division
DPIE Water	NSW Department of Planning, Industry and Environment – Water
DPI Fisheries	NSW Department of Primary Industries Fisheries
EWAG	Environmental Water Advisory Group
EWR	Environmental water requirement
HEW	Held environmental water
IUFMPNW	Interim Unregulated Flow Management Plan for North West NSW
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	Natural Resources Access Regulator
NSW	New South Wales
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

Active environmental water	The water in the unregulated river water source identified on any given day as requiring protection from extraction so it can remain in-stream and be used for environmental purposes.
Active floodplain	The area that is inundated under contemporary climate.
Active management	An increased level of management proposed in unregulated rivers, that are downstream from regulated water sources, to manage environmental water being used in-stream for environmental purposes, this water is referred to as active environmental water.
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 DOI–W, which is determined within the context of demand, inflows, rainfall forecasts and stored water.
Allochthonous	Organic material (leaf litter, understory plants, trees) derived from outside rivers, including riparian zones, floodplains and wetlands.
Alluvial	Comprised of material deposited by water.
Autochthonous	Organic material derived from photosynthetic organisms (algal and macrophyte growth) within rivers.
Bankfull flow	River flows at maximum channel capacity with little overflow to adjacent floodplains. Engages the riparian zone, anabranches and flood runners and wetlands located within the meander train. Inundates all in channel habitats including all benches, snags and backwaters.
Baseflow	Reliable background flow levels within a river channel that are generally maintained by seepage from groundwater storage, but also by surface inflows. Typically inundates geomorphic units such as pools and riffle areas.
Basin Plan	The Basin Plan as developed by the Murray–Darling Basin Authority under the *Water Act 2007*.
Biota	The organisms that occupy a geographic region.
Blackwater	Occurs when water moves across the floodplain and releases organic carbon from the soil and leaf litter. The water takes on a tea colour as tannins and other carbon compounds are released from the decaying leaf litter. Blackwater plays an important role in transferring essential nutrients, such as carbon, from wetlands into rivers and vice versa. Carbon is a basic building block of the aquatic food web and an essential part of a healthy river system.
Cease-to-flow	The absence of flowing water in a river channel. Partial or total drying of the river channel. Streams contract to a series of isolated pools.
Cease-to-pump (access rule in WSP)	Pumping is not permitted: • from in-channel pools when the water level is lower than its full capacity • from natural off-river pools when the water level is lower than its full capacity or at an agreed pool draw down level • from pump sites when there is no visible flow. These rules apply unless there is a commence-to-pump access rule that specifies a higher flow rate that licence holders can begin pumping.

Constraints	The physical or operational constraints that 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 and around wetlands and floodplains.
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 and cultural value based on its cultural significance to Aboriginal people and is related to the water resource.
Cultural water-dependent value	An object, plant, animal, spiritual connection or use that is dependent on water and 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 and is a basic building block available to bacteria and algae that microscopic animals feed on, that are in turn consumed by fish larvae, small bodied fish species, yabbies and shrimp. DOC is essential for building the primary food webs in rivers, wetlands and floodplains, ultimately generating a food source for large bodied fish like Murray cod and golden perch and predators such as waterbirds.
Ecological asset	The physical features that make up an ecosystem.
Ecological function	The resources and services that sustain human, plant and animal communities and are provided by the processes and interactions occurring within and between ecosystems.
Ecological objective	Objective for the protection and/or restoration of an ecological asset or function.
Ecological target	Level of measured performance that must be met 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 and their physical environment. It includes all the living things in that community, interacting with their non-living environment (weather, earth, sun, soil, climate and atmosphere) and with each other.
Environmental water	Water for the environment. It serves a multitude of benefits to not only the environment, but to communities, industry and society. It includes water held in reservoirs (held environmental water) or protected from extraction from waterways (planned environmental water) for meeting the water requirements of water-dependent ecosystems.

Environmental water requirement	An environmental water requirement (EWR, singular) describes the characteristics of a flow event (e.g. magnitude, duration, timing, frequency, and maximum dry period) within a particular flow category (e.g. small fresh), that are required for that event to achieve a specified ecological objective or set of objectives (e.g. to support fish spawning and in-channel vegetation). There may be multiple EWRs defined within a flow category, and numerous EWRs across multiple flow categories within a Planning Unit. Achievement of each of the EWRs will be required to achieve the full set of ecological objectives for a Planning Unit. The water required to support the completion of all elements of a lifecycle of an organism or group of organisms (taxonomic or spatial), consistent with the objective/target, measured at the most appropriate gauge. It includes all water in the system including natural inflows, held environmental water and planned environmental water
Floodplain harvesting	The collection, extraction or impoundment of water flowing across floodplains. NSW is currently bringing floodplain harvesting extraction under regulation and licencing framework and to be included under Water Sharing Plans.
Flow regime	The pattern of flows in a waterway over time that will influence the response and persistence of plants, animals and their ecosystems.
Freshes	Temporary in-channel increased flow in response to rainfall or release from water storages.
Groundwater	Water that is located below the earth's surface in soil pore spaces and in the fractures of rock formations. Groundwater is recharged from, and eventually flows to, the surface naturally.
Held environmental water (HEW)	Water available under a water access 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).
Hydrological connectivity	The link of natural aquatic environments.
Hydrology	The occurrence, distribution and movement of water.
Hypoxic Blackwater	Occurs when dissolved oxygen (DO) levels, as measured in milligrams per litre (mg/L), fall below the level needed to sustain native fish and other water dependent species. Native fish begin to stress when DO levels fall below 4 mg/L and fish mortality occurs when DO levels are less than 2 mg/L. When bacteria that feed on dissolved organic carbon multiply rapidly, their rate of oxygen consumption can exceed the rate at which oxygen can be dissolved in the water, oxygen levels fall and a hypoxic (low oxygen) condition occurs.
Large fresh	High-magnitude flow pulse that remains in-channel, connects most in channel habitats, provides partial longitudinal connectivity by drowning out of some low-level weirs and other in channel barriers and may engage flood runners and inundate low-lying wetlands.
Lateral connectivity	The flow linking rivers channels and 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 and 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 and 20-year timeframes.
Longitudinal connectivity	The consistent 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 (PU)	A spatial division of a water resource plan area based on water requirements or a sub-catchment boundary.
Population structure	The range of age and size classes within a species population. A population with a range of age and size, with a good number of sexually mature individuals, demonstrates regular recruitment and is healthy.
Priority ecological function	Ecological functions that can be managed with environmental water.
Priority ecological asset	A place of ecological significance that is water-dependent and can be managed with environmental water. This includes planned and held environmental water.
Recruitment	Successful development and growth of offspring; so that they can contribute to the next generation.
Regulated river	A river that is gazetted under the *NSW Water Management Act 2000.* Major dams, water storages and weirs largely control flow. River regulation increases reliability of water supplies in most years but alters the natural flow regime required by water-dependent environmental assets and values.
Riffle	A rocky or shallow part of a river where river flow is rapid and broken.
Riparian	The part of the landscape adjoining rivers and streams that has a direct influence on the water and aquatic ecosystems within them.
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 and trigger animal movement.
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 uncontrolled 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 and reservoirs. Although separate from groundwater, they are interrelated and 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.
Unregulated river	A waterway where flow is mostly uncontrolled by dams, weirs or other structures.
Very low flow	Small flow that joins river pools, thus providing partial or complete connectivity in a reach. Can improve DO saturation and reduce stratification in pools.
Water quality management plan (WQMP)	A document prepared by state authorities, as part of the Water Resource Plan that is accredited by the Commonwealth under the Basin Plan. It aims to provide a framework to protect, enhance and restore water quality.
Water resource plan (WRP)	A policy package prepared by state authorities and accredited by the Commonwealth under the Basin Plan. It describes how water will be managed and shared between users in an area and 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 and trading water between the various water users and the environment in a specified water management area. A water sharing plan will be a component of a water resource plan.

Definitions and explanatory text for EWRs

Duration	The duration for which flows must be above the specified flow rate for the flow event to achieve the specified ecological objective(s) of the EWR. Typically this is expressed as a minimum duration. Longer durations will often be desirable and deliver better ecological outcomes. Some species may suffer from extended durations of inundation, and where relevant a maximum duration may also be specified. Flows may persist on floodplains and within wetland systems after a flow event has past. Where relevant a second duration may also be specified, representing the duration for which water should be retained within floodplain and wetland systems.
EWR code	Each EWR is given a specific code that abbreviates the EWR name (e.g. SF1 for small fresh 1). This code is used to link ecological objectives and EWRs.
Flow category	Flows in rivers vary over time in response to rainfall, river regulation, extractions and other factors. The sequence of flows over time can be considered as a series of discrete events. These events can be placed into different flow categories (e.g. baseflows, freshes, bankfull, overbank and wetland flows) according to the magnitude of flow discharge or height within a watercourse, and the types of outcomes associated with the events (e.g. inundation of specific features such as channel benches, riparian zones or the floodplain). Flow categories used in LTWPs are illustrated and defined in Figure 11 and Table 7 in Part A of each LTWP.
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.
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, and 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 and recruitment of native fish, vegetation and 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 and maximum inter-flow period, and the two must be considered together when evaluating outcomes or managing systems. Where a range of frequencies is indicated (e.g. 3–5 years in 10), the range reflects factors including the natural variability in population requirements, uncertainty in the knowledge base, and variability in response during different climate sequences (e.g. maintenance of populations during dry climate sequences at the lower end of the range, and population improvement and recovery during wet climate sequences at the upper end of the range).

	The lower end of the frequency range (when applied over the long term) may not be sufficient to maintain populations and is unlikely to achieve any recovery or improvement targets. As such, when evaluating EWR achievement over the long term through statistical analysis of modelled or observed flow records, DPIE recommend that the average of the frequency range is used as the minimum long-term target frequency.
Gauge	The flow gauging station that best represents the flow within the planning unit, for the purpose of the respective EWR and associated ecological objective(s). To assess the achievement of the EWR, flow recorded at this gauge should be used.
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.
Other requirements and comments	Other conditions that should occur to assist ecological objectives to be met – for example rates of rise and fall in flows. Also comments regarding limitations on delivering environmental flows and achieving the EWR.
Timing	The required timing (or season, typically expressed as a range of months within the year) for a flow event to achieve the specified ecological objective(s) of the EWR. In some cases, a preferred timing is provided, along with a note that the event may occur at ‘anytime’. This indicates that ecological objectives may be achieved outside the preferred timing window, but perhaps with sub-optimal outcomes. In these instances, for the purposes of managing and delivering environmental water, the preferred timing should be used to give greater confidence in achieving ecological objectives. Natural events may occur at other times and still achieve ecological objectives.

Summary

Rivers, creeks, wetlands and floodplains play a vital role in sustaining healthy communities and economies. They provide benefits for people, plants and animals that extend well beyond the river bank and floodplains.

Over the past 200 years the natural flow regimes of rivers, wetlands and floodplains in New South Wales (NSW) have been disrupted because of dams, weirs, floodplain development, and water regulation and extraction.

The purpose of the Barwon–Darling Long Term Water Plan (LTWP) is to describe the flow regimes that are required to maintain or improve environmental outcomes. The LTWP identifies strategies for maintaining and improving the long-term health of the Barwon–Darling riverine and floodplain 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 will help water managers make decisions about where, when and how available water can be used to achieve agreed long-term ecological objectives. The LTWP considers all sources of water and how these can be managed to help support environmental outcomes in the catchment. 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 coordinate 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 water resource plan areas (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.

The Barwon–Darling Long Term Water Plan

The Barwon–Darling 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:

- undertaking a comprehensive **stocktake** of water-dependent environmental assets and ecosystem functions within the LTWP area 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 Barwon–Darling

- 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 potential **management strategies** to meet environmental water requirements
- identifying **complementary investments** to address **risks and constraints** to meeting the long-term water requirements of priority environmental assets and ecosystem functions.

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

Environmental values of the Barwon–Darling

The Barwon–Darling catchment 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 Commonwealth-listed threatened ecological communities, threatened, endangered and migratory waterbirds, and threatened native fish species, by providing habitat and food resources. The Barwon-Darling plays a pivotal role in the Murray–Darling Basin, connecting the northern and southern basins. This critical function is most apparent in the Basin's fish population where successful fish spawning and dispersal in the Barwon–Darling leads to improved native fish communities across the Basin. Connection with the northern tributaries and the southern Basin are critical to the continued health of the Barwon–Darling and the Murray–Darling Basin.

The ecological condition of the Barwon–Darling water-dependent environmental assets is largely driven by 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, replenish refuge pools to maintain water quality, trigger movement and breeding of native fish and waterbirds, and directly impact vegetation condition, dispersal of propagules and habitat availability.

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 NSW Barwon–Darling environmental values closely aligns with material in the NSW Department of Industry *NSW Barwon–Darling Water Resource Plan Risk Assessment* (NSW DPIE 2019b).

Water for the environment

The Barwon–Darling LTWP contains ecological objectives and targets for priority environmental assets and ecosystem functions in the Barwon–Darling LTWP area. 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. Objectives and targets for improving connectivity within the LTWP area, with its tributaries, and with the Lower Darling are also included because longitudinal connectivity is vital to achieving Basin-wide outcomes. As noted in the BWS, each of these themes is a good indicator of river and wetland health and is responsive to flow.

The objectives reflect the current understanding of environmental outcomes that might be expected from implementation of the Basin Plan in the rivers, wetlands, floodplains, and watercourses of the Barwon–Darling. The targets for each ecological objective provide a transparent means of evaluating progress towards their achievement and the long-term success of management strategies.

Table 1 A summary of environmental outcomes sought for the Barwon–Darling

Broad outcomes	Overarching objectives	Example uses of water for the environment to achieve LTWP objectives
Maintain current species diversity, extend distributions, improve breeding success and numbers of native fish and threatened aquatic species such as mussels and snails.	Increase native fish distribution and abundance, and ensure stable population structures	• Protection of fresh events to support native fish spawning, recruitment and dispersal • Reduction in the length of cease-to-flow events to maintain water quality and allow for fish migration • Provide flows for fish passage from the Lower Darling and Menindee Lakes into the Barwon–Darling
Maintain the extent and improve the condition of native vegetation	Maintain and improve the viability and extent of river red gum, black box and coolibah communities, lignum shrublands and non-woody wetland vegetation	• Protect the frequency and duration of flows that inundate floodplain wetland vegetation • Provide bank-full events to inundate riparian vegetation
Maintain the current species diversity, improve breeding success and numbers of waterbirds	Restoration of habitat for waterbirds to contribute to recovery of waterbird populations across the Murray-Darling Basin	• Support the successful completion of colonial waterbird breeding (yellow-billed spoonbill, pied cormorant in the floodplain wetlands of the Upper Darling) • Provide foraging habitat for waterbirds
Improve connections along rivers and between rivers and their floodplains for improved river system health	Improve ecosystem functioning to provide healthy ecosystems capable of supporting native biota	• Improve connection with tributary catchments • Improve connectivity with the southern Basin (Menindee Lakes and Lower Darling) • Protect environmental water • Protect first flush following a dry period • Coordinate flow planning on a northern basin scale

Protection of water for the environment

The Barwon–Darling is an unregulated river system. This indicates that the achievement of environmental flows is contingent on inflows from the tributary valleys of the northern basin and subsequently provisions in the Water Sharing Plan (WSP) to protect a sufficient portion and pattern of those inflows. The management of the Barwon–Darling under the 2012 WSP, and the effects of management from tributary catchments, has not achieved the environmental water requirements of the Barwon–Darling across the full range of flows. Improving environmental flow outcomes from the management of water in the Barwon–Darling is a central focus of the NSW Government's environmental water component of the NSW Water Reform Action Plan. This plan is progressing the following measures:

- better understanding northern connectivity
- actively managing held environmental water in-stream
- managing resumption of flows in the Barwon–Darling, after an extended dry period

- limiting daily water take in the Barwon–Darling River.

These will be undertaken in conjunction with improvements in the NSW non-urban water metering framework, development of pilot technology and commissioning of NRAR for improved water metering and compliance. Improved environmental outcomes in the Barwon–Darling and connected systems will rely on these measures being adequately implemented.

Complementary investments

Complementary measures that are needed to help achieve the LTWPs objectives and targets have been identified in this plan (see Chapter 7). In the Barwon–Darling this includes connectivity work for the 2018 water reform action plan (NSW DOI 2018; Matthews 2017a,b), addressing fish passage and habitat, planning effectively for climate change and short-term intensive drought, and establishing community engagement mechanisms appropriate for the geographic extent and required diversity in membership.

Monitoring and evaluation of the Long Term Water Plan

Over the 20-year duration of this LTWP, NSW and Commonwealth agencies will, if sufficient resources and funding are made available, undertake monitoring of the health of rivers, wetlands and floodplains within the NSW Barwon–Darling to:

- monitor and demonstrate progress towards the objectives and targets identified in the LTWP
- inform and support the management of environmental water
- provide early information to test the assumptions and conditions that underpin the plan.

Review and update of the LTWP

As knowledge and evidence of ecological processes in the Barwon–Darling improves it may be necessary to review and update the LTWP. To ensure the information in this LTWP 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, remake or amendment to the WSP or WRP for the NSW Barwon–Darling catchment
- revision of the BWS that materially affects this LTWP
- a sustainable diversion limit (SDL) adjustment
- new information arising from evaluating responses to environmental 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.

1. Introduction

The NSW Barwon River commences at the confluence of the Macintyre and Weir rivers on the NSW–Queensland border, 25 kilometres upstream of Mungindi. Northeast of Bourke in northern NSW the Barwon River converges with the Culgoa River. Downstream of this point, the river is known as the Darling River.

The Barwon–Darling Water Resource Plan Area (WRPA) consists of the main channel from the Queensland border to the upper limits of Lake Wetherell (the pool of the Menindee Weir and the initial storage of the Menindee Lakes system), downstream of Wilcannia. The planning area for this Long Term Water Plan (LTWP) is based on this WRPA, with the addition of Talyawalka Creek and associated floodplains, as shown Figure 1.

The catchment area for the Barwon–Darling is approximately 700,000 square kilometres (CLWD 2017), which includes catchments in southern Queensland and northern NSW. Commencing upstream of Mungindi, the Barwon River has many large tributary rivers including the Culgoa and Condamine–Balonne Rivers in Queensland and the Gwydir, Namoi, Macintyre, Macquarie, Castlereagh and Bogan Rivers in NSW. Downstream of Bourke, the Paroo and Warrego rivers contribute intermittent flows but can provide significant volumes (NSW DPI 2012). These catchment areas and waterways are included in neighbouring WRPA and addressed in other LTWPs. A schematic of the catchment is shown in Figure 12.

The tributary rivers vary in their connectivity to the Barwon–Darling system. Catchments that have large floodplains and wetlands in their lower reaches, such as the Macquarie River, tend to attenuate flow and normally contribute extended periods of low flow. Well-connected catchments such as Border Rivers and Namoi are able to contribute flows of higher peaks and shorter durations (MDBA 2016).

Extreme climatic variability between the contributing catchment areas, low rainfall in the river's immediate vicinity, and a semi-arid landscape characterise the nature of the Barwon–Darling river system. Prolonged drought and floods orders of magnitude above average annual flow are features of the natural system. Average annual rainfall decreases in a westward direction and summer dominant rainfall influences the northern tributary catchments, changing to evenly distributed monthly rainfall at Menindee (NSW DPI 2012). High evaporation rates are experienced along the length of the Barwon–Darling due to very hot summers.

All of these factors contribute to the highly variable streamflow for which the Barwon–Darling is renowned. The highest rates of flow and floods are usually driven by widespread summer rainfall in the northern catchments. Flow rates reduce downstream of Bourke due to evaporation and fewer contributions from tributary rivers below this point. Despite the semi-arid nature of the river, periods of no flow are uncommon, with small freshes experienced once or twice per year (NSW DPI 2012). Historical records of river flow have been collected at Brewarrina since 1892 and show periods of drought, large and major floods recurring over cycles of up to thirty years.

The Barwon is a tightly meandering river with many in-channel benches and a narrow floodplain. From Walgett, the river's floodplain widens across alluvial plains, has numerous anabranches and effluent creeks, and receives significant tributary inflows.

The Darling River below Bourke is an incised channel as deep as 25m with a narrow floodplain and few in-channel benches (NSW DPI 2012). The Darling to Menindee is known for its unique ephemeral nature, sinuous character and network of anabranches and billabongs.

Following flooding, the many small lagoons and anabranches along the length of the Barwon–Darling create extensive wetland habitat. Typically, they are made up of swamps, billabongs, lakes, waterholes and swales. Brennan et al 2002 identified and classified

583 floodplain wetlands between Mungindi to Menindee, including some artificial storages close to the main channel. The Barwon–Darling's instream habitats such as waterhole refuges, benches, snags and woody debris are important for aquatic species (NSW DPI 2017a).

The Talyawalka Anabranch and Teryawynia Creek at the lower end of the system between Wilcannia and Menindee are listed as wetlands of national importance (Directory of Important Wetlands). This anabranch system includes Teryawynia, Dry, White Water, Eucalyptus/Waterloo, Victoria, Brummeys, Dennys, Brennans, Sayers, Gum, Boolaboolka, North and Ratcatchers Lakes, plus associated wetlands. It is a system of overflow lakes filled by the distributary channel (Teryawynia Creek) when the Darling River is in flood. They are of national importance as a representative example of semi-arid inland floodplain wetland systems, especially of black box woodland. When inundated, these lakes provide habitat for large numbers of waterbirds (Environment Australia 2001, CSIRO 2008). Middens evidencing Aboriginal occupation of the lake area attests to the reliability of the lake system to provide resources for human populations. (Environment Australia 2001, CSIRO 2008).

The Barwon–Darling waterway is central to the Indigenous people whose nations include these waterways, and beyond. These nations include Barkindji, Murrawarri, Ngemba and Ngiyampaa (MDBA 2015), among others. 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 Barwon–Darling WRPA.

Significant Aboriginal cultural water dependent sites that were identified through the Barwon–Darling Floodplain Management Plan (NSW DPI 2017c), or 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 four sites of relevance to this LTWP. These registered examples provide a small insight into the significance of the area to Indigenous people (NSW OEH 2018).

- the Collarenebri Aboriginal Cemetery is on the northern bank of the Barwon River, about 4 kilometres east of Collarenebri. It was established as a result of a town camp located at a nearby lagoon. It is a place of ceremonial significance holding rare and aesthetically significant graves as well as demonstrating the cultural practices of people of this area. Water is used for the ongoing practice of preparing glass for grave decoration.
- the Brewarrina Aboriginal Mission site is next to the Barwon River, east of Brewarrina. This site was a long-standing institution, housing local Aboriginal people and others from Tibooburra, Angledool, Goodooga and Culgoa. Those living at Brewarrina Mission supplemented their rations by fishing from the Barwon River and gathering mussels. The river also provided water to the Mission. The site, which contains a highly valued cemetery, is significant to many people from across NSW and particularly the Ngemba and Murrawarri people. Ancestral remains have been returned to this site, demonstrating its ongoing importance as a place of belonging.
- the National Heritage listed Baiame's Ngunnhu (Brewarrina Aboriginal Fish Traps) exemplify an ancient and enduring connection to the Barwon River and the creation story significant to the region. The fish traps consist of dry-stone walls and holding ponds extending for half a kilometre along a bedrock feature along the Barwon River in Brewarrina. The structure enabled fish and eels to be herded and caught during both high and low flows in the river. The Ngemba people are custodians of the fish traps however their significance and responsibility is shared with people from western and northern NSW who gathered for subsistence, cultural and spiritual reasons.

Demonstrating the site's influence within the greater landscape, Baiame's Ngunnhu was one of the most important Aboriginal meeting places in eastern Australia.

- Steamers Point Aboriginal Place on the Darling River in Wilcannia is an important site holding ceremonial and cultural significance to the Barkandji and other local Aboriginal people. The site next to the Darling River has been a camping site and source of food and water on a travel route. There are significant archaeological objects in the area including middens, and the area remains a special place and key to understanding and connecting with the past.

Town centres occurring along the river include Mungindi, Collarenebri, Walgett, Brewarrina, Bourke, Louth, Tilpa and Wilcannia. Grazing is the main land use in the region, while dryland cropping and irrigation occurs along the river around Bourke, Brewarrina and Collarenebri (CLWD 2017, NSW DPI 2019a). The most significant water extraction activity on the Barwon–Darling, with the largest impact on river health is extraction for irrigation. Most of the licensed water shares in the Barwon–Darling WSP are unregulated river irrigation licenses. They are primarily held in the upper Darling and along the length of the Barwon. Extraction for town water supply represents approximately three per cent of shares and licensed stock and domestic supply 1.5%. There is a small portion of non-licensed domestic and stock rights. Basic landholder rights also include native title rights to water for domestic and traditional purposes.

There are no major storages on the Barwon–Darling but 70% of the river's inflow comes from regulated NSW catchments and the river is heavily impacted by the storages within these upstream water sources (CLWD 2017). Major headwater dams across the Northern Basin have a combined storage capacity of about 5,200 GL (NSW DPI 2012) and the volume of private storages, mostly associated with floodplain harvesting activities, was estimated at approximately 3,000 GL in 2007 (Webb McKeown and Associates 2007) and is likely to be greater now due to increase floodplain harvesting developments in NSW. Along the Barwon-Darling River there are also a number of large, private, off-channel storages with a combined capacity of approximately 284 GL (CSIRO 2008 in CLWD 2017). These are filled by pumping from the river during high flows, harvesting runoff from the floodplain or retaining irrigation tailwater (NSW DPI 2012).

The Barwon-Darling has 15 major weirs which retain water and help to create the depth required for pumping for town water supply and irrigation (CLWD 2017). Like natural pools these weirs provide refuge habitat for aquatic biota during periods of low or no flow, however unlike natural pools man-made weirs restrict the passage of low flows down the river system, severely restrict fish migration and can have a significant impact on water quality, particularly if impacted by high nutrients (NSW DPI 2017a). Weirs are an instream structure included for listing as a Key Threatening Process that adversely affects threatened species populations or ecological communities. The habitat created by weirs is suitable for pest species, which reduces the capacity of the pools to act as a refuge habitat for native fish and other instream biota. High-impact fish barriers (NSW DPI 2016c) are shown in Figure 1 and detailed in Part B for each LTWP planning unit.

River regulation and extraction within the Barwon–Darling and its tributaries has reduced the total volume of river flow, and has had the greatest impact on reducing the frequency of small to moderate-sized flows. The condition of the catchment's riverine and floodplain ecosystems, and the plants and animals they support has declined as a result (Kingsford 2000, Davies et al 2012). Changes in land use and disruption of the natural hydrological regime have affected water quality, which impacts a range of aquatic organisms and the suitability of water for human use and enterprise.

1.1 Water sharing arrangements

The water of the Barwon–Darling River is managed according to the *Water Sharing Plan for the Barwon–Darling Unregulated Water Source 2012*. The WSP divides the river into four sections for the purpose of managing water trade, and 14 management zones to set access rules to local conditions. The river floodplain included as part of this LTWP is also covered by Water Sharing Plans for Upper Darling Alluvial, Intersecting Streams, NSW Border Rivers, Gwydir, Namoi and Macquarie-Castlereagh water sources.

WSPs determine how water is shared between the environment and consumptive users. Provisions for the environment in the Barwon–Darling Unregulated Water Source WSP include:

- limiting the availability of water for extraction. The long term average annual extraction limit (LTAAEL) and available water determinations, give the total volume of extraction allowed from the water resource and the annual volume allocated to each license.
- access rules. Cease-to-pump rules require holders of a certain class of license to stop taking water when flow declines below a prescribed level within a management zone. The differing flow limits for each license class are one tool to manage the relative impact of take under different flow conditions.
- trading rules. The WSP has established river sections to mitigate the effects of trade. If water trade results in a concentration of extraction in a river section, the effects on the environment are also concentrated rather than dispersed along the length of the river.
- environmental water holdings. Licences for environmental use are allowed within the water source.

The Interim Unregulated North–West Flow Plan (NSW DWR 1992) is a document referenced in the Barwon–Darling, Border Rivers, Gwydir and Namoi WSPs. The plan guides restriction to supplementary access in the tributary streams, and B and C class licenses in the Barwon–Darling, unless specific flow thresholds are met. It allows for consideration of downstream triggers when granting water access upstream (NSW DPI 2012).

The alteration of the river's natural flow regime and water extraction provide a challenging context for maintaining riverine health. The NSW Government has developed the Barwon–Darling LTWP with the aim of improving the health of the Barwon–Darling riverine and floodplain ecosystems. It also recognises the Barwon–Darling connection and contribution to the environmental health of the NSW Murray–Lower Darling system.

1.2 Approach to developing the Barwon–Darling Long Term Water Plan

The Barwon–Darling LTWP applies to the Barwon–Darling 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 2012a).

The Barwon–Darling 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 Barwon–Darling LTWP has involved five main steps:

- undertaking a **comprehensive stocktake** of water-dependent environmental assets and ecosystem functions across the Barwon–Darling system 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 Barwon–Darling
- 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 NSW Department of Planning, Industry and Environment (Biodiversity and Conservation) and the Commonwealth Environmental Water Office (CEWO)
- informing planning processes that influence river and wetland health outcomes, including development of WSPs and WRPs
- identifying opportunities for more strategic river operations and 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 Barwon–Darling LTWP is presented in eight 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 Barwon–Darling water-dependent environmental assets and ecosystem functions and articulates 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 Barwon–Darling and outlines potential strategies.
- **Chapter 6** identifies opportunities for the use of held and planned environmental water, and other system flows to support flow regimes to meet the EWRs of the Barwon–Darling's environmental assets and values under dry, moderate and wet water resource availability scenarios.
- **Chapter 7** describes potential cooperative arrangements and prioritised investment opportunities to achieve the environmental outcomes described in this LTWP.
- **Appendix A** details the ecological values relevant to each planning unit.
- **Appendix B** provides detail on the ecological objectives relevant to each planning unit.

Part B

- **Chapter 8** introduces Part B of the LTWP and presents the LTWP at the planning unit (PU) scale. This includes a summary of the environmental values the planning unit supports and an evaluation of the impact of water resource development on local hydrology. This chapter also provides the planning unit scale EWRs.

1.5 Planning units

Figure 1 shows the Barwon–Darling area and planning units (PU) used to develop this LTWP. Unlike the WSP, this LTWP includes the river reach, floodplain and Talyawalka Creek system. To identify the floodplain boundary for the LTWP a combination of data sources and evidence has been used. This includes NSW Healthy Floodplain project mapping in the north (NSW DPI-W 2017c), TVD[1] Floodplain modelling in the south (Dutta et al 2016) and The Mitchell landscapes boundary in the far south to define the area around the Talyawalka Creek (NSW OEH 2016). Planning Unit boundaries align with the management zones defined by the Barwon–Darling WSP (NSW DPI 2014).

[1] TVD (Teng-Vaze-Dutta) – A model to simulate floods under various antecedent soil moisture conditions, producing spatio-temporal details of floodplain water balance.

Figure 1 **Map of planning units used along the Barwon–Darling River as part of the Long Term Water Plan showing high impact fish barriers (NSW DPI 2016b)**

2. Environmental assets of the Barwon–Darling

The Barwon–Darling 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 and animal species they support and ecosystem functions they perform.

The Barwon–Darling is a significant waterway in the Murray–Darling Basin, connecting the northern and southern basins. This critical function is most apparent in the Basin's native fish population where successful fish spawning and dispersal in the Barwon–Darling leads to improved fish communities across the Basin. This connection is also key to providing inflows to the Lower Darling system for downstream ecological objectives.

2.1 Priority environmental assets in the Barwon–Darling

Schedule 8 of the Basin Plan outlines criteria for identifying water-dependent ecosystems that should be recognised as environmental assets in the Murray–Darling Basin. 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 Barwon–Darling, which are comprised of waterbodies and the water-dependent values (plants, animals and functions) they support, 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 Aboriginal Heritage Information Management System (AHIMS) were also included as water-dependent assets in the LTWP. Results of the analysis are presented Figure 2.

Priority environmental assets in LTWP's are the water-dependent assets that have been identified using Schedule 8 criteria that can be managed through:

- NSW's planned environmental water (PEW), and/or
- NSW's and CEWO's held environmental water (HEW), and/or
- often in combination with other river flows, and
- supported by implementation of the Barwon–Darling Water Sharing Plan (WSP) rules and compliance.

Priority environmental assets may be, for example, a reach of river channel and its floodplain features at a geographic location, or a wetland complex or anabranch. Priority environmental assets and values in the Barwon–Darling LTWP are listed in the relevant planning units in Part B.

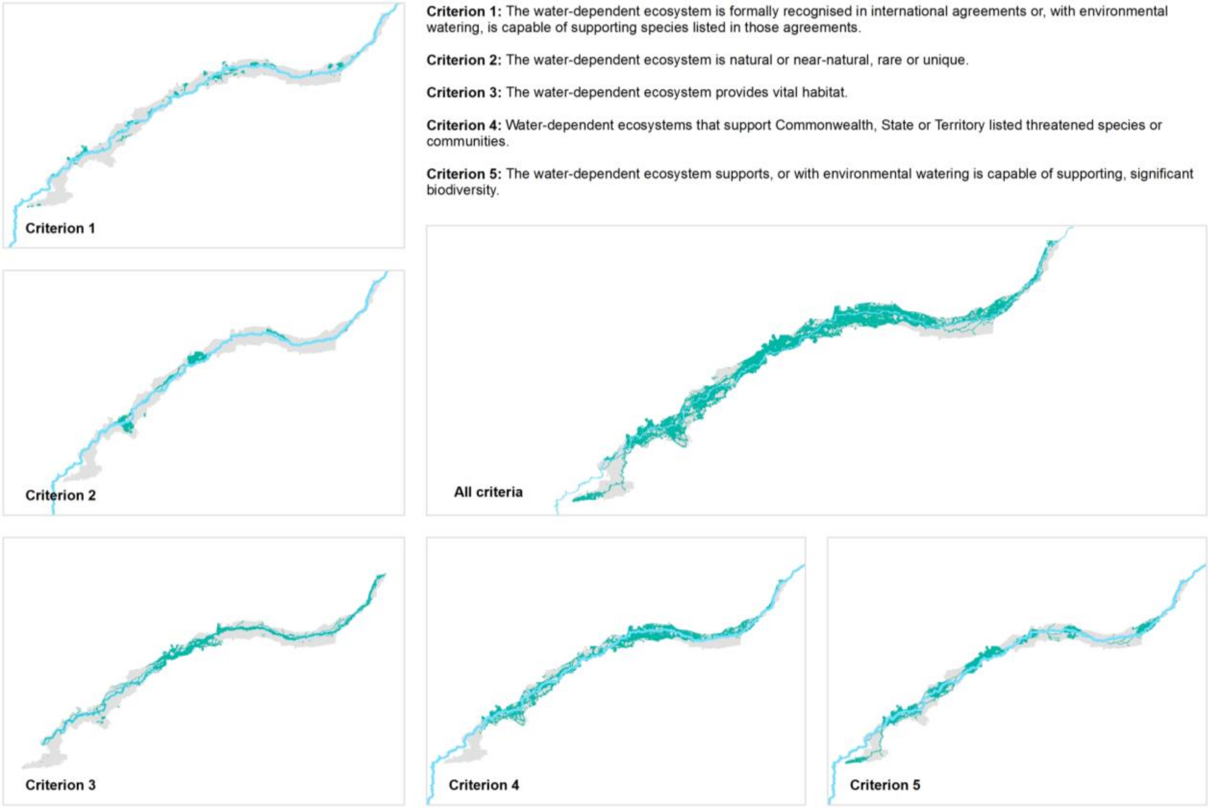

Figure 2 **Five criteria for identification of environmental assets applied to Barwon–Darling**

Figure 3 **Barwon River near Mungindi**
Photo: Terry Cooke

3. Ecological objectives and targets

Ecological objectives and targets have been established for priority environmental assets and values in the Barwon–Darling (sections 3.1–3.4). The LTWP ecological objectives align with the ecological objectives of the Basin Plan, Basin-wide Watering Strategy (BWS) and Barwon–Darling WSP. These alignment details are provided in Table 1 of Schedule E of the Barwon–Darling WRP, providing details as to how one planning activity relates and contributes to another.

Consistent with the BWS, the objectives are grouped into four themes: native fish, native vegetation, waterbirds and ecosystem functions (MDBA 2014). The water requirements of indicator species, functional groups of species, or ecosystem functions within each theme are representative of those needed by other water-dependent species such as frogs, turtles, and rakali (water-rat). 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. The targets will provide an indication of how the environment is responding to environmental water management and inform any refinement to the described flow regime or water management strategies. It is important to note that the 20-year targets in the LTWP assume implementation of reforms and investment to improve and enable better management of environmental water (NSW DOI 2018).

The ecological objectives for the Barwon–Darling's priority environmental assets, as they relate to individual planning units, are listed in Appendix B. The selection of ecological objectives recognises the values that the priority environmental asset supports (e.g. native fish species, native vegetation communities, waterbirds) or the ecosystem function it performs (e.g. provides vital instream habitat).

3.1 Native fish values and objectives

The endangered ecological community (EEC) known as the Lowland Darling River aquatic ecological community incorporates 21 native fish species and hundreds of aquatic invertebrate species (NSW DPI 2007).

The fish community of the Barwon–Darling includes 15 native species recorded or expected to occur and up to five alien species (NSW DPI 2015). Purple spotted gudgeon, freshwater catfish (eel-tailed catfish) of the Murray–Darling Basin and the olive perchlet (western population) are listed as endangered, while silver perch and Murray cod are listed as vulnerable under the *Fisheries Management Act 1994* (FM Act) (NSW DPI 2015, NSW DPI 2016a). The silver perch is listed as critically endangered and Murray cod as vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999.* The purple-spotted gudgeon has not been recorded in recent years (NSW DPI 2017a). Indicative distributions of these species is shown in Figure 5. In addition, the Darling River snail is listed as a critically endangered species (FM Act 1994) of the Barwon–Darling aquatic community (NSW DPI 2015). Recorded alien species include the carp, goldfish, gambusia and redfin perch (NSW DPI 2015).

The Barwon–Darling also supports several species of river mussels, including *Alathyria jacksoni,* which is highly responsive to changes in low and zero flows (Jones 2007). More frequent and extended cease-to-flow events that are characteristic of the regulated Barwon–Darling has resulted in the loss of resilience of this species, as well as other benthic macroinvertebrate communities (Davies *et al* 2012).

Menindee Lake and associated lakes (Menindee Lakes Storages) are natural depressions that would fill during flood events. These lakes provide critical habitat for fish and other water-dependent species, for example, fish nursery habitat for growing out silver perch, golden perch and Murray cod. Golden perch[2] spawn in the Barwon–Darling and northern NSW rivers, with larval and juvenile fish travelling down to the lakes and dispersing throughout the Murray–Darling Basin. The fish population dynamics in the Barwon–Darling and Menindee Lakes Storages influences fish populations throughout the Basin. End-of-system needs in the Barwon–Darling are focused on the supply of water into the Menindee Lakes Storages. The strong connection between golden perch spawning and recruitment in the Barwon–Darling and Menindee Lakes means that the success of these fish populations in the whole of the Basin is influenced by management of Menindee Lakes Storages and sufficient connection from the Darling River.

The fish community of the Barwon–Darling's main channel is in fair condition. The Talyawalka Creek system contains communities rated in good condition (see Figure 4).

Figure 4 The current fish community status in the Barwon–Darling (NSW DPI 2016c)

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 and Cheshire 2013). In addition, the BWS (MDBA 2014) has identified as important environmental assets for native fish:

- Barwon–Darling River (Menindee to Mungindi) – values include 'key movement corridor', 'high biodiversity', 'key site of hydrodynamic diversity', 'threatened species' and 'dry spell/drought refuge'
- Talyawalka Anabranch – values include 'key movement corridor', 'key site of hydrodynamic diversity' and 'dry spell/drought refuge'

The meandering channels of the Barwon–Darling include a variety of habitats as assets, such as deep channels, pools, wetlands, gravel beds, instream woody habitats, aquatic plants, and floodplains. This variety in habitat combined with variations in flow has resulted in native flora and fauna that have adapted to the conditions and rely on them for life stages such as spawning (NSW DPI 2007).

The Barwon–Darling and its associated aquatic biota, 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.

[2] This life history may possibly also relate to silver perch, although they are now too rare to confirm this in the northern Darling.

There are 14 weirs identified as high priority by NSW DPI Fisheries for remediation to improve fish passage (NSW DPI 2017b). Individually, the structures have varying impacts, but cumulatively they are significant in impeding natural flows and affecting fish migration and spawning. Previous works to improve fish passage have occurred at Brewarrina Weir and Woorawadian Weir (now removed) (NSW DPI 2017b).

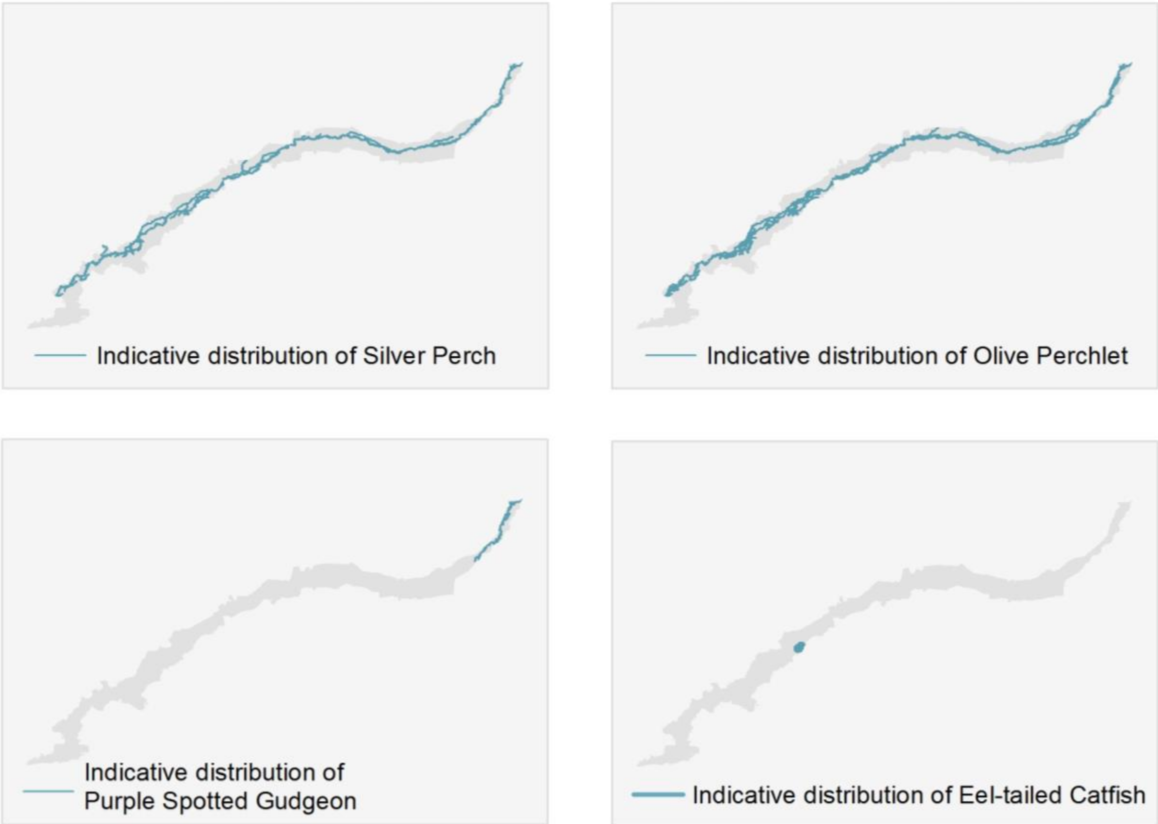

Figure 5 **Maps of indicative distribution of four key native fish species in the Barwon Darling (NSW DPI 2016c)**

Figure 6 **Murray cod and freshwater catfish**
Photos: G. Schmida

Murray cod make an upstream migration to spawn. In late winter and early spring when river levels are high, Murray cod migrate upstream for up to 120 km to release their eggs. The male guards the ‘nest’ during incubation and the eggs hatch after 5–13 days. After spawning the fish return downstream to the same area they occupied before the migration, usually to exactly the same snag. (MDBC 2007a)

Table 2 Native fish (NF) ecological objectives

<table>
<tr><th colspan="2" rowspan="2">Objective</th><th rowspan="2">Target fish species</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">NF1</td><td rowspan="2">No loss of native fish species</td><td rowspan="2">All recorded fish species</td><td colspan="3">All known species detected annually</td></tr>
<tr><td></td><td colspan="2">Fish community status improved by one category compared to 2014 assessment</td></tr>
<tr><td>NF2</td><td>Increase the distribution and abundance of short to moderate-lived generalist native fish species</td><td>Australian smelt, carp gudgeon, western carp gudgeon, bony herring, Murray–Darling rainbowfish, un-specked hardyhead</td><td colspan="3" rowspan="2">Increased distribution and 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)</td></tr>
<tr><td>NF3</td><td>Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species</td><td>Olive perchlet</td></tr>
<tr><td>NF4</td><td>Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species</td><td>Golden perch, silver perch, spangled perch, Hyrtl’s tandan</td><td colspan="3">Juvenile and 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</td></tr>
<tr><td>NF5</td><td>Improve native fish population structure for moderate to long-lived riverine specialist native fish species</td><td>Murray cod, freshwater catfish, southern purple-spotted gudgeon</td><td>Minimum of 1 significant recruitment event in 5 years</td><td>Minimum of 2 significant recruitment events in 10 years</td><td>Minimum of 4 significant recruitment events in 20 years</td></tr>
<tr><td>NF6</td><td>A 25% increase in abundance of mature (harvestable sized) golden perch and Murray cod</td><td>Golden perch
Murray cod</td><td colspan="3">Length-frequency distributions include size classes of legal take size for golden perch and Murray cod
25% increase in abundance of mature golden perch and Murray cod</td></tr>
</table>

Objective		Target fish species	Targets		
			5 years (2024)	10 years (2029)	20 years (2039)
NF8[3]	Increase the prevalence and/or expand the population of key moderate to long-lived riverine specialist native fish species into new areas (within historical range)	Freshwater catfish	Adults detected annually in specified planning units No more than 2 years without detection of immature fish in specified planning units (moderate-lived species) No more than 4 years without detection of immature fish in specified planning units (long-lived species)		
NF9	Increase the prevalence and/or expand the population of key moderate to long-lived flow pulse specialist native fish species into new areas (within historical range)	Silver perch	Adults detected annually in specified planning units No more than 2 years without detection of immature fish in specified planning units (moderate-lived species) No more than 4 years without detection of immature fish in specified planning units (long-lived species)		

[3] NF7 refers to range expansion objectives relating to short to moderate-lived floodplain specialist native fish (olive perchlet). Whilst these species have a distribution in Barwon-Darling, core populations for this species in other valleys are prioritised for these objectives/targets.

3.2 Native vegetation values and objectives

Figure 7 **Darling River red gums at Bourke Wharf**
Photo: Philip Nicholas (DPIE)

The objectives and targets of this plan aim to maintain the current extent of woody vegetation because increasing the extent may not be possible due to agricultural land development. This requires woody vegetation to be maintained in good condition as described in Table 3 and to retain episodic recruitment events to replace losses. Objectives and targets for in-channel vegetation, lignum shrublands and non-woody wetland vegetation recognise the ongoing need for vegetative growth and regular seed setting to ensure population viability of these shorter lived species (Roberts and Marston 2011; Casanova 2015).

Endangered Ecological Communities found along the Barwon–Darling include the Coolibah–Black Box Woodland in the southern section of the river, Carbeen Open Forest in the northern section and the critically endangered Marsh Club-rush sedgeland in the far northern section (www.environment.nsw.gov.au, Figure 15 in CLWD 2017). Brigalow–Gidgee woodland (north-west floodplain woodland) and Weeping Myall Woodland (north-west floodplain woodland/semi-arid floodplain grassland) are also water-dependent EEC in the LTWP area. The *Environment Protection and Biodiversity Conservation Act 1999* also lists as Endangered the Coolibah–Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions, Weeping Myall Woodlands and Brigalow. The threatened plant species including *Myriophyllum implicatum* and Menindee nightshade *Solanum karsense* also form important habitat in the Barwon–Darling (NSW DPI 2017a).

River red gum woodland occurs in areas closely adjoining the main river channels and lower floodplain and dominates the banks of the river, tributaries, anabranches, wetlands and lakes (NSW DPI 2012). It covers a relatively small area (compared to other vegetation assets) but occurs in all planning units. The Talyawalka Anabranch and Teryawynia Creek lakes support areas of black box and river red gum. In the Barwon–Darling LTWP Area, river red gum is predominantly found in riparian zones and requires relatively frequent watering. Poor recruitment hinders red gum and other native vegetation along the riparian zone due to feral goats and other grazing stock removing the seedlings following successful germination after a fresh or flood event. This threat impacts on the condition and viability of this community and relates to a number of the LTWP native vegetation and other objectives (see section 5.2).

Coolibah and black box remnants can be found on the outer floodplain and require less frequent surface water to maintain condition and extent (Roberts and Marston 2011; Casanova 2015). Most coolibah is found around Brewarrina, Bourke down to Wilcannia, while black box largely occurs from Brewarrina upstream to Walgett and Collarenebri. Within these patches of remnant vegetation, there is a gradient of condition, with vegetation having more frequent access to water generally being in better condition (Casanova 2015). Flooding is required for recruitment (Roberts and Marston 2011; Casanova 2015).

Lignum is most prolific in the planning units around Wilcannia and non-woody wetland mostly occurs in the most downstream sections of the river (see Figure 8). Dry Lake supports a dense covering of Lignum, and thick patches of Nardoo occur on receding floodwaters (Environment Australia 2001, CSIRO 2008). Talyawalka Creek is lined with cane grass (Environment Australia 2001, CSIRO 2008).

Floodplain vegetation in Figure 8 represents other floodplain species that occur on higher ground away from the main channels and wetted areas (e.g. weeping myall woodland, belah woodland, poplar box – coolibah floodplain woodland).

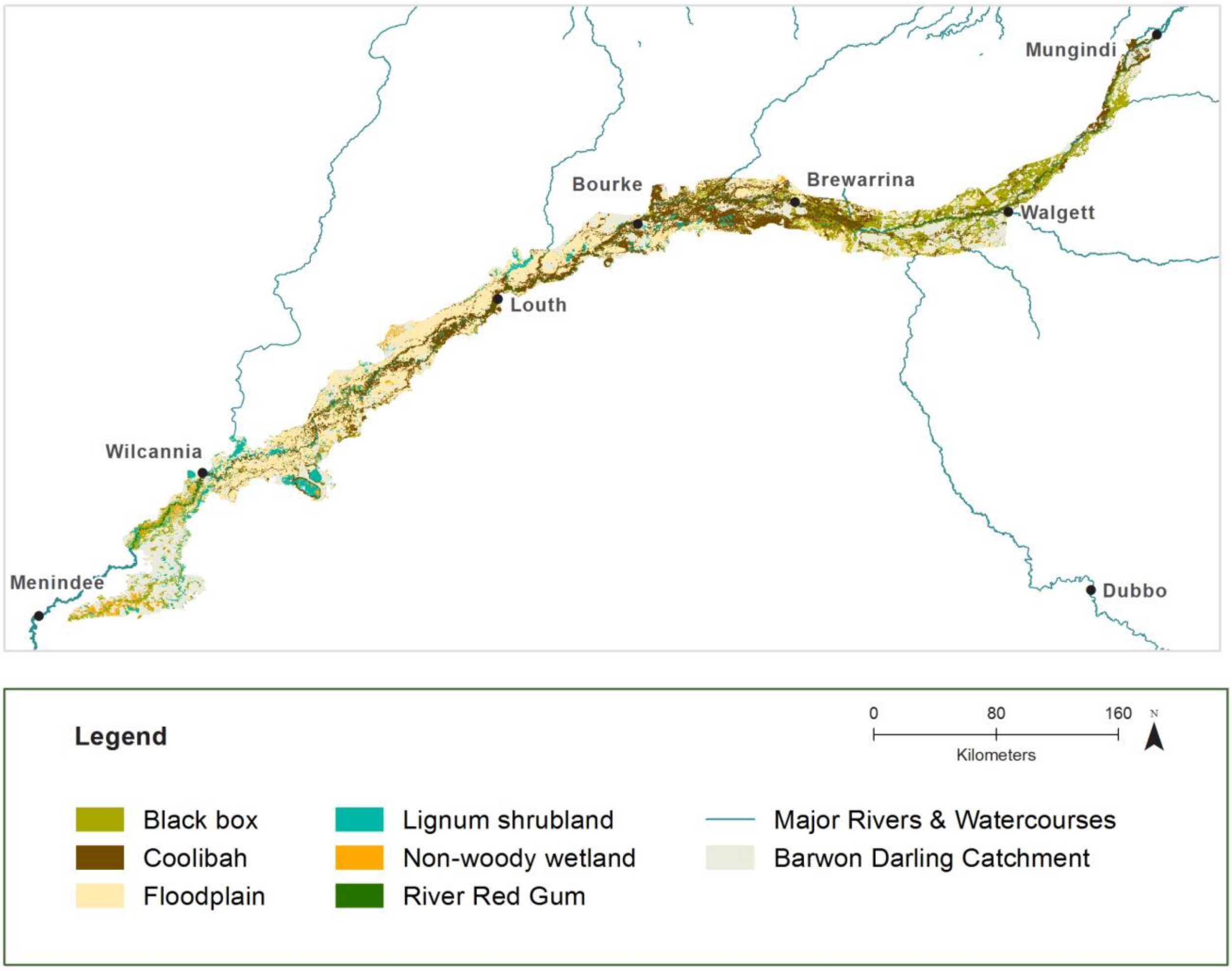

Figure 8 Map of native vegetation assets on the Barwon–Darling

Table 3 Native vegetation (NV) ecological objectives

<table>
<tr><th colspan="3" rowspan="2">Objective</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>NV1</td><td colspan="2">Maintain the extent and viability of non-woody vegetation communities occurring within channels</td><td colspan="3">Increase the cover of non-woody, inundation-dependent vegetation within or closely fringing river channels following inundation events</td></tr>
<tr><td>NV2</td><td colspan="2">Maintain or increase the extent and maintain the viability of non-woody vegetation communities occurring in wetlands and on floodplains</td><td colspan="3">Over a 5-year rolling period, non-woody floodplain vegetation to flower and set seed seasonally at least 2 years in 5
Maintain the total area of non-woody wetland vegetation communities</td></tr>
<tr><td rowspan="2">NV3[4]</td><td colspan="2" rowspan="2">Maintain the extent and improve the condition of river red gum communities closely fringing river channels</td><td colspan="3">Maintain the 2016 mapped extent[5] of river red gum woodland communities closely fringing river channels</td></tr>
<tr><td>Over a 5-year rolling period:
• maintain the extent and 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 or degraded condition</td><td colspan="2">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[6] of river red gum communities closely fringing river channels that are in poor, degraded or severely degraded condition by at least one condition score</td></tr>
<tr><td>NV4c</td><td>Maintain or increase the extent and maintain or improve the condition of native woodland and shrubland communities on floodplains</td><td>Black box woodland</td><td>Over a 5-year rolling period:
• maintain the extent and proportion of woodlands in moderate or good condition</td><td colspan="2">Over a 5-year rolling period:
• increase the proportion of woodlands in moderate or good condition</td></tr>
</table>

[4] No additional objective has been included for river red gum woodland occurring on the floodplain. It is assumed that most or all the red gum will be captured by NV3 (fringing).

[5] Extent based on compiled native vegetation plant community type (PCT) mapping. Map compiled by DPIE from best available PTC mapping as at 2016.

[6] Condition score according to the MDBA Stand Condition tool (Cunningham et al. 2009).

Objective			Targets: 5 years (2024)	Targets: 10 years (2029)	Targets: 20 years (2039)
NV4d		Coolibah woodland	• no further decline in the condition of woodlands in poor or degraded condition • increase the abundance of woodland seedlings and saplings in degraded communities on the active floodplain	• improve the condition score of woodlands in poor, degraded or severely degraded condition by at least one condition score • Support successful recruitment of trees in the long-term by increasing the abundance of young adult trees (10–30 cm DBH) compared to the previous 10-year period	
NV4e		Lignum shrublands	Maintain the 2016 mapped extent[5] of lignum shrubland communities	Increase the total area of lignum shrublands by 10% occurring within the active floodplain	
			Over a 5-year rolling period: • maintain the extent and proportion of shrublands in moderate or good condition • no further decline in the condition of shrublands in poor or degraded condition • increase the abundance of woodland seedlings and saplings in degraded communities on the active floodplain	Over a 5-year rolling period: • increase the proportion of shrublands in moderate or good condition • improve the condition score of shrublands in poor, degraded or severely degraded condition by at least one condition score	

3.3 Waterbird values and objectives

Waterbirds are useful indicators of the health of water-dependent ecosystems (Amat and Green 2010). In the 30 years to 2012, annual aerial waterbird surveys revealed a 72% decline in average waterbird abundance in the Murray–Darling Basin (MDBA 2014). This is a critical observation because waterbird 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). 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 and Norman 2002).

Waterbirds are a group of highly mobile species and can respond to flows over large spatial scales (Kingsford and Norman 2002; Amat and Green 2010). An improvement in waterbird populations across the Murray–Darling Basin is one of the main ecological objectives of the Basin Plan. With more water available for 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).

More than 100 waterbird species have been recorded in the NSW portion of the MDB (MDBA 2014). Seven wetland sites in the Barwon–Darling have been recorded as having supported breeding for waterbird species, including two colonial breeding species in the Upper Darling[7] (Brandis and Bino 2016). Records show that the various wetlands and waterholes in the Barwon–Darling also support internationally significant waterbirds and vulnerable and endangered species including the nationally endangered Australian painted snipe (Table 4). The Talyawalka and Upper Darling River have been listed as important basin assets for waterbirds in the BWS for total abundance and diversity (for both locations) and also drought refuge for the Upper Darling (MDBA 2014).

Seventy-four waterbird species have been recorded in the Barwon–Darling River system (Brandis and Bino 2016). Records of breeding events along the Barwon–Darling River show the Darling floodplains on the northern bank near Louth (grey teal, Australian wood duck, yellow-billed spoonbill) and floodplains at the Darling–Warrego confluence (yellow-billed spoonbill, Pacific black duck) as most numerous (Brandis and Bino 2016). Records for the lakes of the Talyawalka system (grey teal, Australian wood duck, black swan, pink-eared duck) are fewer (Brandis and Bino 2016). These sites are dependent on overbank flows to receive water by floodplain inundation (Brandis and Bino 2016). The Barwon–Darling contains habitat suitable for threatened waterbird species such as brolga, black-necked stork, blue-billed duck and freckled duck (NSW DPI 2017a).

Table 4 Notable waterbird species recorded in the Barwon-Darling grouped by the five functional waterbird groups

Functional waterbird groups	Species and status
Ducks	Blue-billed duck (V), Freckled duck (V)
Herbivores	Wandering whistling-duck
Large waders	Brolga (V), black-necked stork (NSW E), glossy ibis (B, CN)
Piscivores	Caspian tern (J)

[7] Upper Darling, in this LTWP, usually means the Bourke to Louth planning unit where the Warrego junction floodplain is located.

Shorebirds	Australian painted snipe (E), common greenshank (C, J, K), Oriental pratincole (C, J, K), red-necked stint (C, J, K), sharp-tailed sandpiper (C, J, K)

V = listed as vulnerable on NSW threatened species list, NSW E = listed as endangered on NSW threatened species list, E = endangered on Commonwealth EPBC Act, C = CAMBA listed, J = JAMBA listed, K = RoKAMBA listed, B = Bonn Convention listed, CN = colonially nesting species

The total number of waterbird species and total number of individuals can change rapidly in response to flows, through 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). Such conditions 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 emergent vegetation dependent waterbirds, such as crakes, rails and bitterns. As wetlands dry exposed mudflats can form, providing feeding habitat for resident and migratory shorebird species.

Table 5 Waterbird (WB) ecological objectives

<table>
<tr><th colspan="2" rowspan="2">Ecological objectives</th><th colspan="3">Targets[8]</th></tr>
<tr><th>5 years (2024)</th><th>10 years (2029)</th><th>20 years[9] (2039)</th></tr>
<tr><td rowspan="2">WB1</td><td rowspan="2">Maintain the number and type of waterbird species[10]</td><td colspan="3">Maintain a five-year rolling average of 10 or more recorded waterbird species across the five functional groups in the Upper Darling and 12 or more waterbird species across the five functional groups in the Talyawalka System</td></tr>
<tr><td></td><td>Record the presence of at least 41 waterbird species in the Upper Darling and 42 waterbird species in the Talyawalka System in a ten-year period</td><td>Record the presence of at least 51 waterbird species in the Talyawalka and Upper Darling in a 20-year period</td></tr>
<tr><td>WB2</td><td>Increase total waterbird abundance across all functional groups</td><td>Maintain total waterbird abundance across all functional groups in the Talyawalka and Upper Darling compared to the five-year 2012-16 period</td><td>Total waterbird abundance increased in the Talyawalka and Upper Darling by 20-25% with increase in all functional groups in the next 10-year period.</td><td>Maintain or increase total waterbird abundance in the Talyawalka and Upper Darling 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 colspan="3">Maintain or increase the number of non-colonial breeding species and total abundance of non-colonial waterbirds by supporting breeding opportunities in the Talyawalka and Upper Darling[11].</td></tr>
<tr><td>WB4</td><td>Increase opportunities for colonial waterbird breeding</td><td colspan="3">Support active waterbird colonies in the Upper Darling by maintaining the water depth and duration of flooding (as required) to support breeding through to completion (from egg laying through to fledging including post-fledgling care) and maintain duration of flooding in key foraging habitats to enhance breeding success and the survival of young</td></tr>
<tr><td>WB5</td><td>Maintain the extent and improve condition of</td><td colspan="3">Maintain extent and improve condition of nesting vegetation, including lignum, cumbungi, river red gum and river cooba, in known colonial breeding locations in the waterbird area (floodplain wetlands at Warrego junction and near Louth.</td></tr>
</table>

[8] Waterbird targets are based on available data from Atlas of NSW Wildlife (NSW BioNet) 1980-2016 (NSW Bionet (2016)), Atlas of Living Australia (ALA) 1980-2016 (ALA (2017)), UNSW Aerial Waterbird Survey of Eastern Australia (AWSEA) 1983-2016 (Porter et al. (2016)), UNSW Specified Environmental Asset (SEA) (formerly Hydrological Indicator Surveys (HIS)) 2010-2016 (Bino et al. (2015), Kingsford et al. (2013)) and UNSW National Waterbird Survey 2008 (Kingsford et al. (2009)). These targets apply to Talyawalka and Upper Darling areas only, however ecological waterbird objectives are relevant to a wider range of planning units.

[9] 20-year targets will be further refined following additional data collection.

[10] Note that this objective refers to number of species, not number of individuals.

[11] Insufficient data between 2012-2016 to determine baseline target. Target to be refined when additional data available

Ecological objectives		Targets[8]		
		5 years (2024)	10 years (2029)	20 years[9] (2039)
	waterbird habitats	Maintain extent and improve condition of waterbird foraging and breeding locations in the Talyawalka and Teryaweynya Creeks and floodplain wetlands at floodplain wetlands at Warrego junction and near Louth (to be evaluated under targets set for native vegetation)		

Figure 9 **Grey teal, hardheads, wood duck and black duck, Warrego River floodplain in Bourke to Louth planning unit (see Part B)**
Photo: DPIE

3.4 Ecosystem function values and objectives

The Barwon–Darling 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 and Arthington 2002).

Schedule 9 of the Basin Plan describes priority ecosystem functions, which are:

- provision of vital habitat 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 channels,
- movement of water-dependent species,
- maintenance of water quality suitable for the persistence of flora and fauna.

The BWS also describes expected outcomes for river flows and connectivity in the Barwon–Darling, which are vital for supporting many of the LTWP objectives for priority ecosystem functions.

- maintain baseflows at least 60% of the natural level[12]
- a 10% overall increase in flows from increased tributary contributions[13]
- a 30% overall increase in the River Murray from increased tributary contributions[14]
- a 10–20% increase of freshes and bankfull events

Ecosystem functions have been broadly grouped based on the broad 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 and 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 (Boulton 2003). 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 re-colonisation and population growth (Adams and 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 and 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 and Mitrovic 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 allow organisms to move and disperse 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, conditioning, and re-colonisation 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 and King 2004).

[12] cease-to-flow events should not exceed natural, where possible

[13] contributions are expected from the Condamine-Balonne, Border Rivers, Gwydir, Namoi and Macquarie-Castlereagh catchments collectively

[14] contributions are expected from the Murrumbidgee, Goulburn, Campaspe, Loddon and Lower Darling Catchments (which the Barwon-Darling is directly connected to)

Figure 10 Low flows reveal fish habitat in the Barwon–Darling River
Photo: Neal Foster

Instream and floodplain productivity

The supply of organic material underpins all river food webs by providing the food energy needed to drive life. 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. Instream productivity can be gained by wetting surfaces at higher elevation and higher velocity in-channel flows that scour and break down filamentous algae (Davie and Mitrovic 2014).

Groundwater-dependent ecosystems

While this LTWP is primarily focused on the management of surface water, there are interactions with groundwater and groundwater-dependent ecosystems. It is important that surface water and groundwater are managed in a coordinated way to continue to support groundwater dependent ecosystems and low flows in highly connected areas in the Barwon–Darling. Objectives in the LTWP relate to maintaining the mapped extent of groundwater-dependent vegetation communities and groundwater levels within their long-term natural ranges.

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 loss of lateral connectivity between rivers and their floodplains has altered water movement, the flux of sediment, nutrients, carbon, and biota from and to the river (Baldwin et al. 2016). 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 planning units (PUs) and with Menindee Lakes and the Lower Darling and Murray River during critical spawning periods will support native fish outcomes and contribute to improved outcomes in the Barwon–Darling 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 Ecosystem Function (EF) ecological objectives

Ecological objective			Description and key contributing processes	Targets		
				5 years (2024)	10 years (2029)	20 years (2039)
EF1	Provide and protect a diversity of refugia across the landscape		Water depth and quality in pools (in-channel), core wetlands and lakes Condition of vegetation in core wetlands and riparian zones	Adequate water depth is maintained in key refuge pools during dry times; strategies may include ensuring cease-to-flow periods do not exceed maximum durations as specified in planning unit EWRs Maintain dissolved oxygen >4 mg/L (and salinity levels at ecologically tolerable levels) in key refuge pools		
EF2	Create quality instream, floodplain and wetland habitat		Regulation of dissolved oxygen, salinity and water temperature Flow variability and hydrodynamic diversity Provision of diverse wetted areas Appropriate wetting and drying cycles Geomorphic (erosion/deposition) processes that create and maintain diverse physical habitats Appropriate rates of fall to avoid excessive bank erosion Control of woody-vegetation encroachment into river channels and wetlands	Rates of fall in flow or water height do not exceed the 95th percentile of natural rates, for example in pools or areas of high hydrological stress. Implement (through protection or creation) flows in all flow categories to provide variability in the flow regime along the system to inundate a variety of in-channel and floodplain wetland habitats		
EF3a	Provide movement and dispersal opportunities for water dependent	within catchments	Dispersal of eggs, larvae, propagules and seeds downstream and into off-channel habitats Migration to fulfil life-history requirements Foraging of aquatic species	Annual detection of species and life stages representative of the whole fish community through key fish passages in specified planning units Protect the recommended frequency and duration of flows providing lateral connectivity with anabranches, wetlands and floodplains Increase in passage of key moderate to long-lived riverine and flow pulse specialists through key fish passages in the Barwon–Darling compared to passage rates detected in 2014–2019		

Ecological objective		Description and key contributing processes	Targets		
			5 years (2024)	10 years (2029)	20 years (2039)
EF3b	biota to complete lifecycles and disperse into new habitats between catchments	Re-colonisation following disturbance	Protect dispersal opportunities between catchments for native fish species, with a focus on moderate to long-lived flow pulse specialist native fish species, within 12 months of major breeding events and dry spells.		
EF4	Support instream and floodplain productivity	Aquatic primary productivity (algae, macrophytes, biofilms, phytoplankton) Terrestrial primary productivity (vegetation) Aquatic secondary productivity (zooplankton, macroinvertebrates, fish larvae, adult fish) Decomposition of organic matter	Maintain or increase the proportion of wetland and floodplain vegetation that is in good condition over a 5-year rolling period Maintain native fish population structure that indicates successful transition from young-of-year to juveniles Protect riverine productivity to support increased food availability for aquatic food webs by increasing the supply of autochthonous and allochthonous carbon and nutrients		
			No decline in key native fish species condition metrics Maintain the abundance and distribution of decapod crustaceans	Improve key native fish species condition metrics Improve the abundance and distribution of decapod crustaceans	
EF5	Support nutrient, carbon and sediment transport along channels, and between channels and floodplains/wetlands	Sediment delivery to downstream reaches and to/from anabranches, floodplains and wetlands Mobilisation of carbon and nutrients from in-channel surfaces (e.g. benches/banks), floodplains and wetlands and transport to downstream reaches and off-channel habitats Dilution of carbon and nutrients that have returned to rivers	Protect lateral connectivity with anabranches, wetlands and floodplains, as specified in EWRs for large freshes, bankfull events and overbank flows Maintain extent and condition of floodplain vegetation		
				Maintain nutrient and carbon (DOC) pulses at multiple locations along a channel during freshes, bankfull and overbank events	
					Maintain soil nitrogen, phosphorus and carbon levels at long-term natural levels

Ecological objective		Description and key contributing processes	Targets		
			5 years (2024)	10 years (2029)	20 years (2039)
EF6	Support groundwater conditions to sustain groundwater dependent biota	Groundwater recharge and discharge Dilution of saline/acidic groundwater Salt export from the Murray–Darling Basin	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 the contribution of flows into the Lower–Darling and Murray.	Provision of end-of-system flows to support ecological objectives in downstream catchments	No reduction in rolling 5-year average flows at each end of planning unit gauge and end of catchment gauge. No increase in the long term average number of days of cease-to-flow conditions.		

3.5 Aboriginal cultural values and objectives

NSW LTWPs recognise the importance of rivers and wetlands to Aboriginal culture. For First Nations People, water is a sacred source of life. The natural flow of water sustains aquatic ecosystems that are central to their spirituality, culture and wellbeing. Rivers are described as ‘the veins of Country’, carrying water to sustain all parts of their sacred landscape, and the wetlands described as the ‘kidneys’, filtering the water as it passes through the land (National Cultural Flows Research Project, 2019).

The waterways and floodplains of the Barwon–Darling WRPA are central to its Traditional owners, who have longstanding and continuing ties to country, the waterways and life sustained by it.

Aboriginal cultural values are related to specific places, plants and animals and to the landscape as a whole. There are important linkages between flow events and cultural outcomes. NSW LTWPs acknowledge Aboriginal connection to country and aim to protect country by maintaining the health of rivers and wetlands, and water-dependent plants and animals that have cultural value.

Consultation with Aboriginal Nations of the Barwon–Darling WRPA on cultural values and objectives related to water-dependant ecosystems and management of water more broadly is ongoing, including as part of the development of the *Barwon–Darling Surface Water Resource Plan* (NSW DPIE 2019a).

Aboriginal Waterways Assessments (AWA) provide a tool for Aboriginal communities to measure the health of rivers and wetlands, including a site’s cultural significance and current use. These assessments provide a means for Aboriginal Traditional Owners to participate and inform various water planning processes including the development of Water Resource Plans, Long Term Water Plans, Basin annual watering priorities and the Basin Watering Strategy (MLDRIN undated).

4. Environmental water requirements

Flow and inundation regimes drive the ecological characteristics of rivers and floodplain wetlands (Poff and Zimmermann 2010). A flow regime represents the sequence of flow events over time, and it is this sequence of different flow magnitudes that produce flooding and drying patterns. Flow regimes govern river channel and wetland formation, their configuration and connectivity with the floodplain. Flow regimes prompt key ecological processes such as nutrient cycling and energy flow, breeding and migration, and dispersal of plants and animals.

The sequence of flows over time can be considered as a series of discrete events. These events can be placed into different flow categories (e.g. baseflows, freshes, bankfull, overbank and wetland flows) according to the magnitude of flow discharge or height within a watercourse, and the types of outcomes associated with the events (e.g. inundation of specific features such as channel benches, riparian zones or the floodplain).

Each flow category can provide 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. Flow categories describe the height or level of a flow within a river channel or its extent across a floodplain (Figure 11 and Table 7). Flow rates for flow categories at sites along the Barwon–Darling are shown in Table 9.

An environmental water requirement (EWR) is the flow or inundation regime that a species, or community, needs to ensure its survival and persistence. It can also be the flow regime needed to meet the water requirements of a range of species in a defined geographic area. EWRs are based on knowledge of a species' biological and ecological needs, such as what it needs to feed, breed, disperse and migrate.

Meeting the full life-history needs of an aquatic organism (plant or animal) typically requires a combination of several different flow categories 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.

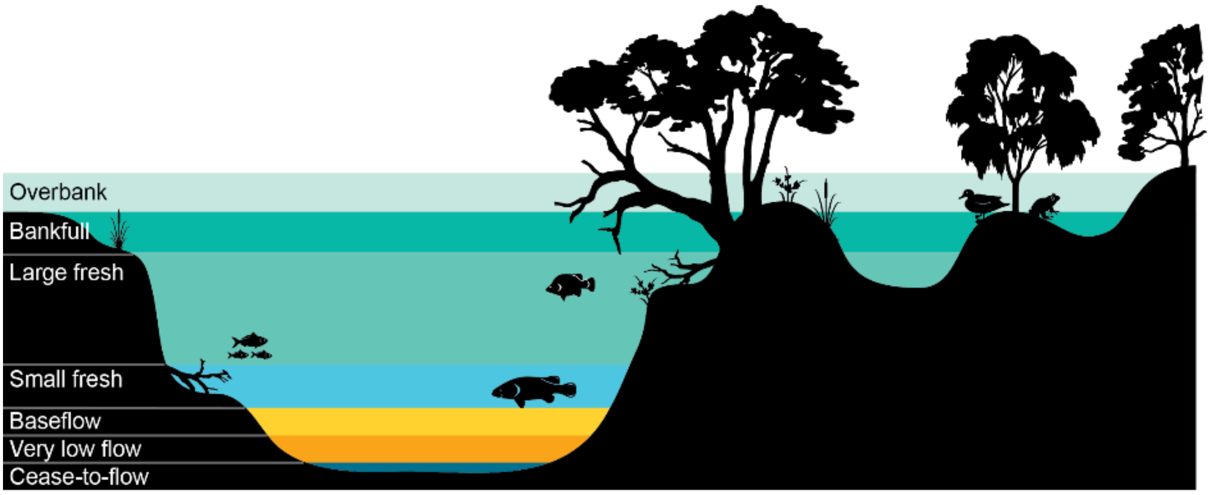

Figure 11 A simplified conceptual model of the role of each flow category

Table 7 Description of the role of each flow category

Flow category	Description
Overbank flow (OB)	Floodplain connection flows provide broad scale lateral connectivity with floodplain and wetlands. They support nutrient, carbon and sediment cycling between the floodplain and channel, and promote large-scale productivity.
Bankfull flow (BK)	Inundates all in-channel habitats and connects many low-lying wetlands. They provide partial or full longitudinal connectivity and drown out of most small in-channel barriers (e.g. small weirs).
Large fresh (pulse) (LF)	Inundates benches, snags and inundation-tolerant vegetation higher in the channel. They support productivity and transfer of nutrients, carbon and sediment. They also provide fast-flowing habitat and may connect wetlands and anabranches with low commence-to-flow thresholds. The key benefit of these flows is to increase productivity and nutrient transport in the river channel and increase habitat area.
Small fresh (pulse) (SF)	Improves longitudinal connectivity. They inundate lower banks, bars, snags and in-channel vegetation, and can flush pools and stimulate productivity/food webs. They can provide a trigger for aquatic animal movement and breeding.
Baseflow (BF)	Provides connectivity between pools and riffles and along channels. They provide sufficient depth for fish movement along reaches.
Very low flow (VLF)	Minimum flow in a channel that prevents a cease to flow. They provide connectivity between some pools.
Cease-to-flow (CTF)	Partial or total drying of the channel. The stream contracts to a series of disconnected pools and there is no surface flow.

4.1 Developing environmental watering requirements to support ecological objectives

Development of EWRs for LTWPs drew 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 water requirements (flow category, duration, timing, etc.) overlapped between species or groups, the individual requirements were combined to provide a single EWR that supported the relevant group of environmental objectives.

At the planning unit scale, 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.

Each EWR is expressed as a flow category that has been assigned a flow rate or volume, an ideal timing, duration and frequency, and a maximum inter-event period based on the suite of plants, animals and functions it supports (see the Table 8 for full description of EWR terms). Complete EWRs for each planning unit the Barwon–Darling, including flow rates and total volumes, can be found in Part B.

A summary of flow rates for flow categories at sites along the Barwon–Darling are shown in Table 9. The timing, duration and frequency components of EWRs, grouped by flow category, for all biota and functions in the Barwon-Darling catchment and the objectives they support, are presented in Table 10.

Table 8 Description of terms used for environmental water requirements (see Table 10)

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 and 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), and a short description of key objectives and life stages being targeted (e.g. spawning or recruitment). Bold text indicates the primary objectives of each EWR. See Tables 2, 3, 5 and 6 for full objectives.
Gauge	The flow gauging station that best represents the flow within the planning unit, for the purpose of the respective EWR and associated ecological objective(s). To assess the achievement of the EWR, flow recorded at this gauge should be used.
Flow rate or flow volume	The flow rate (typically ML/d) or flow volume (typically GL over a defined period of time) that is required to achieve the relevant ecological objective(s) for the EWR. Most EWRs are defined using a flow rate, whilst flow volumes are used for EWRs that represent flows into some large wetland systems.
Timing	The required timing (or season, typically expressed as a range of months within the year) for a flow event to achieve the specified ecological objective(s) of the EWR. In some cases, a preferred timing is provided, along with a note that the event may occur at 'anytime'. This indicates that ecological objectives <u>may</u> be achieved outside the preferred timing window, but perhaps with sub-optimal outcomes. In these instances, for the purposes of managing and delivering environmental water, the preferred timing should be used to give greater confidence in achieving ecological objectives. Natural events may occur at other times and still achieve ecological objectives.
Duration	The duration for which flows must be above the specified flow rate for the flow event to achieve the specified ecological objective(s) of the EWR. Typically this is expressed as a minimum duration. Longer durations will often be desirable and deliver better ecological outcomes. Some species may suffer from extended durations of inundation, and where relevant a maximum duration may also be specified. Flows may persist on floodplains and within wetland systems after a flow event has past. Where relevant a second duration may also be specified, representing the duration for which water should be retained within floodplain and wetland systems.
Gauge	The flow gauging station that best represents the flow within the planning unit, for the purpose of the respective EWR and associated ecological objective(s). To assess the achievement of the EWR, flow recorded at this gauge should be used.
Flow rate or flow volume	The flow rate (typically ML/d) or flow volume (typically GL over a defined period of time) that is required to achieve the relevant ecological objective(s) for the EWR. Most EWRs are defined using a flow rate, whilst flow volumes are used for EWRs that represent flows into some large wetland systems.
Timing	The required timing (or season, typically expressed as a range of months within the year) for a flow event to achieve the specified ecological objective(s) of the EWR. In some cases, a preferred timing is provided, along with a note that the event may occur at 'anytime'. This indicates that ecological objectives

Term	Definition
	may be achieved outside the preferred timing window, but perhaps with sub-optimal outcomes. In these instances, for the purposes of managing and delivering environmental water, the preferred timing should be used to give greater confidence in achieving ecological objectives. Natural events may occur at other times and still achieve ecological objectives.
Duration	The duration for which flows must be above the specified flow rate for the flow event to achieve the specified ecological objective(s) of the EWR. Typically this is expressed as a minimum duration. Longer durations will often be desirable and deliver better ecological outcomes. Some species may suffer from extended durations of inundation, and where relevant a maximum duration may also be specified. Flows may persist on floodplains and within wetland systems after a flow event has passed. Where relevant a second duration may also be specified, representing the duration for which water should be retained within floodplain and wetland systems.
Frequency	The frequency at which the flow event should occur to achieve the ecological objective(s) associated with the EWR. Frequency is expressed as the number of years that the event should occur within a 10-year period. In most instances, more frequent events will deliver better outcomes, and 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 and recruitment of native fish, vegetation and waterbird 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 and maximum inter-flow period, and the two must be considered together when evaluating outcomes or managing systems. Where a range of frequencies is indicated (e.g. 3–5 years in 10), the range reflects factors including the natural variability in population requirements, uncertainty in the knowledge base, and variability in response during different climate sequences (e.g. maintenance of populations during dry climate sequences at the lower end of the range, and population improvement and recovery during wet climate sequences at the upper end of the range). The lower end of the frequency range (when applied over the long term) may not be sufficient to maintain populations and is unlikely to achieve any recovery or improvement targets. As such, when evaluating EWR achievement over the long-term through statistical analysis of modelled or observed flow records, the LTWP recommends using a minimum long term average (LTA) target frequency that is at least the average of the recommended frequency range but may be higher than the average where required to achieve objectives. For example, for a recommended frequency range of 3–5 years in 10, the minimum LTA frequency should be at least 40% of years but may be up to 50% of years at sites where a higher frequency should be targeted over the long term to ensure recovery in certain species/populations. Whilst these higher frequencies may exceed modelled natural event frequency in some cases, recovery in particularly degraded systems will be unlikely should lower (i.e. average) frequencies be targeted. Minimum LTA target frequencies in this LTWP are reported predominantly as the average of the recommended frequency range, however this may be refined during implementation of the LTWP and in future revisions of the LTWP based on the results of ongoing ecological monitoring.

Term	Definition
Maximum inter-flow or inter-event period	The maximum time between flow events before a significant decline in the condition, survival or viability of a particular population is likely to occur, as relevant to the ecological objective(s) associated with the EWR. This period should not be exceeded wherever possible. *Annual planning of environmental water should consider placing priority on EWRs that are approaching (or have exceeded) the maximum inter-event period, for those EWRs that can be achieved or supported by the use of environmental water or management.*
Additional requirements and comments	Other conditions that should occur to assist ecological objectives to be met – for example rates of rise and fall in flows. Also comments regarding limitations on delivering environmental flows and achieving the EWR.

4.2 Flow thresholds

The flow rates that define each flow category (baseflows, small freshes etc.) and associated EWRs will vary across catchments and river reaches. Table 9 describes the range of flow rates for each flow category at representative gauge sites in the Barwon-Darling catchment (Figure 12). The minimums in these flow ranges are where the benefits of flow categories are likely to begin manifesting. Further substantial benefits occur, particularly for wetland connecting large freshes and overbanks, as flows increase in size. While flow category thresholds are expressed as ranges here in Table 9, flow rates for the complete EWRs (see Part B) are expressed as exceedance thresholds in most cases (e.g. >100 ML/d), meaning that an EWR in the baseflow category (BF1) for example, can be met by flows in the baseflow category range (e.g. 100-500 ML/d) or higher flows.

Table 9 Flow rate threshold estimates (ML/d) for flow categories in the Barwon–Darling

Gauging site	Cease-to-flow	Very low flows	Baseflow	Small fresh	Large fresh	Bankfull	Small overbank	Medium overbank	Large overbank
MUNGINDI TO BOOMI RIVER									
Barwon River at Mungindi (416001)	<1	45-160	160-540	540-3000	3000-7900	7900-9500	>10,000	>13,000	>19,000
Barwon River upstream of Presbury (416050)	<1	35-140	140-500	500-2700	2700-7400	7400-9000	>12,000	>15,000	>23,000
BOOMI RIVER TO MOGIL MOGIL WEIR POOL									
Barwon River at Mogil Mogil (422004)	<1	75-220	220-680	680-5200	5200-13,000	13,000-15,000	>15,000	>18,000	>26,000
DOWNSTREAM MOGIL MOGIL TO COLLARENEBRI									
Barwon River at Collarenebri (422003)	<1	80-280	280-650	650-4200	4200-16,000	16,000-18,000	>18,000	>25,000	>32,000
COLLARENEBRI TO UPSTREAM WALGETT WEIR									
Barwon River at Tara (422025)	<1	75-250	250-500	500-3500	3500-20,000	20,000-25,000	>27,000	>40,000	>50,000
WALGETT WEIR POOL									
Barwon River at Dangar Bridge (422001)	<1	95-320	320-700	700-6500	6500-22,000	22,000-27,000	>45,000	>71,000	>109,000

Gauging site	Cease-to-flow	Very low flows	Baseflow	Small fresh	Large fresh	Bankfull	Small overbank	Medium overbank	Large overbank
DOWNSTREAM WALGETT TO BOOROOMA									
Barwon River at Boorooma (422026)	<1	95-350	350-860	850-7000	7000-17,000	17,000-20,000	>44,000	>68,000	>107,000
BOOROOMA TO BREWARRINA									
Barwon River at Geera (422027)	<1	110-440	440-1000	1000-7000	7000-22,000	22,000-27,000	>34,000	>43,000	>107,000
Barwon River at Brewarrina (422002)	<1	100-500	500-1000	1000-9000	9000-26,000	26,000-32,000	>38,000	>52,000	>83,000
BREWARRINA TO CULGOA RIVER JUNCTION									
Barwon River at Beemery (422028)	<1	110-500	500-1200	1200-12,000	12,000-27,000	27,000-32,000	>42,000	>53,000	>96,000
CULGOA RIVER JUNCTION TO BOURKE									
Darling River at Warraweena (425039)	<1	115-550	550-1500	1500-15,000	15,000-30,000	30,000-35,000	>51,000	>62,000	>130,000
Darling River at Bourke (425003)	<1	105-500	500-1550	1550-15,000	15,000-30,000	30,000-35,000	>50,000	>62,000	>129,000
BOURKE TO LOUTH									
Darling River at Louth (425004)	<1	70-450	450-1500	1500-15,000	15,000-30,000	30,000-35,000	>44,000	>57,000	>125,000
LOUTH TO TILPA									
Darling River at Tilpa (425900)	<1	60-400	400-1450	1450-14,500	14,500-28,000	28,000-33,000	>41,000	>51,000	>120,000
TILPA TO WILCANNIA and WILCANNIA TO LAKE WETHERILL and TALYAWALKA									
Darling River at Wilcannia (425008)	<1	30-350	350-1400	1400-14,000	14,000-25,000	25,000-29,000	>30,000	>31,000	>43,000

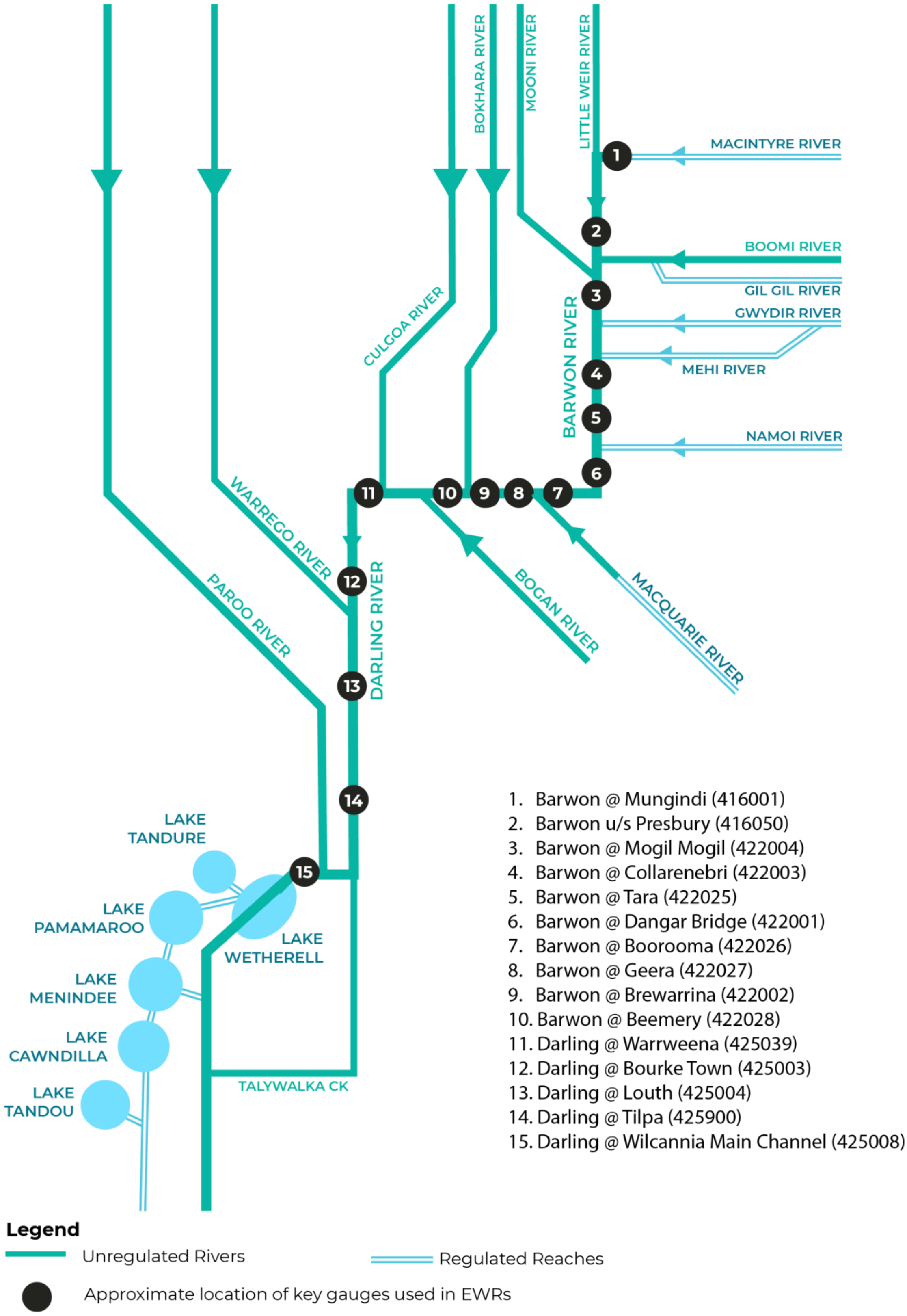

Figure 12 **Schematic diagram showing river gauge locations on the main watercourse of the Barwon–Darling**

4.3 Catchment-scale environmental water requirements

Table 10 Catchment-scale environmental water requirements

Flow category and EWR code[15]		Ecological objectives	Ideal flow timing	Duration	Frequency (LTA freq.)	Maximum inter-event period	Additional requirements/ comments
Cease-to-flow	CTF1	Native Fish: NF1 – **Survival** (all species) Ecosystem Functions: EF1, 2 – **refuge** habitat	In line with low flow season	In line with natural, unless key refuges endangered	No greater than natural	N/A	When managing water to restart flows, avoid harmful water quality impacts, such as de-oxygenated refuge pools.
Very low flow	VLF1	Native Fish: NF1 – **Survival** and condition (all species) Ecosystem Functions: EF1, 2 – **refuge** habitat	Any time	No less than natural	No less than natural	No greater than natural	Flows that provide replenishment volumes to refuge pools along the Barwon-Darling. Waterhole persistence can also be supported by groundwater.
Baseflow	BF1	Native Fish: NF1–9 – **condition and movement** (all species) Native Vegetation: NV1 – in-channel non woody Ecosystem Functions: EF1, 2, 3a	Any time	No less than natural	No less than natural	No less than natural	Aiming to provide a depth of 0.3 m to allow fish passage. Also to manage water quality, prevent destratification and reduce risk of blue-green algal blooms.
	BF2	Native Fish: NF1, 2, 5, 8 – **recruitment of riverine specialists, generalists**	September to March	No less than natural	5–10 years in 10 (75% of years)	2 years	Aiming to provide a depth of 0.3 m or more to allow fish passage.

[15] See Table 8 for definitions of terms and explanatory text for EWRs

Flow category and EWR code[15]		Ecological objectives	Ideal flow timing	Duration	Frequency (LTA freq.)	Maximum inter-event period	Additional requirements/ comments
Small fresh	SF1	Native Fish: NF1 – 9 **dispersal/ condition** (all species) Native Vegetation: **NV1 – in-channel non woody** Waterbirds: WB5 – habitat (some planning units) Ecosystem Functions: EF1, 2, 3, 4, 5	Anytime – but ideally October to April	10 days minimum	Annual (100% of years)	1 year	Ideal timing is based on preferred temperature range for fish spawning – >20°C for most native fish and >18°C for Murray cod. Aiming to provide a depth of 0.5 metres or more to allow movement of large fish. Flow velocity ideally up to 0.3 to 0.4 m/s (depending on channel form). Ideally shortly after LF2 for increased likelihood of successful recruitment of fish, productivity and dispersal.
	SF2	Native Fish: NF1, 2, 5, 8 – **Spawning (river specialists, generalists)** Native Vegetation: NV1 – in-channel non woody Waterbirds: WB5 – habitat (some planning units) Ecosystem Functions: EF1, 2, 3, 4, 5	September to April	14 days minimum	5–10 years in 10 (75% of years)	2 years	Timing is based on preferred temperature range for fish spawning - >20°C for most native fish and >18°C for Murray cod. Aiming to provide a depth of 0.5 metres or more to allow movement of large fish. Flow velocity ideally up to 0.3 to 0.4 m/s (depending on channel form).
Large fresh	LF1	Native Fish: NF1 – 9 – **dispersal/ condition** (all species) Native Vegetation: NV1, 3 – in-channel non woody/ fringing river red gum Waterbirds: WB5 – habitat (some planning units) Ecosystem Functions: EF2 – 7	Anytime, but ideally July to September	15 days minimum	5–10 years in 10 (75% of years)	2 years	This flow in Jul to Sep will improve pre-spawning fish condition. Aiming to provide a depth of 2 m to cover in-stream features and trigger response from fish. Flow velocity ideally 0.3 to 0.4 m/s (depending on channel form).
	LF2	Native Fish: NF1, 4, 6, 9 – **spawning (flow pulse specialist fish)** Native Vegetation: NV1, 3 – in-channel non woody/ fringing river red gum Waterbirds: WB5 – habitat (some planning units) Ecosystem Functions: EF2 – 7	October to April	15 days minimum	3–5 years in 10 (42% of years)	2 years	Aiming to provide a depth of 2 m to cover in-stream features and trigger response from fish. Flow velocity ideally 0.3 to 0.4 m/s (depending on channel form). Temp preferably >17°C to maximise spawning outcomes. Ideally shortly before SF1.

Flow category and EWR code[15]		Ecological objectives	Ideal flow timing	Duration	Frequency (LTA freq.)	Maximum inter-event period	Additional requirements/ comments
Bankfull	BK1	Native Fish: NF1-9 - spawning and recruitment (flow pulse specialists, generalists); dispersal (all species) Vegetation: NV1,2,3,4e - in-channel and **wetland non-woody vegetation**; **fringing river red gum**, lignum Waterbirds: WB1, 2, 5: habitat Ecosystem functions: EF1-7 - **hydraulic diversity**; channel maintenance; lateral connectivity, nutrient and carbon transfer, **productivity,** groundwater recharge, **biotic dispersal**	Anytime	5-15 days minimum, depending on site	5 in 10 years (50% of years)	4 years	
Overbank	OB1	Native Fish: NF1–9 – **spawning and recruitment (flow pulse specialists, floodplain specialists, generalists), dispersal and condition (all species)** Native Vegetation: NV2,3,4c,4e – **fringing river red gum**, black box, **lignum** Waterbirds: WB1–5 colonial and non-colonial habitat, non-colonial breeding Ecosystem Functions: EF2– 7: **lateral connectivity, productivity**, nutrient and carbon transfer	Anytime	5-15 days minimum, depending on site	2 to 4 years in 10 (30% of years)	5 years	Clustered events (i.e. multiple events over 2–3 years) will provide improved conditions for native vegetation recruitment. Multiple events in close proximity will also improve the condition of native veg communities.
	OB2	Native Fish: NF1–9 – **spawning and recruitment (flow pulse specialists, floodplain specialists, generalists), dispersal and condition (all species)** Native Vegetation: NV2,3,4c-e – fringing river red gum, **black box, lignum,** coolibah Waterbirds: WB1–5 **colonial and non-colonial habitat and breeding** Ecosystem Functions: EF2– 7: **lateral connectivity, productivity**, nutrient and carbon transfer	Anytime	5-15 days minimum, depending on site	1 to 3 years in 10 (20% of years)	10 years	Clustered events (i.e. multiple events over 2–3 years) will provide improved conditions for native vegetation recruitment. Multiple events in close proximity will also improve the condition of native veg communities.

Flow category and EWR code[15]		Ecological objectives	Ideal flow timing	Duration	Frequency (LTA freq.)	Maximum inter-event period	Additional requirements/ comments
	OB3	Native Fish: NF1–9 – **spawning and recruitment (flow pulse specialists, floodplain specialists, generalists), dispersal and condition (all species)** Native Vegetation: NV2,3,4c-e – fringing river red gum, **black box**, lignum**, coolibah** Waterbirds: WB1–5 **colonial and non-colonial habitat and breeding** Ecosystem Functions: EF2–: **lateral connectivity, productivity**, nutrient and carbon transfer	Anytime	5-15 days minimum, depending on site	0.5–2 years in 10 (10% of years)	15 years	Clustered events (i.e. multiple events over 2–3 years) will provide improved conditions for native vegetation recruitment. Multiple events in close proximity will also improve the condition of native veg communities.

4.4 Changes to the flow regime

Flows in the Barwon–Darling are highly variable. The flow regime is characterised by flood events and intervening low flow periods, which can last a few months, or occasionally, a few years. Despite the semi-arid nature of the plan area itself, flow events can be expected at least once or twice a year, and long periods of no flow are generally the exception (NSW DPI 2012).

Flows in the Barwon and Darling Rivers have changed significantly since European settlement, owing to river regulation, extraction and land development across the tributary catchments of NSW and QLD, and within the Barwon–Darling plan area itself. The Basin Plan estimates that total diversions across the Northern Basin amount to about 3860 GL/year long-term-average, with 198 GL/year of this associated with diversions from the Barwon–Darling Water Resources Plan area.

Major headwater dams across the Northern Basin have a combined storage capacity of about 5200 GL (NSW DPI 2012) and the volume of private storages, mostly associated with floodplain harvesting activities, was estimated at approximately 3000 GL in 2007 (Webb McKeown and Associates 2007) and is likely to be greater now due to increase floodplain harvesting developments in NSW. To put these figures into context, MDBA modelling estimates total Barwon-Darling inflows under without-development conditions to be about 4400 GL/year, and 2771 GL/year under current modelled conditions (Table 12) (MDBA 2012b).

Change in inflows

The storage and diversion of water for irrigation in the northern basin is having a significant impact on Barwon–Darling inflows, as shown in Table 11. Average annual inflows have reduced by 37%, with the greatest reduction coming from the Condamine–Balonne, where inflows to the Darling are estimated to have reduced by 327 GL (57%).

Table 11 Change in long-term average end of system flows in Barwon–Darling tributary catchments (MDBA 2012b)

Tributary catchment	Modelled without development conditions (GL/year)	Modelled current conditions (GL/year)	Reduction in modelled inflows (GL/year)	Reduction in modelled inflows (%)
Condamine–Balonne	569	242	327	57%
Border Rivers	797	513	284	36%
Gwydir	368	174	194	53%
Namoi	828	653	175	21%
Macquarie	760	577	183	24%
Barwon–Darling – total inflows	**4402**	**2771**	**1631**	**37%**

Change in overall flow volumes

Changes in inflows, together with diversions within the Barwon–Darling, have reduced the annual average flow along the Barwon–Darling River. Table 12 shows annual average flows under modelled without development and current conditions, showing that at Mungindi flow volumes have reduced by 40%, and downstream of Walgett by approximately 50%.

Table 12 Annual average flows under modelled without development and current conditions (DPIE analysis of model data)

Location	Modelled without development conditions (GL/year)	Modelled current conditions (GL/year)	Reduction in modelled inflows (GL/year)	Reduction in modelled inflows (%)
Barwon at Mungindi	540	328	212	39%
Barwon at Walgett	2563	1316	1247	49%
Darling at Bourke	3812	1896	1916	50%
Darling at Wilcannia	2819	1407	1412	50%

Change in occurrence of flow components

Diversion and storage of water for irrigation across the northern basin has impacted on the full spectrum of flows, from low flows (cease-to-flows, very low flows and baseflows) through to overbank flows. Flow peaks are lowered, and the duration of flow events is reduced. There is also less variability in flows (MDBA 2016). Development has increased the duration of no-flows, causing prolonged cease-to-flow events (MDBA 2018).

Table 13 shows the percentage change in the frequency of flows of each category, comparing modelled current conditions and without development conditions. For example, at Bourke, flows in the large fresh flow category are 61% less frequent under modelled current conditions, compared to without development conditions. Note that the Barwon–Darling model is not considered accurate at representing low flow conditions, and accordingly the results for low flows are considered unreliable (grey shading).

Table 13 Change in the modelled frequency of flow categories at sites along the Barwon–Darling (comparing modelled current conditions to modelled without development scenarios)

Flow category	Change in frequency of flow category			
	Barwon at Mungindi	Barwon at Walgett	Darling at Bourke	Darling at Wilcannia
Cease-to-flow[16]	-2%	1%	1%	2%
Very low flows	-5%	-7%	6%	5%
Baseflows	-12%	-21%	-12%	-17%
Small freshes	-25%	-28%	-37%	-42%
Large freshes	-54%	-47%	-61%	-56%
Bankfull	-43%	-51%	-59%	-59%
Small overbank	-32%	-52%	-51%	-51%
Medium overbank	-	-55%	-49%	-
Large overbank	-35%	-56%	-61%	-50%

[16] The Barwon-Darling river system model is not considered accurate at representing low flow conditions, and accordingly the results for low flows are not considered reliable (grey shading)

Given uncertainties in the model representation of low flow conditions, analysis of observed flows is best used to identify changes in low flow conditions. Figure 13 shows observed flows at Bourke since 1944 (when continuous records commenced) together with the percentage of time that cease-to-flow conditions were experienced, by decade. This shows that from 1944 to 1990 cease-to-flow conditions were experienced about 4% of the time. From 2000 to 2019, the proportion of time that cease-to-flow conditions are experienced at Bourke has increased to about 25% of the time.

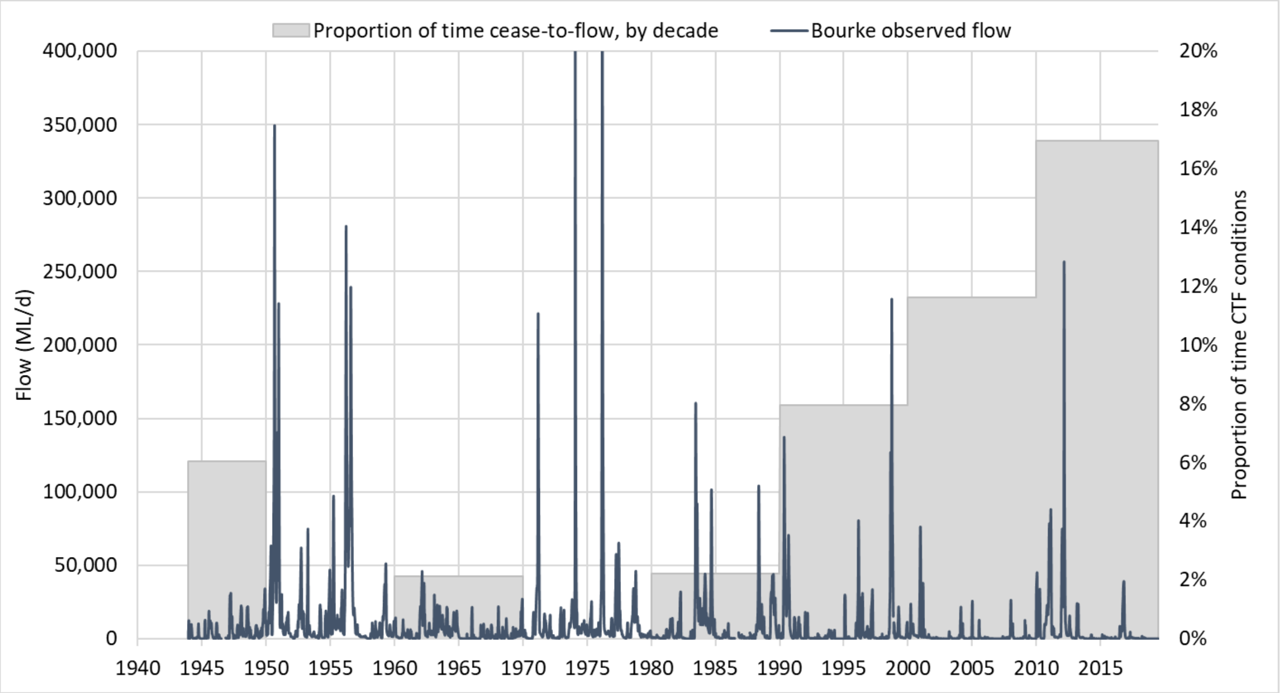

Figure 13 **Observed flows at Bourke (425003) since 1944, together with the proportion of time that cease-to-flow conditions (<1 ML/d) were experienced, by decade (DPIE analysis)**

Figure 14 **Darling floodwaters**
Photo: Josh Smith

5. Risks, constraints and strategies

This chapter considers risks, constraints and future management strategies to improve environmental outcomes for the Barwon–Darling. Water managers focus on delivering these outcomes in a modified landscape, with a variable climate and reliance on upstream tributary systems.

There are many factors that could potentially impact implementation of components of this plan, and how the environment responds to management actions. These are primarily recognised as either *risks* or *constraints* in relation to achieving outcomes.

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

- meet the stated EWRs of environmental assets, values and functions (Section 4)
- achieve the ecological objectives of the LTWP (Section 3).

In order to help address these, this LTWP has identified some key investment opportunities that would contribute to improving the likelihood that EWRs and ecological objectives can be achieved (Table 24). These are split into flow and non-flow based risks and constraints in section 5.1 and 5.2 respectively.

The *Risk Assessment for the Barwon–Darling Water Resource Plan Area* (NSW DPIE 2019b) was undertaken to inform water resource planning in the Barwon–Darling WRPA. It identifies risks to areas of conservation value based on hydrological change and significance of values within sub-catchments. This chapter of the Barwon-Darling LTWP aims to complement the DPIE Water Risk Assessment, addressing the specific risks and constraints related to delivering water for the environment.

Figure 15 The Darling River downstream of Wilcannia
Photo: Neal Foster

5.1 Risks and constraints to meeting EWRs in the Barwon–Darling LTWP Area

Table 14 below presents the flow-related risks in the following sub-sections:

- Risks to inflows from tributaries
- Risks to inflows from QLD tributaries
- Risks within the Barwon–Darling WRPA
- Water quality risks arising from altered flow regime
- Risks arising from downstream management

Table 14 Flow-related risks to meeting EWRs identified in the Barwon–Darling

Type of risk	Description	Potential management strategies	Potential project partners
Risks to inflows from tributaries			
Protection of Planned Environmental Water (PEW) from tributaries. The provision of planned environmental water (long-term average annual flow) within the Barwon–Darling is not ensured by tributary catchment Water Resource Plans. (See below for separate risk relating to protection of held and discretionary environmental water flowing from regulated into unregulated systems.)	Water recovered for the environment in tributary catchments is, in some cases, constrained from flowing into the Barwon–Darling via rule sets in those WRP Areas. Some WRP Areas have end-of-system flow rules though these are not always intended to provide connectivity between WRPA, and contribute flows to Barwon–Darling and basin. Gap between modelled outcomes being reflected in flow rules leaves operational practice a major risk to connectivity.	Review end-of-system rules to ensure they maximise environmental outcomes for both the tributary WRPA and the Barwon–Darling and give effect to shared recovery targets.	DPIE Water
	Flows subject to Supplementary take in regulated tributary catchments can contribute to achieving EWRs in the Barwon–Darling if protected. Specifically, IUFMPNW (NSW DWR 1992) targets for fish and algae are met more often when protection is implemented. This measure is currently present in Gwydir, Namoi, Border Rivers WSP but not implemented, leaving operational practice a major risk to connectivity.	Implement triggers for upstream supplementary access restrictions in the same style as that expressed in Interim Unregulated Flow Management Plan for the North–West of NSW (NSW DWR 1992). Investigate the application of similar measures within other tributary catchments. Improve hydrometric capacity, flow forecasting to support implementation.	DPIE Water
	In very dry conditions, the presence of unregulated planned and held environmental water sources may be inadequate to achieve environmental outcomes, requiring other sources of water to be obtained on an event-based or temporary basis.	Explore options such as: -store and release environmental water using private irrigation infrastructure -the purchase of stored water from willing sellers Consider use of regulated	DPIE BC and CEWO

Type of risk	Description	Potential management strategies	Potential project partners
		environmental water sources from tributary WRP Areas if possible.	
Protection of discretionary PEW (from tributary catchments) and Held Environmental Water (HEW) (both from tributaries and within the Barwon-Darling). Additional environmental water in the Barwon-Darling WRPA cannot achieve intended environmental benefit due to inadequate protection from extraction. In the absence of other measures, HEW and discretionary PEW become available for legal consumptive take downstream of the nominal accounting point. Environmental water provides unintended benefit to consumptive users.	Without specific measures, flows above commence-to-pump thresholds can legally be taken, including water that is present due to its planned release as environmental water, or as it is water that has been purchased from the water market as unregulated access entitlement.	Temporary Protection of flow events (usually whole flow) put in place for a specific event, to achieve a specific outcome.	DPIE BC DPIE Water Water NSW NRAR
		Introduce active management to share flow events and provide protection for environmental water in unregulated streams. Active management protects the passage of active environmental water through the Barwon–Darling. It also protects the passage of environmental water through unregulated portions of tributary catchments where appropriate. Implementation will require investment in hydrometric network, accounting, communication, modelling (Table 24). This is a strategy being progressed by the Water Reform Action Plan. (NSW DOI 2018).	
	Coordinated flows are an approach to using held environmental water from tributary catchments so that it meets with other natural or released flows to form a combined event in the Barwon–Darling. This maximises the benefits of smaller holdings and allows for increased longitudinal connectivity in the Barwon–Darling.	Improved hydrometric capability in some areas. Protection of environmental flows through the implementation of active management or s324 temporary protections when combined flows are proposed. This is a strategy being progressed by the Water Renewal Action Plan. (2018).	

Type of risk	Description	Potential management strategies	Potential project partners
Meeting the required frequency of overbank flow events in the Barwon–Darling is at significant risk. Overbank flow events cannot be achieved with recovered water, as high flow rates are required.	Overbank flows that support floodplain vegetation require a volume of water that is beyond what can be achieved with water recovery.	Implement floodplain harvesting and structures regulation within tributary catchments. This is a strategy being progressed under the Healthy Floodplains Program.	DPIE Water NRAR
Inadequate suspension in extractions (upstream and within the Barwon–Darling) resulting in an extended cease-to-flow event in downstream river sections.	The resumption of flows after an extended period of cease-to-flow is ecologically critical to refill weir pools and re-wet dry riverbeds. Since flows in the Barwon–Darling are reliant on tributary catchments, flows in upstream areas also need to be considered for protection from extraction. This risk applies to inflows from both NSW and QLD catchments.	WSP rule to provide for an adequate resumption flow after a cease to flow event. This is a strategy being progressed by the Water Renewal Action Plan. (2018). Use of temporary protection of flow events to achieve a specific outcome, such as filling weir pools. Consider use of EWRs to inform the environmental impact assessment of access to imminent flows under *Sections 48 and 49 of the WSP (section numbers may change)*	DPIE Water
Climatic variability and drought in the Barwon-Darling catchment area (northern Basin)	Notwithstanding climate change, the natural variability in rainfall over the tributary catchments of the Barwon–Darling poses risks for meeting EWRs. The longest period of no flow observed in the Barwon–Darling River varies from gauge to gauge. In the middle of the millennium drought, in 2006/07 there was a cease to flow event of 3 months at Brewarrina, and an event of just under 12 months at Wilcannia (DOIW, Incident response guide).	Effective use of regulated system to meet high priority water commitments, allowing held environmental water to be used to support drought refugia where possible.	DPIE Water, DPIE BC

Type of risk	Description	Potential management strategies	Potential project partners
	Water management during times of drought is addressed in the Water Management Act (2000)		
Increasing infrastructure to address urban water security	Proposed new and augmented dams, weirs, pipelines and other major infrastructure that has the potential to impact on connectivity to the Barwon–Darling.	Use EWRs in assessment of WSP rules once amended by new infrastructure regime.	DPIE Water
Risks to inflows from QLD tributaries			
Compliance of the water management regime that QLD has in place to protect volume and variability of flow delivering the end-of-system requirements of the Basin Plan.	QLD implementation of the Basin Plan is required to provide adequate flows to connect catchments to the downstream environment. Harvesting floodplain flows influences high overbank floods, flow variability, low flow events and flow volume. Rules to promote connectivity under non-flood conditions.	Monitor and report on Basin Plan compliance. Share information See above for risk to overbank flow events.	MDBA, CEWO, DPIE Water, QLD
Poor or lack of protection of HEW to and across the NSW border.	In Queensland tributary catchments, current water sharing plans do not account for, or protect, held environmental water that would otherwise flow into Barwon–Darling (QLD Border Rivers, Moonie, Condamine–Balonne, Warrego–Paroo–Nebine). Information about what additional water is coming into NSW WRPA leads to difficulties in implementation.	Governance arrangements with QLD to address protecting HEW (Commonwealth held) that is delivered from Queensland.	MDBA, CEWO, DPIE Water, QLD
Risks within the Barwon–Darling WRPA			
Compliance of the LTAAEL for the Barwon–Darling relies on a planning model that is not fit-for-purpose.	The bulk of environmental water in the Barwon–Darling is reserved through a limit on extraction (LTAAEL). 2,607 GL/yr or 94% of long-term average annual flow is protected through this mechanism.	The model should reflect the rules, all extractions, and tributary inflows to provide adequate compliance. Metering and/or compliance assessment of extraction (including	DPIE Water

Type of risk	Description	Potential management strategies	Potential project partners
	Effective compliance of extraction limits in the Barwon–Darling and tributary catchments is essential to ensure that environmental water is protected in the Barwon–Darling. The model is not updated regularly enough to ensure compliance with the LTAAEL. The compliance model is not appropriate for low flows so doesn't reflect the management needs of EWRs.	unregulated) at a frequency (annual) that will ensure the LTAAEL is not exceeded in the Barwon–Darling or upstream tributaries. Inclusion of floodplain harvesting within the LTAAEL/SDL and associated monitoring and compliance, to prevent growth in extraction by this method. This is a strategy being progressed by the Water Renewal Action Plan. (2018). Monitor growth in use to ensure LTAAEL is managed.	
	Long term (LTAAEL/SDL) compliance alone is not an effective environmental management measure when event-based outcomes are sought i.e. to assess impacts on EWRs	Address difficulty in measuring event-based compliance in unregulated resource areas. This includes event metering and IDELs compliance. This is a strategy being progressed by the Water Renewal Action Plan. (2018). Broadly, assess new water sharing rules against EWRs to determine environmental impact and benefit.	DPIE Water
Inadequate sharing of flow events (daily limits to pumping) does not achieve flow variability above the cease-to-pump level.	At some gauges, access rule thresholds do not align with ecological flow category thresholds. Ideally, access rule thresholds would support relevant EWRs.	Review cease-to-pump thresholds against EWRs.	DPIE Water
	The removal of pump capacity restrictions means greater pressure on flow events.	Implement IDELs and TDELs in accordance with the 2012 WSP to address flow sharing between license holders and the environment. This is a strategy	DPIE Water

Type of risk	Description	Potential management strategies	Potential project partners
		being progressed by the Water Renewal Action Plan. (2018). Consider protection of EWRs in the development of TDEL rules. Improved hydrometric capability and event-based metering	
Weir pools in the Barwon–Darling are critically important as drought refuge but are also typically subject to human extraction pressures.	Pumping from weir pools has potential for direct impact on ecosystem functions objectives like the survival of native threatened fish species.	Investigate the extent of impact of this risk and explore options such as changes to rules, improved metering and trade out of high-risk areas. Review the commence to pump rules against EWRs.	
Environmental water is extracted for town water supply and basic landholder rights	In periods of water shortage, urban water utilities and riparian landholders may use environmental water used to replenish refuge pools. This can reduce the efficiency of managed environmental flows in the WRPA.	Ensure that other sources of water are available to towns and urban supplies rather than a reliance upon environmental water alone.	DPIE Water WaterNSW,
Domestic and Stock rights are not easily quantified and accounted for in planning.	In dry times, the unknown quantity of take resulting from domestic and stock rights presents a risk for managing refugia sites.	Develop reasonable use guidelines for Basic Landholder Rights categories of take.	DPIE Water
In-stream structures and barriers affecting in-stream EWRs	There is potential for new infrastructure to reduce hydrological connectivity, which has a range of effects. These include provision of nil flow areas which can favour carp, and support development of blue green algae and water hypoxia.	Review environmental conditions and monitoring of larger in-stream storages and for any new proposed structures. This should include consideration of the potential need for environmental releases.	
Floodplain structures and preventing flows that would meet overbank and EWRs	Construction of structures (e.g. levees, diversion channels, sediment blockage of culverts) that causes barriers to flows to wetlands and ecological-important floodplain areas.	Implement the Floodplain Management Plan for the Barwon–Darling Valley Floodplain 2017 to ensure floodplain developments do not change flows to and around environmental assets.	NRAR DAWR, DPIE Water

Type of risk	Description	Potential management strategies	Potential project partners
	Any further development of water storages and weirs along the Barwon–Darling are likely to further exacerbate this current shortage of water and may act as barriers to high value ecological areas.	Implement programs to remediate existing flood works that have an adverse impact on flood behaviour. Ensure compliance with existing rules for constructing floodplain infrastructure Government programs that fund water efficiency schemes should consider potential impacts of off-river storages if such structures are included in proposals	
Groundwater take	Connectivity with groundwater resources can impact on surface water availability, particularly during drought and low flow conditions.	Monitor growth in groundwater use and its impact on low flows in highly connected areas in the Barwon–Darling.	DPIE Water
Water quality risks arising from altered flow regime			
Altered flow regime, resulting in less water volume and less variability in flow category, exacerbates a number of water quality risks	Poor water quality may reduce ecosystem resilience to disturbances and reduce the extent of ecological response from watering. A number of risks arise due to the combination of altered water flow and land use practices. These have been represented in both sections 5.1 and 5.2 where appropriate.	Implement recommendations detailed in the *Water Quality Management Plan for the Barwon–Darling WRPA* (NSW DPIE 2019c)	DPIE Water, WaterNSW
		Provide flow regimes that avoid extended dry or very low-flow periods.	Water NSW, DPIE Water
		Consider potential for benefits to water quality when managing water to meet ecological and other objectives.	DPIE BC, CEWO
		Consider implementing resumption of flow rules which protect the first flows that follow cease-to-flow or low flow periods to reduce the risk of hypoxic blackwater.	DPIE Water

Type of risk	Description	Potential management strategies	Potential project partners
		Consider risks when delivering environmental flows during high-risk periods, such as warm weather in late spring and summer. Where risks exist, monitor dissolved oxygen for active management of water actions.	DPIE BC and CEWO
Low dissolved oxygen and pool stratification.	Low flow velocities in weir pools, or cease-to-flow conditions, can lead to stratification with the cooler bottom layer becoming stagnant and hypoxic. Thermal stratification effectively reduces the habitat area of the weir pool. Subsequent sudden destratification can make the entire waterbody hypoxic and cause fish kills.	Improve water quality monitoring at pools susceptible to fish kills. Monitoring should include temperature stratification and dissolved oxygen. See Table 24. Implement real-time management of water quality risks at cease-to-flow and flow resumption.	WaterNSW, DPIE Water
		Consider and, where appropriate, implement recommendations of the review of the 2019 (Baldwin 2019). These recommendations are likely to include provision of adequate flows during identified high-risk periods. See Table 24.	WaterNSW, DPIE Water
Salinity outside of target values.	Salinity occurs downstream of Bourke associated with salty springs which results in salty discharge to the river when flows are less than 4500 ML/d.	Manage salinity in accordance with the *Basin Salinity Management 2030 Strategy* (MDB Ministerial Council 2015). Under this Strategy the government is monitoring salinity and identifying and implementing measures for salinity management. Monitor the Darling River Salt Interception Scheme.	DPIE Water
Algal blooms, associated toxicity and their contribution to	Algal blooms can occur during warmer months. More commonly found in weir pools, such as	Reduce or decommission barriers creating low flow.	DPIE Water

Type of risk	Description	Potential management strategies	Potential project partners
low dissolved oxygen environments.	Collarenebri, Walgett and Brewarrina, Bourke, Louth and Tilpa. Low flows contribute to this risk.	Suspend irrigation take until critical water quality requirements are met, as per IUFPNW (DWR 1992). NSW Draft algal risk management sub plan (2014).	
Risks arising from downstream management			
Lack of rules to achieve end-of-system flow requirement from the Barwon–Darling into Lower Darling and Menindee Lakes.	End-of-system flow requirements need to take into account the Menindee Lakes/Lower Darling. These downstream requirements should express both the ecological requirements of the Lakes and the downstream or basin requirements for flows leaving the lakes. Failure to consider this requirement may lead to emergency measures being required to alleviate poor water quality, loss of environmental values (e.g. fish deaths) or a lack of connection for fish movement.	Consider adding end-of-system targets within the Barwon–Darling WSP. These could tie to resumption of flows or other rule sets.	DPIE BC, DPIE Water, DPI–Fisheries
Changed management in the Lower Darling and Menindee Lakes System arising from the SDLAM project to reduce evaporative losses.	Environmental outcomes may be compromised by implementation of this project (refer to the Murray Lower Darling LTWP).	This is a strategy being progressed by the Sustainable Diversion Limit Adjustment Mechanism.	

5.2 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 15). While managing these risks and constraints is outside the direct scope of this LTWP, they have been included to highlight their influence on river and wetland health, and linkages of this plan with broader natural resource management initiatives.

Figure 16 **The Darling River**
Photo: Neal Foster

Table 15 Non-flow management related risks and constraints to meeting LTWP ecological objectives

Risk	Description	Potential management strategies	Potential project partners
Risks to waterbirds			
Change in rainfall patterns stemming from climate change affecting breeding opportunities for waterbirds.	Predicted changes to rainfall and surface water flows as a result of climate change indicate a potential change in the seasonality and possibly a reduction in the overall volume of flows.	Monitor breeding opportunities. Incorporate into climate change adaptation strategies.	DPIE BC, NPWS
Removal or loss of riparian vegetation will reduce breeding locations for some species and impact on foraging opportunities	Riparian vegetation communities are at risk from land clearing, erosion (both natural and accelerated) and sedimentation, uncontrolled grazing and degradation from invasive plant and animal species.	Map and prioritise high-risk points areas for protection and rehabilitation, with a commitment to manage risk and monitor outcomes.	DPIE BC, LLS
Persistent chemicals can impact on eggs	Viability of breeding opportunities can be eroded by chemical contamination if inappropriate chemicals are deployed and released into the environment.	Continue to regulate the impacts of chemical usage for agriculture and other industries.	EPA
Risks to vegetation			
Native vegetation clearing impacting on achieving LTWP vegetation extent objectives	Native vegetation clearing has direct impacts on LTWP vegetation objectives. Changes to riparian vegetation can also impact on water quality, stream erosion and instream habitat.	Identify and protect target vegetation communities using legislation and native vegetation regulation	DPIE BC
		Implement the *Local Land Services Act 2016* and *Biodiversity Conservation Act 2016*	DPIE BC, LLS, Private landholders
Impacts of unmanaged total grazing pressure and stock access to waterways impacting on	If not managed carefully, grazing pressure from stock, feral and native herbivores, and access of stock to riverbanks can:	Map and identify critical riparian and aquatic habitat to inform development of incentivised formal agreements in a unified strategy.	DPIE BC DPI Fisheries LLS BCT

Risk	Description	Potential management strategies	Potential project partners
achieving LTWP vegetation objectives	reduce groundcover which allows weeds to establish and biodiversity to be reduced reduce streambank stability damage important instream habitat and change channel geomorphology for fish and other organisms reduce water quality reduce or eliminate regeneration of woodland species	Prioritise reaches for management in partnership with LLS and landholders. See Table 25 Conduct works to improve instream habitat	
		Investigate communication products and incentives to improve management of riparian areas and wetlands on private land (grazing, native herbivores, riverbank access).	LLS, BCT DPIE Kangaroo Management Private Landholders
		Investigate measures to control the abundance of native herbivores on public lands.	DPIE National Parks DPIE Kangaroo Management
Pest plant species impacting on achieving LTWP vegetation condition objectives	The presence and spread of aquatic and terrestrial weed species such as Lippia, Noogoora burr, tobacco weed can negatively affect the condition of vegetation communities.	Prioritise reaches for management in partnership with LLS and landholders. See Table 25 Maintain existing weed control programs Implement NSW Invasive Species Plan 2018–2021 Monitor for pest species, including for potential emerging pest species present in tributary catchments (e.g. alligator weed, water hyacinth).	DPIE BC and LLS National Parks, local government, private landholders, DPI Fisheries,
Pest animal species impacting on achieving LTWP vegetation objectives	Riparian areas, wetlands and streams support populations of invasive animals such as Feral pigs, cats, foxes, goats and Common Carp. Unchecked, these populations can impact upon native vegetation extent and condition.	Support recommendations in pest species management plans, with implementation of control programs such as those for: - feral pigs (vegetation, predation impacts) - feral goats (vegetation impacts) - foxes and feral cats (predation impacts)	DPIE BC, National Parks, DPI Fisheries, WaterNSW, Local Govt, private landholders

Risk	Description	Potential management strategies	Potential project partners
Climate Change directly impacting on vegetation regeneration	Higher average and peak temperatures combined with longer dry spells under climate change predictions might mean reduced recruitment of some species as they perish over hot, drier summers or don't produce as many propagules or seeds.	Monitor vegetation regeneration. Incorporate into climate change adaptation strategies.	DPIE BC, NPWS
Risks to native fish			
Instream barriers and structures impacting fish passage	Major barriers including weirs impede connectivity. Achieving some fish population objectives is dependent on river connectivity. Until additional fishways are constructed, drowning out weirs is required for fish movement upstream.	Assessing and addressing priority barriers to fish passage Determine flow rates required to drown out barriers	NRAR DPI Fisheries
		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	DPIE Water, DPI Fisheries
		Implement the *Fisheries Management Act 1994* for all new or upgrading of in-stream structures	DPI Fisheries
		Investigate opportunities to identify and modify existing structures e.g. levees, town weirs, privately owned weirs and regulators	WaterNSW, Councils, landholders, DPI Fisheries, DPIE BC, LLS
Upstream tributary water development impacts	Increased water storage infrastructure in tributary catchments for water security will mean a reduction in flow events and pool persistence downstream during dry times.	All new proposals that will decrease flow to the Barwon Darling should be subject to proper hydrological assessment, including cumulative impact assessment, and possibly subject to offsets.	DPIE Planning DPIE BC WaterNSW DPIE Water

Risk	Description	Potential management strategies	Potential project partners
Poor water quality including high nutrient levels, algae and elevated turbidity impacting LTWP fish and functions objectives	Water quality affects the ecology and survival of aquatic organisms. Nitrogen and phosphorus are high throughout the middle and lower Darling due to nutrient inputs from upper catchments, particularly during high flows and associated with erosion. High level of nutrients contribute to algal blooms that can occur during warmer months. Turbidity is elevated in the middle and lower Darling due to the widespread conversion of land for cropping, riverbank and riparian condition, erosion, presence of carp and grazing practices.	Implement recommendations detailed in the *Water Quality Management Plan for the Barwon–Darling WRPA* (NSW DPIE 2019c) Implement grazing control measures and revegetation of the riparian zone. NSW Draft algal risk management sub plan (2014), Regional Algal Coordination Committees Reintroduction, translocation and stocking of threatened fish species in key locations as required.	DPIE Water, WaterNSW, DPI Fisheries, LLS, any others with land management responsibility including private landholders.
Unscreened pumps and other water intakes impacting on fish populations	Pumps and other water intakes can remove fish and their eggs and larvae from the river. Native fish are commonly injured or killed when sucked into irrigation pumps. This directly impacts on all the native fish objectives. Mortality or removal of native fish due to entrainment places additional pressure on successful spawning and recruitment events to maintain populations.	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 Implement pump screening methods	DPI Fisheries, Irrigators Local Government, Industry groups
Poorly designed weirs impacting on fish populations	Some weir types, such as undershot weirs, create turbulence and kill fish larvae.	Replace inappropriately designed structures with fish-friendly structures	Infrastructure owners DPI Fisheries
Pest fish species impacting on achieving LTWP native fish objectives	The current flow regime, including environmental water, supports populations of invasive aquatic species such as Common Carp, Goldfish and Gambusia. These populations compete with native fish.	Support recommendations in pest species management plans, with implementation of control programs such as those for: – Common carp including implementing the carp management strategy and National Carp Control Plan	DPIE BC, National Parks, DPI Fisheries, WaterNSW

Risk	Description	Potential management strategies	Potential project partners
		– other invasive fish such as gambusia (competition with native fish and predation	
		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)	DPI Fisheries
Illegal fishing or excessive quotas impacting on native fish populations	There is a risk of recreational and commercial fishing impacting on native fish populations, particularly during breeding seasons and dry times when populations and individuals are under stress.	Compliance on fishing activities including closed seasons. Review bag limits if impacts are detected.	DPI Fisheries
Risks to connectivity (non-flow related)			
Increased infrastructure in upstream tributaries impacting connectivity	Increased infrastructure in upstream tributaries for water security might mean a reduction in low flows that would otherwise maintain connectivity.	All new proposals that will decrease flow to the Barwon Darling should be subject to proper hydrological assessment, including cumulative impact assessment, and possibly subject to offsets.	DPIE Planning DPIE BC WaterNSW DPIE Water
River operational changes and practice reducing connectivity	River operational changes and practice can impact upon connectivity, particularly from regulated upstream catchments. Operations can change without public scrutiny.	Where there are unstated or ambiguous operational requirements that impact upon the environment, these should be added to the water sharing plan to create certainty. Proposed changes to operating licences and works approvals should be exhibited for comment.	DPIE Water
Problematic erosion and sedimentation may impact upon various LTWP objectives underpinned by connectivity	Erosion (both natural and accelerated) and sedimentation may result in a variety of changes including longitudinal and lateral connections	Map and prioritise high-risk areas for rehabilitation, with a commitment to manage risk and monitor outcomes.	DPIE BC, LLS

Risk	Description	Potential management strategies	Potential project partners
Climate change altering seasonality of inflows	Predicted changes to rainfall and surface water flows as a result of climate change indicate a potential change in the seasonality and possibly a reduction in the overall volume of inflows.	Monitor inflows. Incorporate into climate change adaptation strategies.	DPIE BC, DPIE Water.
Governance risks			
Ongoing management of events using *ad hoc* section 324 orders (event embargos, temporary water restriction)	Imposing Section 324 orders uses an ad hoc mechanism with reduced certainty for environmental water planners, communities and other water users. This level of intervention is more appropriate for severe and extreme event management rather than routine use.	Investigate rule changes to reduce the use of Section 324 orders for environmental water protection. 'Active Management' is one such mechanism	DPIE Water
Environmental water needs to be shared between tributaries and the Barwon–Darling based on need.	Providing significant volumes via HEW from connecting tributary catchments to the Barwon–Darling is an infrequent event under current arrangements. Sometimes connection is hydrologically unachievable, other times the in-valley priorities in the tributary catchments may override the needs in the Barwon–Darling. As environmental water protection improves in unregulated systems, finding a balance between tributary catchments and downstream systems will become increasingly challenging.	Consider broadening the scope of responsibility of more established tributary EWAGs to explicitly consider downstream catchments and basin outcomes, in addition to considering their local needs. Communicating the whole-of-system management approach to help improve understanding of the importance of protecting environmental flows Further investigate fish passage, hydrological connectivity and environmental water protection measures to make decisions to connect less risky, particularly in dry times.	DPIE BC MDBA CEWO DPIE Water EWAGs

5.3 Climate change

Climate change is a key long-term risk to river, wetland and floodplain health. Current modelling indicates it will exacerbate the natural seasonal variability that exists in the catchment areas of the Barwon–Darling, making it more challenging to manage landscapes and ecosystems and the human activities that depend on them.

Best available climate change predictions for the Barwon–Darling are currently the NARCLiM model[17] (scenario 2) outputs. The modelled changes are summarised in Table 19 and include conditions predicted by 2030 and 2070.

Since a significant catchment area and contributor of flows for the Barwon–Darling WRPA is located in Queensland and not the subject of NARCLiM modelling, a separate table (Table 20) has been included to reflect predictions in these catchments (Queensland Government accessed 2019). Different models have been used in the development of Queensland predictions, than in NARCLiM modelling.

There are uncertainties with these climate change predictions, and predicted changes would not occur in isolation. Rather, the predicted changes are projected to occur alongside other changes owing to water resource development, land use, and environmental water management. Accordingly, it is currently unclear what specific overall impact these climatic changes will have on the flow-dependent environmental assets of the Barwon–Darling WRPA, but they will require careful consideration by the water and land managers involved.

[17] 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 16 Potential climate-related risks in the northern MDB NSW catchments that affect the Barwon–Darling Water Resource Plan Area (NARCLiM model[17])

Potential climate change risk	Description of risk		NARCliM projection (scenario 2)					
			2020–39			2060–79		
			North East[18]	South East[19]	West[20]	North East	South East	West
Change in rainfall	Rainfall changes are projected to vary across the regions, with the greatest increases predicted to occur during summer and autumn. Spring and winter rainfall are primarily decreasing across the regions.	Summer	-3.3%	-1.1%	+3.1%	+9.8%	+13.2%	+12.6%
		Autumn	+14.9%	+14.7%	+14.1%	+16.8%	+13.5%	+13.7%
		Winter	-7.6%	-4.2%	-7.2%	-0.7%	+5.4%	+4.1%
		Spring	+2.6%	-7.6%	-10.3%	-0.7%	-5.8%	-5.4%
Change in average temperature	Mean temperatures are projected to rise by 0.7 ºC by 2030. The increases are occurring across the regions, with the greatest increase during summer. All models show there are no declines in mean temperatures across the Barwon-Darling regions.	Summer	+0.89°C	+0.95°C	+0.90°C	+2.4°C	+2.44°C	+2.49°C
		Autumn	+0.75°C	+0.65°C	+0.59°C	+2.16°C	+2.04°C	+2.05°C
		Winter	+0.48°C	+0.40°C	+0.41°C	+1.92°C	+1.65°C	+1.64°C
		Spring	+0.80°C	+0.80°C	+0.80°C	+2.33°C	+2.30°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 23–35 days per year, mostly in the summer months by 2070.	Annual number of days	+7.1	+9.1	+11.5	+23.4	+27.0	+35.1

[18] North East refers to the New England and North West region in the NARCLiM and includes NSW Border Rivers, Gwydir and Namoi tributary catchments
[19] South East refers to the Central west and Orana region in the NARCLiM and includes Macquarie-Cudgegong tributary catchments
[20] West refers to the Far West region in the NARCLiM and includes Intersecting Streams tributary catchments

Potential climate change risk	Description of risk	**NARCliM projection** (scenario 2)						
			2020–39			**2060–79**		
			North East[18]	South East[19]	West[20]	North East	South East	West
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 north eastern region. Changes in cold nights can have considerable impacts on native ecosystems.	Annual number of days	-8.8	-7.7	-3.2	-26.1	-22.5	-9.5
Bushfires Changes in number of days a year FFDI>50[21]	Severe fire weather is projected to increase across the region by 2030 during summer and spring. Declines are projected 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) and peak fire risk season (summer). Overall severe fire weather is projected to have a small increase across the region by 2030 with increased severe fire weather in spring and summer.	Annual number of days	+0.2	+0.5	+1.3	+0.9	+1.3	+3.2
Erosion Risk	Removal of groundcover due to climate-related change will increase the risk of erosion significantly in some areas. Significant increases in erosion are predicted to occur in the western region (Yang 2015).	Mean per cent change	4.3%	4.6%	10.92%	17.4%	20.0%	29.1%
Biodiversity	Rising temperature, increased fire frequency and changing fire regimes, storm damage and increases in droughts will all affect native population, species and community resilience and survivability. Ultimately we can expect non-mobile or specialist species to be highly affected and a general increased reliance and pressure placed on remaining refugia and movement corridors, such as along rivers.							

[21] 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.

Table 17 Potential climate-related risks in Queensland catchments relevant to the Barwon–Darling Water Resource Plan Area (Queensland Government, accessed 2019)

Potential climate change risk	Description of risk	Climate change predictions						
			Lower emissions[22]			High emissions[23]		
		Year	East[24]	Central[25]	West[26]	East	Central	West
Change in seasonal rainfall	The median value of annual rainfall is projected to slightly increase in the summer months, with a larger decrease over winter. However, there are a large range of projected rainfall changes across the regions from an annual increase of 15% to a decrease of 23% under high emissions.	2030 (summer)	-1%	0%	-1.9%	-0.4%	+1.1%	+1.1%
		2030 (winter)	-0.7%	-3.8%	-1.9%	-7.2%	-9.8%	-10.2%
		2050 (summer)	+1.6%	+3.1%	+2.6%	+0.2%	+3.4%	+1.5%
		2050 (winter)	-9.2%	-9.9%	-9.5%	-13.7%	-13.8%	-9.5%
		2070 (summer)	+1.3%	+3.2%	+2.5%	-1.8%	0%	+4.1%
		2070 (winter)	-9.4%	-10.5%	-7%	-14.8%	-15.9%	-12.2%
Change in average temperature	Average annual median temperatures are projected to increase by as much as 2–3°C in all regions in the Barwon–Darling by 2070.	2030	+1°C	+1.1°C	+1.1°C	+1.1°C	+1.3°C	+1.2°C
		2050	+1.4°C	+1.5°C	+1.6°C	+1.9°C	+2.1°C	+2.1°C
		2070	+1.8°C	+2.0°C	+2.0°C	+2.9°C	+3.2°C	+3.4°C
Potential change in annual evaporation	By 2050 the median value of annual potential evaporation is projected to increase across all regions by approximately 5% under both lower and high emissions.	2030	+3.5%	+3.2%	+2.8%	+3.7%	+3.2%	+2.4%
		2050	+5.4%	+4.8%	+4.6%	+6.1%	+5.7%	+5.1%
		2070	+6.5%	+5.7%	+5.2%	+10%	+9%	+9.1%

[22] Based on the climate change projection assuming a reduction in greenhouse gas emissions

[23] Based on the climate change projection assuming business as usual or no curbing of greenhouse gas emissions.

[24] East refers to the Eastern Downs region in the Queensland climate change predictions and includes QLD Border Rivers, Moonie and Condamine tributary catchments

[25] Central refers to the Maranoa and District region in the Queensland climate change predictions and includes Maranoa, Culgoa and Balonne tributary catchments

[26] West refers to the South West region in the Queensland climate change predictions and includes Warrego, Paroo and Nebine tributary catchments

Strategies for mitigating climate-related risks

Water Resource Plans and environmental water managers will need to adapt to changes in climate and flows when and if they occur. In striving to respond to the environmental demands of rivers, wetlands and floodplains, environmental water managers consider the range of priorities and strategies at their disposal on a 1–3 year timeframe. A changing climate that departs from historic records will be another important variable in this decision-making process.

Figure 17 **The Darling River at weir 20A, upstream of Louth**
Photo: Neal Foster

6. Water management under different water availability scenarios in the unregulated Barwon–Darling

Environmental water managers and environmental water advisory groups consider a range of factors when determining how discretionary water for the environment should be managed. Key considerations (DECCW 2011) include:

- the water demands of plants and animals based on a variety of information including condition assessments, the recent history connectivity of river channels to their floodplain systems, rainfall history and predictions
- the hydrological antecedent conditions – temperatures, local rainfall, pool levels
- predictions and trends in weather and climate
- water availability from the range of environmental water sources.

Support for flow-dependent environmental assets and values amid this variability means that planning and implementation must be adaptive. Watering activities can range from actively building system resilience and promoting ecological restoration when water is abundant, to minimising damage to populations by maintaining drought refugia when water resources become scarce.

Ecological resilience can be gained through:

- working to avoid key thresholds known to result in decline to condition or damage to values (e.g. fish kills)
- maintaining healthy condition of flow-dependent values, including species populations when conditions allow
- protection of refugia during drought and other disturbances
- facilitating recruitment during wetter times (e.g. vegetation regeneration, fish recruitment, waterbird breeding)
- encouraging repopulation and/or recolonisation following drought or other major disturbances; and
- minimising human-induced threats (e.g. invasive species, habitat fragmentation).

The Barwon–Darling WRPA, as an unregulated system, has no mechanism to generate new flow events, and is limited to receiving the relatively low and small volume flows generated by environmental water events in tributaries. The primary mechanisms for achieving ecological objectives are to maintain and enhance flow event sharing and planned environmental water protections. These same protections may also support more outcomes from Held Environmental Water present in the Barwon–Darling WRPA itself.

Should flow event protection mechanisms be implemented, environmental water holders will be able to more fully realise the potential benefits of using HEW licences within the unregulated Barwon–Darling. Likewise, water managers and river operators in the tributary catchments will need to consider the potential downstream benefits and outcomes that can be derived from environmental water sourced from those valleys.

6.1 Priority short-term management strategies

Section 6.1 sets out a proposed framework to help inform shorter-term (1–3 year) water management decisions by:

1. environmental water holders (currently DPIE Biodiversity and Conservation and CEWO)
2. the MDBA in setting basin priorities
3. river operators (currently Water NSW) and regulators (currently NRAR)
4. those involved in short-term interventions, such as DPIE Water for drought response and water quality.

This information is presented in terms of a water resource availability scenario (RAS) as proposed by MDBA (2012c). It is noted that:

1. the current RAS calculation method has limited application in the unregulated Barwon–Darling. As such, scenarios are intended as a guide only and will be determined through a range of means including determinations by environmental water managers.
2. a RAS in this WRP Area should consider conditions and available deliverable water within tributary catchments
3. each RAS is described below in two tables that include:
    - the broad priorities (upper tables) that are likely to apply to management under the water availability scenario along with management strategies for achieving these priorities – a 'toolkit' of opportunities to consider.
    - the priority LTWP objectives identified for each scenario (lower tables). These tables also outline the flow categories (marked with an X) that would be required to support those priority objectives.

Note the wording of the LTWP objectives has been adjusted to highlight the most relevant aspect of the objective under the scenario. For example, an LTWP objective that over 20 years seeks 'improvement' may only seek to 'maintain' under a dry scenario. Some of the wording of the objectives has been summarised for better presentation. The full objectives can be found in section three.

Priority water management strategies under 'Very Dry' and 'Dry' Water Resource Availability Scenarios

	Broad water management priorities	Key management strategies for consideration
Very Dry	Avoid critical loss of species, communities and ecosystems Maintain refugia Avoid irretrievable damage or catastrophic events Avoid unnaturally prolonged dry periods between flow events Support targeted longitudinal connectivity within catchment for functional processes and a range of flora and fauna	Focus on limiting exceedance of maximum inter-flow periods. The following strategies could be deployed: • Use HEW within the Barwon–Darling whenever possible to support low flows • Provide targeted low flows from tributaries, where possible, to boost water quality and quantity in key refugia. This could be via held environmental water, water quality allowances or specific drought interventions by the NSW Government (e.g. S.324s) • When available, restrict supplementary take in tributary catchments to meet EWRs • Protect flow following a period of cease-to-flow to provide longitudinal connectivity in the river ('resumption flow'). • Use active management to protect environmental flows

Table 18 Priority LTWP objectives and flow categories in 'very dry' and 'dry' RAS

Priority objectives	Flow categories							
	Cease to Flow	Very Low Flow	Baseflow	Small Fresh	Large Fresh	Bankfull	Small Overbank	Large Overbank
NF1: No loss of native fish species	X	X	X	X				
NV1: Maintain non-woody vegetation communities occurring within channels	X	X	X	X				
NV2: Maintain non-woody vegetation communities occurring in drought refuge sites								
WB1: Maintain waterbird species diversity		X	X					
WB2: Maintain waterbird abundance								
WB5: Maintain waterbird habitats								
EF1: Provide and protect refugia	X	X	X	X				
EF2: Maintain quality instream and wetland habitat	X	X	X	X				
EF3a: Provide movement and dispersal opportunities within catchments			X	X				

Priority water management strategies under a 'moderate' Water Resource Availability Scenario

	Broad water management priorities	Key management strategies for consideration
Moderate	Enable growth, reproduction and small-scale recruitment for a diverse range of flora and fauna Promote low-lying floodplain-river connectivity Support medium flow river and floodplain functional processes Support longitudinal connectivity within and between catchments for functional processes and a range of flora and fauna Support low flow lateral connectivity and end of system flows	• Use HEW within the Barwon-Darling to support a range of flows where possible • Use connection flows from the tributary catchments, where possible, to provide connection opportunities. • Use active management to protect environmental flows • Environmental Water holders could consider trade in IDELs or allocation (temporary trades) to provide/protect specific events.

Table 19 Priority objectives and flow categories in a moderate resource availability scenario

Priority LTWP objective	Flow categories							
	Cease-to-flow	Very Low Flow	Baseflow	Small Fresh	Large Fresh	Bankfull	Small Overbank	Large Overbank
NF1: No loss of native fish species	X	X	X	X	X			
NF2: Improve short to moderate-lived generalist native fish			X	X	X			
NF3: Improve moderate-lived floodplain specialist native fish			X	X	X			
NF4: Improve moderate to long-lived flow pulse specialist native fish			X	X	X			
NF5: Improve moderate to long-lived riverine specialist native fish			X	X	X			
NF6: Increase mature (harvestable sized) golden perch and Murray Cod			X	X	X			
NF8: Expand key moderate to long-lived riverine specialist native fish into new areas			X	X	X			
NF9: Expand key moderate to long-lived flow pulse specialist native fish into new areas			X	X	X			
NV1: Maintain non-woody vegetation communities occurring within channels			X	X	X			
NV3: Maintain river red gum communities closely fringing river channels					X			
WB1: Maintain waterbird species diversity			X	X	X			
WB2: Increase waterbird abundance					X			
WB3: Increase opportunities for non-colonial waterbird breeding					X			
WB5: Maintain waterbird habitats					X			
EF1: Provide and protect refugia	X	X	X	X		X		
EF2: Create instream, floodplain and wetland habitat	X	X	X	X	X			
EF3a: Provide movement and dispersal opportunities within catchments			X	X	X			
EF3b: Provide movement and dispersal opportunities between catchments				X	X			
EF4: Support instream and floodplain wetland productivity			X	X	X			
EF5: Support nutrient, carbon and sediment transport and exchange				X	X			
EF6: Support groundwater conditions to sustain groundwater-dependent biota					X			
EF7: Increase the contribution of flows into the Menindee Lakes and Lower Darling from tributaries				X	X			

Priority water management strategies under a 'wet' and 'very wet' Water Resource Availability Scenarios

	Broad water management priorities	Key management strategies for consideration
Wet	Enable growth, reproduction and large-scale recruitment for a diverse range of flora and fauna Support longitudinal connectivity within and between catchments for functional processes and a range of flora and fauna Support high flow lateral connectivity and end of system flows	Support events at ideal frequencies. • Where possible and relevant, build on natural events with tributary HEW to provide wetland and floodplain inundation at ecologically relevant times

Table 20 Priority objectives and flow categories in a 'wet' or 'very wet' resource availability scenario

Priority LTWP objective	Flow categories							
	Cease-to-flow	Very Low Flow	Baseflow	Small Fresh	Large Fresh	Bankfull	Small Overbank	Large Overbank
NF1: No loss of native fish species			X	X	X	X	X	X
NF2: Improve short to moderate-lived generalist native fish			X	X	X	X		
NF3: Improve moderate-lived floodplain specialist native fish			X	X	X	X	X	X
NF4: Improve moderate to long-lived flow pulse specialist native fish			X	X	X	X		
NF5: Improve moderate to long-lived riverine specialist native fish			X	X	X	X		
NF6: Increase mature (harvestable sized) golden perch and Murray Cod			X	X	X	X		
NF8: Expand key moderate to long-lived riverine specialist native fish into new areas			X	X	X	X		
NF9: Expand key moderate to long-lived flow pulse specialist native fish into new areas			X	X	X	X		
NV1: Increase non-woody vegetation communities occurring within channels			X	X	X			

Priority LTWP objective	Flow categories							
	Cease-to-flow	Very Low Flow	Baseflow	Small Fresh	Large Fresh	Bankfull	Small Overbank	Large Overbank
NV2: Maintain non-woody vegetation occurring in wetlands and on floodplains						X	X	X
NV3: Maintain river red gum communities closely fringing river channels					X	X		
NV4c: Maintain extent and maintain or increase the condition of black box, coolibah and lignum						X	X	X
NV4d:								X
NV4e:							X	X
WB1: Maintain waterbird species diversity			X	X	X	X	X	X
WB2: Increase waterbird abundance					X	X	X	X
WB3: Increase opportunities for non-colonial waterbird breeding					X	X	X	X
WB4: Increase opportunities for colonial waterbird breeding						X	X	X
WB5: Improve waterbird habitats					X	X	X	X
EF2: Create instream, floodplain and wetland habitat			X	X	X	X	X	X
EF3a: Provide movement and dispersal opportunities within catchments			X	X	X	X	X	X
EF3b: Provide movement and dispersal opportunities between catchments				X	X			
EF4: Support instream and floodplain wetland productivity			X	X	X	X	X	X
EF5: Support nutrient, carbon and sediment transport and exchange				X	X	X	X	X
EF6: Support groundwater conditions to sustain groundwater-dependent biota					X	X	X	X
EF7: Increase the contribution of flows into the Lower Murray and Murray from tributaries				X	X			

6.2 Long-term management strategies – protection of environmental water in unregulated Barwon–Darling

In the Barwon–Darling system, where water cannot be delivered directly from a regulating structure, EWRs are mostly met with the planned environmental water rules of the *Barwon–Darling Unregulated Water Sharing Plan*. Held Environmental water delivered from the tributaries and used within the Barwon–Darling provides additional measures. Table 21 sets out management strategies that could be supported by the Water Resources Plan to ensure important flows are protected.

Table 21 Long-term water management strategies to protect ecologically important flows in the unregulated Barwon–Darling

Review cease-to-pump rules Access (commence-to-pump) rules provide licensed access based on the class of flow and licence. Further enquiry could include: • review of commence-to-pump thresholds for each flow class based on identified ecological requirements • consider the effect of seasonal or dry time vs. wet time commence-to-pump thresholds
A resumption of flow (first flush) rule Conceptually, this restricts access to flows following an identified cease-to-flow event. It would normally be relevant to the first flow event after extended dry conditions. Typically, first flush rules are time/duration based and when determined, provide certainty to license holders compared to ad hoc pumping restrictions.
Review SDL and LTAAEL to a sustainable take level in the long term There may be points in time where further review of the SDL and Barwon–Darling LTAAEL may be appropriate.
Implement Individual and Total Daily Extraction Limits (IDELs / TDELs) IDELs are a mechanism to share flows above the commence-to-pump thresholds via limiting the daily take by individual licences to particular pumping rates. They can be used to allow flows to be better shared between users or between users and the environment. IDELs could value-add to other tools such as trading or active management of flows (e.g. protecting HEW instream) on an event basis.
End-of-system flow requirements A flow requirement at the end of a system designed to maintain connectivity, which is met from natural flows or releases from upstream storage, could be useful to ensure fish movement and refugia are supported, along with related stock and domestic, social and cultural outcomes.
Use of downstream environmental requirements as a trigger to manage upstream access. This framework is in place in some water sharing plans and uses identified downstream flow requirements for prevention of supplementary take in regulated catchments.
Protect HEW held in Barwon–Darling HEW could be protected via WRP rules aimed to prevent unregulated licensed access to environmental flows. Currently there is limited legal protection of these flows.

Targeted purchase of water entitlements in Barwon–Darling. Targeted purchase of water entitlements in other catchments for the shared target, which will benefit Barwon–Darling (MDBA 2016).
Protect HEW and EWA in tributary catchments and in the Barwon–Darling Rules-based restrictions can be placed on consumptive water extraction in the Barwon–Darling and connected unregulated water sources (e.g. Lower Macquarie River) when held environmental water is ordered in regulated tributaries. Accounting would need to recognise held environmental water and EWA when it enters the unregulated system from a regulated system and allow for losses associated with the flows. This would replace ad hoc protections available to provide increased certainty, particularly during dry times.
Continue and refine temporary access restrictions such as through WMA s324 orders Temporary protection measures, using s324 orders, are currently available and decision-making on these could be refined and made more transparent with all catchment community members.

Figure 18 **Barwon River at Mungindi**
Photo: Terry Cooke

6.3 Water management during ecologically critical water quality incidents and extreme conditions

The quantity and quality of water are important drivers of ecological processes and contribute to the overall health of a waterway. Physical and chemical properties such as temperature, pH, electrical conductivity, algal blooms, heavy metals, pesticides, and dissolved oxygen affect the biology and ecology of aquatic plants and animals, especially when outside tolerable levels (Watson *et al.* 2009).

Insufficient water or water of poor quality can impact all water users, including water used for crops or livestock, recreational activities, and drinking. The responsibility for managing water to prevent or reduce the severity of water quality issues or during extreme conditions therefore lies with all users.

The effective management of water quality incidents relies on the timely access to monitoring information at key sites and the identification of risk factors. Whilst environmental water may be used in certain instances to provide refuge habitat, there is insufficient environmental water to avoid, mitigate or offset water quality issues in NSW rivers, nor is it the responsibility of environmental water managers to do so.

Table 22 and Table 23 describe critical water quality incidents and extreme conditions respectively, and recommended management strategies for environmental water managers. In these two instances, the management priorities of water managers are to:

1. avoid irretrievable damage or catastrophic events
2. avoid critical loss of species, communities and ecosystems
3. protect critical refuges
4. maximise the environmental benefits of all water in the system.

For a more detailed description of the roles and responsibilities for each critical incident stage, please refer to the *Barwon-Darling Surface Water Incident Response Guide* in the WRP (DPIE–Water 2019).

Table 22 Priorities and strategies for managing water during critical water quality incidents

Critical water quality incident description	Identifying features	Management strategies for achieving priorities
Water quality does not meet Australian and New Zealand Guidelines for Fresh and Marine Water Quality, and is causing or is likely to cause	Weir/refuge pools are stratified Water quality sampling and analysis demonstrates unfavourable conditions: • lack of dissolved oxygen[28] • unnatural change in temperature • unnatural change in pH • unnatural change in salinity	DPIE-BC will work with CEWO and/or EWAG to prioritise environmental water needs and DPIE-Water and WaterNSW to ensure that these needs are considered in the management of all water Work with WaterNSW to protect, or if possible, provide baseflows and

[28] Dissolved oxygen levels should be high enough to prevent the asphyxiation of respiring organisms, typically >4mg/L

significant impact on aquatic ecosystems[27]	• excess suspended particulate matter[29] • elevated levels of nutrients[30] • chemical contamination[31]	very low flows[32] to support suitable water quality in rivers and critical refuge pools[33] Sustain critical in-channel refuge pools and instream habitat Use infrastructure-assisted delivery, where possible, to create small-scale refuges of good quality water for native biota[33]

Table 23 Priorities and strategies for managing water during extreme conditions

Extreme conditions description	Identifying features	Management strategies for achieving priorities
A critical drought and/or water shortage where only restricted town water supply, stock and domestic and other restricted high priority demands can be delivered	Very low to no natural or regulated flows resulting in disconnected pools Limited water held in storages Limited ability to deliver water for critical human needs WSP may be suspended	DPIE-BC will work with CEWO and/or EWAG to prioritise environmental water needs and DOI-W and WaterNSW to ensure that these needs are considered in the management of all water Sustain critical in-channel refuge pools and core wetland areas Work with WaterNSW to protect, or if possible, provide very low flows or replenishment flows[32] to relieve severe unnatural prolonged dry periods and support suitable water quality in critical refuge pools[33]

[27] Description of the types of water quality degradation, their main causes, and where they are likely to occur in the Barwon-Darling LTWP Area can be found in the Barwon-Darling Surface Water Quality Management Plan in the WRP (DPIE-Water 2019)

[29] Excess particulate matter may be identified through poor optical properties of waterbodies, the smothering of benthic organisms, or the reduction in photosynthesis (which will inhibit primary production)

[30] May lead to nuisance growth of aquatic plants

[31] Diffuse or point source pollutants may have lethal or sub-lethal effects on aquatic biota

[32] As described in the relevant EWRs in the LTWP

[33] Natural flows, operational water, PEW and water quality allowances (where they exist) should be used in the first instance before considering the use of HEW

7. Going forward

Since the commencement of the Barwon–Darling Unregulated WSP in 2012, the Barwon–Darling rivers have experienced some significant events, including but not limited to:

- significant drought across the northern basin, particularly in 2018/19
- changes in extraction patterns due to water trading and relaxation of pump limitations
- water recovery actions by the Commonwealth and NSW Governments including the purchase of Toorale
- highly publicised events of the Lower Darling, Menindee, and various media reports
- a new compliance organisation (NRAR)
- managed environmental water connection events from the Macquarie (2017), Gwydir and Macintyre/border rivers catchments (2018, 2019)
- clearer recognition of the need for cultural water.

These events, in addition to the government policy and technical reviews, new research and community advocacy have resulted in some proposed changes to the Barwon–Darling Water Resources Plan. As such, Barwon–Darling river management is likely to see ongoing changes in the coming decade. The LTWP objectives and EWRs can support discussions during this period.

This section addresses some currently foreseen potential changes in river management that may occur during the life of the LTWP (2019–2039).

7.1 Cooperative arrangements

Cooperative Water Management Arrangements

Managing water for the environment at the catchment or basin scale requires cooperation between agencies. Such cooperative arrangements support better environmental outcomes. Water for the environment in NSW is managed cooperatively by the Commonwealth Environmental Water Office and the NSW Department of Planning, Industry and Environment's Biodiversity and Conservation Division as the NSW Environmental Water Manager.

This management is supported by the water rule set – the Water Sharing Plan as part of the Water Resources Plan, development and managed by DPIE Water with implementation of river operations under licence to Water NSW. DPI-Fisheries is also integral to several processes, like fish passage and in-stream structures compliance.

Agencies should consider a multi-agency, intergovernmental working group to collaboratively scope and to develop an ongoing program to implement the LTWP for the Barwon–Darling.

River operations to benefit the environment

In the Barwon–Darling WRPA the nature of unregulated environmental holdings means river operations typically play a less active role than in regulated systems. However, there are still some ways that river operators can influence the achievement of ecological outcomes.

The following river operations strategies would help to maximise the environmental benefit of all water in the system:

- develop and implement 'active management' type river operations that protect water for the environment while achieving the hierarchy of water supply under the NSW *Water*

Management Act 2000 and the transparent and equitable water ordering by other water users
- consider environmental needs in the scheduling of maintenance works on Water NSW infrastructure and keep environmental water managers informed of upcoming works schedules. This is currently achieved through the Customer Advisory Group (CAG) and direct engagement.

Complementary natural resources management

Complementary management of flow-dependent environmental assets and values is vital to the success of this LTWP. Cooperative arrangements between government agencies such as LLS, private industry groups, individual landholders, Traditional Owners, non-government organisations and community groups that support stewardship of environmental assets are essential.

Complementary measures that result in environmental benefits include fish passage works, grazing management of riparian and wetland areas, addressing fish entrainment in pumps, minimising erosion, addressing salinity, pollution control, pest species management (aquatic and terrestrial, plant and animal), fire management (e.g. in river red gum woodlands) and native vegetation conservation.

Cooperative investment opportunities

Several future investment priorities have been identified for the Barwon–Darling WRPA (Table 24). Identification of funding opportunities and subsequent implementation of projects to address these priorities would contribute significantly to the environmental outcomes identified in this plan. Investment opportunities in tributary catchments may have the benefit of contributing to environmental outcomes in the Barwon–Darling and should be considered on these merits.

Through the life of the plan, DPIE will seek opportunities to build links and partnerships to support implementation of projects that will contribute to the ecological objectives of the LTWP.

Figure 19 Brewarrina weir and fishway
Photo: David Preston (DPIE)

Table 24 Recommended investment and projects to improve environmental water outcomes in the Barwon–Darling WRPA

Investment opportunity	Description	Potential project partners	Relevant LTWP section
Improving knowledge about connectivity in the Northern Basin	Connectivity is the key to restoring base and low flows from the major tributaries to the Barwon and Darling Rivers. Expressing end-of-system requirements for the regulated and unregulated tributaries will make changes to water sharing plans and river operations practices possible. Connectivity will depend on a policy vehicle that links the individual WRP/WSPs together and set the objectives and strategies of the WRPs and LTWPs to guide river operations and planning.	DPIE Water, WaterNSW, MDBA	Section 5.1
Complementary Measures	Complementary measures that will make water recovery more effective include: 1. Fish passage within the Barwon–Darling, including lateral connectivity to habitat, and to tributaries and the Lower Darling. 2. Riparian land management, particularly priority groundcover protection using fencing, feral goat management and grazing management.	DPI Fisheries, LLS, Landholders, Biodiversity Conservation Trust	Section 5.2
Climate change adaptation	1. Preparing for climate change and short-term intensive drought requires an effective plan to prioritise flows for municipal supply and the environment over general security users. An approach for how water resources are shared on a short-term basis needs to be transparent and clearly documented, with governance arrangements that ensure the principles of the WMA 2000 are applied. 2. Proposals to improve security of municipal water supply present risks to achieving LTWP objectives when they result in further reducing flows into the lower reaches of tributary valleys and into the Barwon–Darling. All proposals related to improving water security in the NSW Northern Basin should be assessed for their impact on EWRs in the Barwon–Darling as well as within the valley they are proposed.	DPIE Water	Section 5.2

Investment opportunity	Description	Potential project partners	Relevant LTWP section
Northern Basin Community Engagement	An EWAG, committee for Northern Basin environmental water and cross-border group will be required to build community engagement and secure cross-border collaboration and coordination for complementary measures as well as flow management.	DPIE, CEWO, QLD government, DPIE Water	
Aboriginal inclusion in water management	In the period covered by this LTWP, Cultural Water initiatives and Aboriginal inclusion in water management in NSW will become more significant. Activities are likely to include: 1. capacity building to initiate cultural water programs; 2. consideration of the range of uses of cultural water and where they are complementary to ecological outcomes 3. consideration of where challenges in balancing cultural and ecological outcomes may occur, and how to address them; 4. consideration of how cultural water objectives and strategies may be built into the LTWP review in 5 years.	CEWO, MDBA, NBAN, MLDRIN, Aboriginal nations,	Section 7.4
Monitoring, Evaluation and reporting gaps	The WRP's Barwon–Darling Surface Water Monitoring Evaluation and Reporting Plan identifies gaps between current monitoring resources and those required to track against objectives. This will require multi-agency solutions.	DPIE Water, DPI Fisheries, DPIE, CEWO, MDBA	

7.2 Governance

Improving the cooperative management of water within and between river systems will help to protect and improve aquatic ecosystems in the Barwon–Darling system, whilst also enhancing equitable cultural, social and economic outcomes from water. It is likely that changes to the management structures for water in both the Barwon–Darling and the upstream tributary catchments are required to achieve the environmental water requirements.

Regional collaboration

An appropriate mechanism is required to gain regional input and build regional ownership of environmental water management in the Barwon–Darling. This will need to recognise the interdependence of northern catchments and the role of the Darling River in linking to the southern basin.

It is proposed to implement an Environmental Water Advisory Group (or EWAG) for decision-making around Held environmental water in the Barwon–Darling and Warrego Rivers (Toorale) to draw on the expertise and experience of community members to help inform the decision-making process. This group could build water literacy and foster ownership.

This may:

- enable broad representation: Elsewhere in NSW, EWAGs can include water managers, recreational fishers, landholders, irrigators, Aboriginal communities, independent scientists, conservation organisations and a variety of partner agencies. This would need to be tailored to the catchment.
- use adaptive management: EWAGs discuss proposed or upcoming watering events, related issues or concerns, the results of watering events and future opportunities. They help to develop strategies for various weather scenarios and provide advice on how to minimise disruption to other water users and communities.
- bring local priorities into decision-making: The groups recommend which assets to target for watering given the local and basin-wide priorities, as well as the best timing to maximise outcomes for rivers and wetlands and the plants and animals that depend on them.
- use best available evidence: an EWAG enables the use of new and evolving research, plus learning from any monitoring implemented.

Aboriginal communities

Aboriginal communities living along and belonging to the Baarka (Darling River) have expressed a willingness to contribute to decisions influencing their traditional lands and waters. Native title rights are expected to become defined and utilised within the period of this plan.

Beyond WRP development, environmental water management will benefit from the ongoing participation and advice of representatives from Aboriginal communities. Including or recognising Indigenous values will strengthen the development of environmental water strategies. As such, EWAG membership should include representation from relevant Aboriginal nations.

Northern Basin states

Coordination between NSW and Queensland is essential to improve flows and environmental outcomes in the Barwon–Darling. A standing arrangement used to address strategic decisions relevant to the northern basin such as implementing northern basin toolkit measures, dealing with event-based temporary protection of environmental water and undertaking further research, is required.

An extension of cross-jurisdictional agreement between NSW and QLD to include all MDB river systems would be required to realise the full benefit of environmental water. This would facilitate the use and protection of Commonwealth environmental water, by ensuring equitable conditions are executed in communities within both States.

7.3 Identifying and addressing knowledge gaps

There is growing scientific knowledge of water-dependent ecosystems and environmental flows in the Barwon–Darling WRPA. This includes the following recent work:

- the Northern Basin Review (MDBA 2016) developed new data and analyses around hydrological requirements of the Barwon–Darling and northern basin connectivity.
- the Fish and Flows monitoring project by DPI-Fisheries has made a significant contribution to informing the objectives and EWRs for the Barwon–Darling River. Enabling a new ability to detect outcomes like an improved population resilience of Murray cod, silver perch spawning aggregation and improved populations of carp Gudgeon, this information can be linked to specific flow events and improve the evidence base for management decisions and refining EWRs.
- other work such as habitat mapping in Barwon River by DPI–Fisheries, funded by various LLS and DPIE projects, can inform the spatial prioritisation of objectives.

These past projects have made an important contribution to the EWRs developed under the current LTWP.

Despite this recent work, considerable knowledge gaps remain in the Barwon–Darling that require further research and monitoring to fully understand the value, condition and watering requirements of key floodplain/wetland and channel values. Key examples include:

- using the EWRs to assess the water management regime and better identify the risks to achieving them
- understanding the influence of Barwon–Darling River environmental values on the overall Northern Basin values – such as fish, mussels or waterbirds
- better identifying and characterising water requirements to achieve longitudinal connectivity
- extending and ongoing resourcing for remotely-sensed floodplain and wetland inundation mapping for overbank events
- identifying priority drought refugia and their flow requirements
- expanding the geographic reach of in-stream habitat mapping
- further identify the location and watering needs of culturally-critical assets and values
- refinement of EWRs over time to reflect new flow analyses and primary research
- revision of the objectives, targets and indicators as tracking against them rolls out.

7.4 Measuring progress

Monitoring, evaluating and reporting (MER) are integral components of adaptive water management. 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.

Historical NSW Government monitoring and evaluation activities in the Barwon–Darling catchment have traditionally been associated with hydrology with some environmental-related monitoring primarily for Water Sharing Plan implementation. In more recent times however, given the purchase of Water Access Licenses by the Commonwealth and NSW Government and general Basin Plan implementation, an increased level of monitoring and evaluation activities are now required from both NSW and Commonwealth agencies. Toorale National Park and the adjacent Darling River frontage is one of the seven ‘Long-term intervention monitoring (LTIM) sites selected for investment by the CEWO.

The *NSW Barwon–Darling Surface Water Monitoring, Evaluation and Reporting Plan* (NSWMERP) aims to inform NSW Government agencies’ approach to MER to deliver on Basin Plan and NSW requirements. It is recognised a significant resourcing issue to allow agencies to inform both success or otherwise of meeting objectives and the adaptive management cycle for discretionary environmental watering decision-making.

Pending the provision of funding for expanded MER programs, the proposed monitoring and evaluation activities in the Barwon–Darling should include: monitoring and reporting by DPIE on the meeting of EWRs (hydrological analysis) and the response of fish, flow-dependent vegetation and waterbirds to decisions made in the management of discretionary environmental flows;

- Basin Plan Environmental Outcomes Monitoring (BPEOM) of fish populations over time (but not timed for flow events) at several locations in the WRPA.
- water quality monitoring at key points across the catchment by WaterNSW on behalf of DPIE Water.
- stand condition using a tool under development by the MDBA which may provide vegetation community condition data.
- aerial flights by DPIE and UNSW as part of the eastern Australian survey transects. Some of these flights do not target the B–D WRPA specifically but allow some indication of regional waterbird abundance and diversity trends.

7.5 Review and update

The demonstrated achievement of environmental water requirements in the Barwon–Darling is contingent on factors including resourcing and implementation of monitoring, the form and compliance with rules of the Water Sharing Plan, and outcomes from the NSW Water Reform Action Plan process. A review of the WSP may benefit from input from the LTWP, and in turn may trigger an update to the LTWP, in particular the risks, constraints and management strategies.

This LTWP brings together the best available information from a range of community, traditional and scientific sources. To ensure the information remains relevant and up-to-date, this LTWP will be reviewed and updated by DPIE BC 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 Namoi catchment
- revision of the BWS that materially affects this LTWP
- a sustainable diversion limit adjustment
- new information arising from evaluating responses to environmental watering
- new knowledge about the ecology of the Barwon–Darling catchment that is relevant to environmental watering

- improved understanding of the effects of climate change and its impacts on the Barwon-Darling catchment
- 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.

Figure 20 Barwon River, front of Northern Fish Flow, near Tara 7 June 2019
Photo: Jane Humphries (CEWO)

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Appendix A Values in each planning unit

The following series of tables provide summaries of the environmental values found in each Barwon–Darling planning unit.

Table 25 Native vegetation in each Barwon–Darling planning unit

Vegetation	Mungindi to Boomi River Confluence	Boomi River Confluence to Upstream Mogil Mogil Weir Pool	Mogil Mogil Weir Pool	Downstream Mogil Mogil to Collarenebri	Collarenebri to Upstream Walgett Weir	Walgett Weir Pool	Downdstream Walgett to Boorooma	Boorooma to Brewarrina	Brewarrina to Culgoa River Junction	Culgoa River Junction to Bourke	Bourke to Louth	Louth to Tilpa	Tilpa to Wilcannia	Wilcannia to Upstream Lake Wetherell
River red gum	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Black box	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Coolibah	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Floodplain	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lignum	X	X		X	X	X	X	X	X	X	X	X	X	X
Non-woody wetland	X	X			X	X	X	X	X	X	X	X	X	X

Table 26 Native fish species expected distribution in each Barwon–Darling planning unit

Native fish species by functional group	Threatened species status[34]	Planning units													
		Mungindi to Boomi River Confluence	Boomi River Confluence to Upstream Mogil Mogil Weir Pool	Mogil Mogil Weir Pool	Downstream Mogil Mogil to Collarenebri	Collarenebri to Upstream Walgett Weir	Walgett Weir Pool	Downdstream Walgett to Boorooma	Boorooma to Brewarrina	Brewarrina to Culgoa River Junction	Culgoa River Junction to Bourke	Bourke to Louth	Louth to Tilpa	Tilpa to Wilcannia	Wilcannia to Upstream Lake Wetherell
Flow pulse specialists															
Golden perch		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Silver perch	V	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Spangled perch		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Hyrtl's tandan								X		X	X	X	Predicted		
River specialists															
Murray cod	V	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Freshwater catfish	E												X		
Purple-spotted gudgeon[35]	E	Predicted		Predicted	Predicted	Predicted									
Olive perchlet[35]	E	X	X	Predicted	X	Predicted	X	Predicted	Predicted	Predicted	X	Predicted	Predicted	X	Predicted
Floodplain specialists															
Olive perchlet	E	X	X	Predicted	X	Predicted	X	Predicted	Predicted	Predicted	X	Predicted	Predicted	X	Predicted
Generalists															
Australian smelt		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Carp gudgeon		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Bony herring		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Murray-Darling rainbowfish		X	X	X	X	X	X	X	X	X	X	X	X	X	X

[34] E = listed as endangered in FM Act 1994, v = listed as vulnerable in FM Act 1994, V = listed as vulnerable in EPBC Act

[35] May be considered either Floodplain specialist or Riverine (lentic) depending on geographical location

Un-specked hardyhead							Predicted	Predicted		X	X	Predicted		Predicted

Appendix B Ecological objectives relevant to each planning unit

Table 27 Ecological objectives for each planning unit in the Barwon–Darling LTWP Area

Code	Ecological Objective	Mungindi to Boomi River Confluence	Boomi River Confluence to Upstream Mogil Mogil Weir Pool	Mogil Mogil Weir Pool	Downstream Mogil Mogil to Collarenebri	Collarenebri to Upstream Walgett Weir	Walgett Weir Pool	Downdstream Walgett to Boorooma	Boorooma to Brewarrina	Brewarrina to Culgoa River Junction	Culgoa River Junction to Bourke	Bourke to Louth	Louth to Tilpa	Tilpa to Wilcannia	Wilcannia to Upstream Lake Wetherell
NATIVE FISH															
NF1	No loss of native fish species	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NF2	Increase the distribution and abundance of short to moderate-lived generalist native fish species	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NF3	Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species: olive perchlet	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NF4	Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species: golden perch, silver perch, spangled perch, Hyrtls tandan	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NF5	Improve native fish population structure for moderate to long-lived riverine specialist native fish species: Murray cod, freshwater catfish, purple-spotted gudgeon	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NF6	A 25% increase in abundance of mature (harvestable sized): golden perch and Murray cod	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Code	Ecological Objective	Mungindi to Boomi River Confluence	Boomi River Confluence to Upstream Mogil Mogil Weir Pool	Mogil Mogil Weir Pool	Downstream Mogil Mogil to Collarenebri	Collarenebri to Upstream Walgett Weir	Walgett Weir Pool	Downdstream Walgett to Boorooma	Boorooma to Brewarrina	Brewarrina to Culgoa River Junction	Culgoa River Junction to Bourke	Bourke to Louth	Louth to Tilpa	Tilpa to Wilcannia	Wilcannia to Upstream Lake Wetherell
NF8[36]	Increase the prevalence and/or expand the population of key moderate to long-lived riverine specialist native fish species into new areas (within historical range): freshwater catfish							X					X		
NF9	Increase the prevalence and/or expand the population of key moderate to long-lived flow pulse specialist native fish species into new areas (within historical range): silver perch	X	X	X	X	X	X	X	X	X	X	X	X	X	X
VEGETATION															
NV1	Maintain the extent and viability of non-woody vegetation communities occurring within channels	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NV2	Maintain or increase the extent and maintain the viability of non-woody vegetation communities occurring in wetlands and on floodplains	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NV3	Maintain the extent and improve the condition of river red gum communities closely fringing river channels	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NV4c	Maintain or increase the extent and maintain or improve the condition of native woodland and shrubland communities on floodplains – Black box woodland	X	X	X	X	X	X	X	X	X	X	X	X	X	X

[36] Maxent data indicates suitable habitat to support the population between Louth and Tilpa. Based on expert opinion, downstream Walgett to Boorooma is also suitable pending improved connectivity to nearby tributary catchments. This is a 20 year target for catfish in the Barwon-Darling given the range of complimentary measures needed to achieve it such as carp control, aquatic habitat and fish passage/connectivity.

Code	Ecological Objective	Mungindi to Boomi River Confluence	Boomi River Confluence to Upstream Mogil Mogil Weir Pool	Mogil Mogil Weir Pool	Downstream Mogil Mogil to Collarenebri	Collarenebri to Upstream Walgett Weir	Walgett Weir Pool	Downdstream Walgett to Boorooma	Boorooma to Brewarrina	Brewarrina to Culgoa River Junction	Culgoa River Junction to Bourke	Bourke to Louth	Louth to Tilpa	Tilpa to Wilcannia	Wilcannia to Upstream Lake Wetherell
NV4d	Maintain or increase the extent and maintain or improve the condition of native woodland and shrubland communities on floodplains – Coolibah woodland	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NV4e	Maintain or increase the extent and maintain or improve the condition of native woodland and shrubland communities on floodplains – Lignum shrublands	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WATERBIRDS															
WB1	Maintain the number and type of waterbird species	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WB2	Increase total waterbird abundance across all functional groups	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WB3	Increase opportunities for non-colonial waterbird breeding										X	X	X	X	X
WB4	Increase opportunities for colonial waterbird breeding											X			
WB5	Maintain the extent and improve condition of waterbird habitats										X	X	X	X	X
ECOSYSTEM FUNCTIONS															
EF1	Provide and protect a diversity of refugia across the landscape	X	X	X	X	X	X	X	X	X	X	X	X	X	X
EF2	Create quality instream, floodplain and wetland habitat	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Code	Ecological Objective	Mungindi to Boomi River Confluence	Boomi River Confluence to Upstream Mogil Mogil Weir Pool	Mogil Mogil Weir Pool	Downstream Mogil Mogil to Collarenebri	Collarenebri to Upstream Walgett Weir	Walgett Weir Pool	Downdstream Walgett to Boorooma	Boorooma to Brewarrina	Brewarrina to Culgoa River Junction	Culgoa River Junction to Bourke	Bourke to Louth	Louth to Tilpa	Tilpa to Wilcannia	Wilcannia to Upstream Lake Wetherell
EF3a	Provide movement and dispersal opportunities for water-dependent biota to complete lifecycles and disperse into new habitats – within catchments	X	X	X	X	X	X	X	X	X	X	X	X	X	X
EF3b	Provide movement and dispersal opportunities catchments for water-dependent biota to complete lifecycles and disperse into new habitats – between catchments	X	X	X	X	X	X	X	X	X	X	X	X	X	X
EF4	Support instream and floodplain productivity	X	X	X	X	X	X	X	X	X	X	X	X	X	X
EF5	Support nutrient, carbon and sediment transport along channels, and exchange between channels and floodplains/wetlands	X	X	X	X	X	X	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	X	X	X	X	X	X
EF7	Increase the contribution of flows into the Murray and Barwon-Darling from tributaries	X	X	X	X	X	X	X	X	X	X	X	X	X	X