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Status and water requirements of the Booroolong frog in the Cockburn River water source

Reporting for the Environmental Outcomes Monitoring and Research Program

April 2024

Acknowledgement of Country

The Department of Climate Change, Energy, the Environment and Water acknowledges that it stands on Aboriginal land. We acknowledge the Traditional Custodians of the land and we show our respect for Elders past, present and emerging through thoughtful and collaborative approaches to our work, seeking to demonstrate our ongoing commitment to providing places in which Aboriginal people are included socially, culturally and economically.

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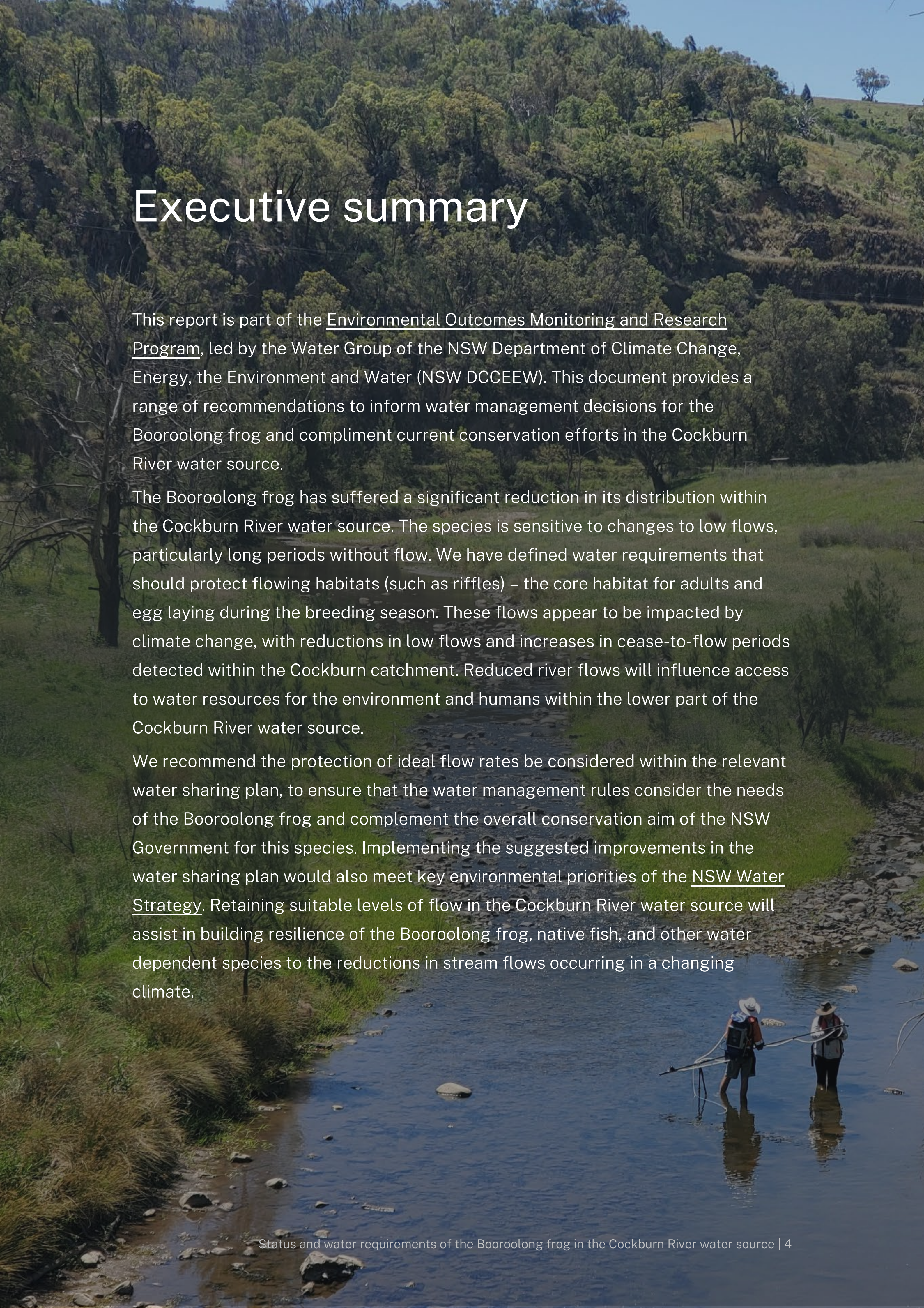

Executive summary

This report is part of the Environmental Outcomes Monitoring and Research Program, led by the Water Group of the NSW Department of Climate Change, Energy, the Environment and Water (NSW DCCEEW). This document provides a range of recommendations to inform water management decisions for the Booroolong frog and compliment current conservation efforts in the Cockburn River water source.

The Booroolong frog has suffered a significant reduction in its distribution within the Cockburn River water source. The species is sensitive to changes to low flows, particularly long periods without flow. We have defined water requirements that should protect flowing habitats (such as riffles) – the core habitat for adults and egg laying during the breeding season. These flows appear to be impacted by climate change, with reductions in low flows and increases in cease-to-flow periods detected within the Cockburn catchment. Reduced river flows will influence access to water resources for the environment and humans within the lower part of the Cockburn River water source.

We recommend the protection of ideal flow rates be considered within the relevant water sharing plan, to ensure that the water management rules consider the needs of the Booroolong frog and complement the overall conservation aim of the NSW Government for this species. Implementing the suggested improvements in the water sharing plan would also meet key environmental priorities of the NSW Water Strategy. Retaining suitable levels of flow in the Cockburn River water source will assist in building resilience of the Booroolong frog, native fish, and other water dependent species to the reductions in stream flows occurring in a changing climate.

1.1 Report aims

The purpose of this report is to provide ecological information for the endangered Booroolong frog that can be used during the remake of the Water Sharing Plan for the Namoi and Peel Unregulated Rivers Water Sources 2012 (the water sharing plan). This includes identifying the current distribution and the preliminary water requirements within the Cockburn River water source. We also look at changes to the flow regime in the Cockburn River water source to provide guidance for water management decisions.

The specific aims are to:

1. identify the current and historic distribution of the Booroolong frog in the Cockburn River water source
2. define the preliminary environmental water requirements using available information for the Booroolong frog in the Cockburn River water source
3. document changes to river flows in key areas where the Booroolong frog is predicted to occur within the catchment.

An endangered Booroolong frog sitting in a flowing riffle in the Cockburn River water source. Image credit: Bec Wood DCCEEW

1.2 Area of interest

This project focuses on the Cockburn River water source which falls within the Peel water sharing plan boundary and includes the Cockburn River and its main tributaries, Swamp Oak Creek, Mulla Mulla Creek and Jamiesons Creek (Figure 1). The rivers within the region support an array of environmental and cultural assets, social amenities, and economic activities. A range of water-dependent flora and fauna occur within the water source, including waterbirds, native fish, turtles, frogs, and aquatic insects.

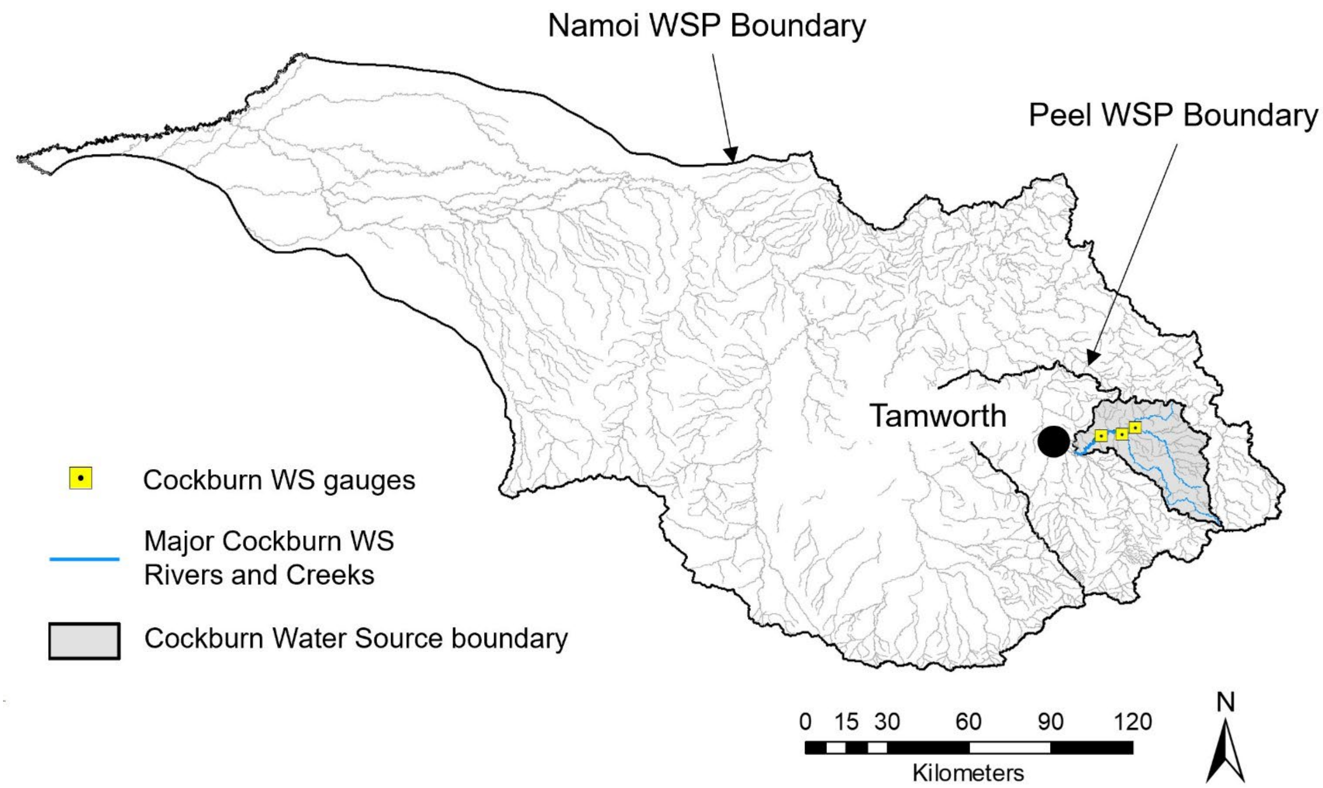

Figure 1 Map of the Namoi and Peel Water Sharing Plan boundaries with the Cockburn River water source shaded grey and relevant streams for the Booroolong frog in blue.

1.3 Water management in the Cockburn River water source

1.3.1 The environmental objectives for the water source

There are a range of environmental objectives listed within state and federal legislation. However, the overall environmental objectives within Part 2 (Section 8.04) of the *Basin Plan 2012* and Chapter 1 (3b) of the *Water Management Act 2000* can be summarised as a focus on the protection and restoration of water-dependent ecosystems within the water sources of the Murray-Darling Basin.

Each water sharing plan has social, economic, cultural and environmental objectives. The broad environmental objective of each water sharing plan is to protect, preserve, maintain or enhance the important river flow dependent and high priority groundwater-dependent ecosystems of these water sources. The mechanisms to achieve these objectives within the water sharing plan are summarised below.

1.3.2 The current water management strategies for the water source

The water sharing plan sets rules for the extraction and trade of water via access licenses and defines extraction limits to ensure the long-term sustainability of the resource. These rules aim to reduce the impacts of extraction and river regulation to support the intended environmental outcomes of the water sharing plan. The key strategies that focus on protecting and or delivering specific components of the flow regime that are impacted by regulation or extraction are listed below:

- manage extractions to the long-term average annual extraction limit and the long-term average sustainable diversion limit
- reserve a portion of flows to maintain longitudinal connectivity within and between these water sources and other connected water sources including the Upper Namoi Regulated River Water Source, the Lower Namoi Regulated River Water Source and the Peel Regulated River Water Source
- reserve a portion of flows to partially mitigate alterations to natural flow regimes in these water sources
- restrict or prevent water supply work approvals in specified circumstances
- restrict the take of water from in-river and off-river pools when the volume of that water is less than full capacity.

1.4 The significance of flows for stream frogs

River flows can be broken into broad flow categories important for frogs, which include cease to flow, low flow, fresh or pulse flow events, and overbank flows. Each flow category can influence a range of life-history stages in frogs. Detailed water-dependent functional groups for NSW frogs were developed by Coleman *et al*. (2024). These can be summarised into 2 groups, and 5 subgroups (Figure 2). The two major groups are:

- Obligate stream spawning (OSS) frogs which are heavily dependent on flowing in-channel stream habitats for breeding. This group includes the Booroolong frog (*Litoria booroolongensis*) (Figure 2A).
- Facultative stream spawning (FSS) frogs which partially rely on river flows but can often breed in other habitats (Figure 2B-C).

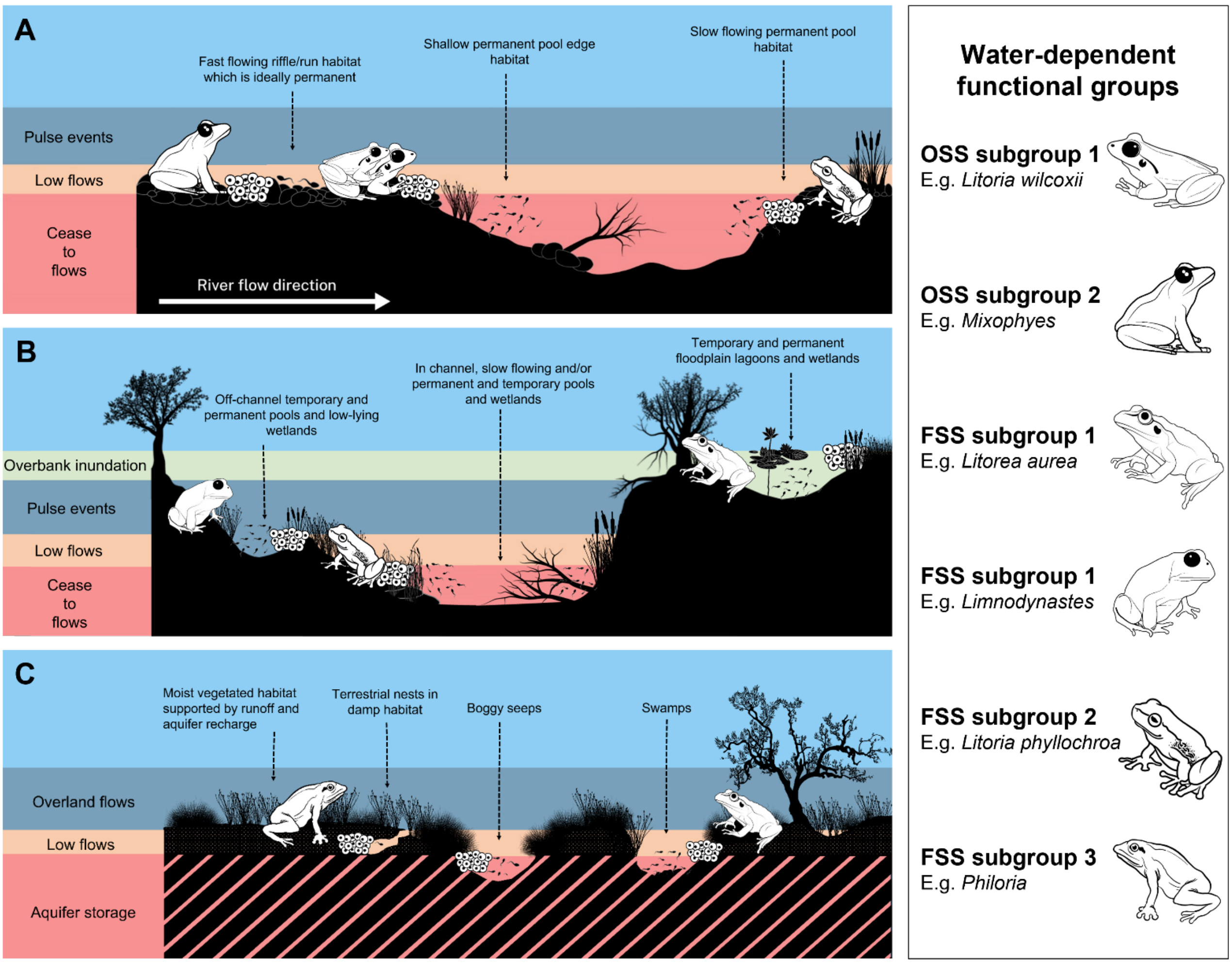

Figure 2 A simple conceptual model of the main flow categories that are important for frogs in NSW. The Booroolong frog is part of the obligate stream spawning subgroup 1 (OSS subgroup 1) which requires flowing water habitats in riffles (A).

1.5 Distribution of the Booroolong frog

Aim 1: Identify the current and historic distribution of the Booroolong frog in the Cockburn water source.

The Cockburn water source supports one of the last known populations of the endangered Booroolong frog in northern NSW. The Booroolong frog was once widespread and common throughout the New England Tablelands, with records prior to 1980 covering the areas surrounding Armidale, Glen Innes and Tamworth (Figure 3). However, in the 1980s the northern population suffered severe decline because of the spread of amphibian disease caused by chytrid fungus and the combined pressures of changes in land use, stream flow alteration, climate change and predation from introduced fish (Portway et al., 2018).

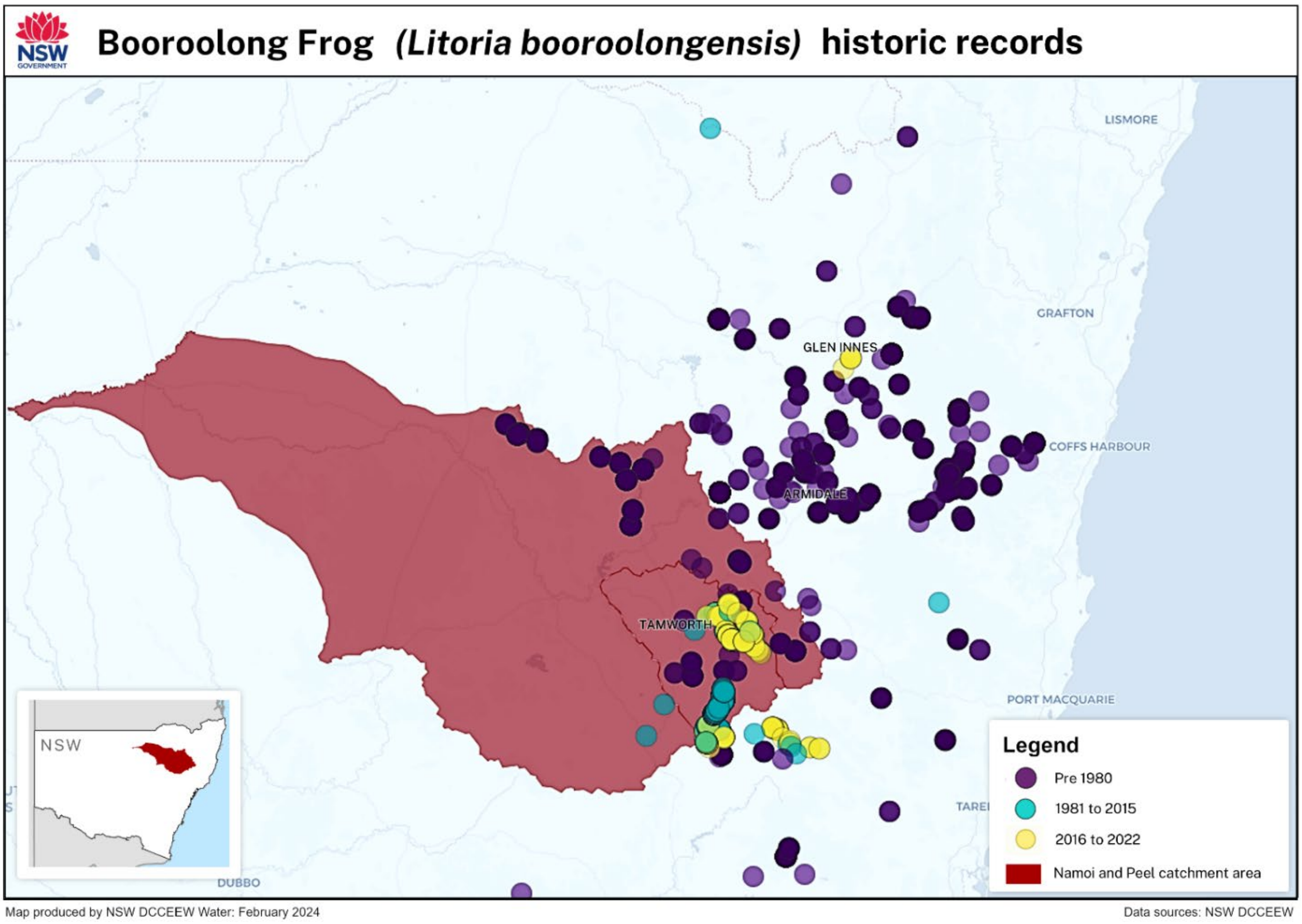

Figure 3 Historic records of the Booroolong frog within the Namoi and Peel catchment based on current and historic data (1900-2022). Data source (DCCEEW – BCS data and FrogID, Australian museum data)

This contraction of the species distribution can be seen in records after 1981 (coloured blue and yellow), which are restricted to 2 small areas of the tablelands near Tamworth and a recently discovered population near Glen Innes (Figure 3) (Rowley & Cutajar, 2018). Through the early 2000s, the Booroolong frog became rarer, but still held on within the Cockburn River and its tributaries. Then, during the 2017-2019 drought, rivers ceased to flow and the species contracted to just a few small pockets where refuge pools persisted.

The NSW Government, led by the Taronga Conservation Society and the NSW DCCEEW Biodiversity, Conservation and Sciences Division established a reintroduction program for the Booroolong frog which collected a subset of frogs from the wild population in the Cockburn catchment area to breed in captivity at Taronga Zoo. The program includes the reintroduction of frogs throughout the Cockburn River catchment area to assist the population to increase its distribution and recover to its predicted distribution (Figure 4).

To date, the NSW Government has invested in a 5-year service level agreement worth $420,000 for captive breeding of the northern Booroolong frog population, focusing on the Cockburn water source; this follows NSW DCCEEW funding a breeding facility. Last year, the NSW Government invested $163,000 in the Cockburn population alone, which includes the establishment of a targeted eDNA monitoring program coordinated by the NSW DCCEEW Surface Water Science unit. Frogs have recently been released back into the wild from Taronga Zoo's insurance population in the Spring and Summer of 2023/2024 and the monitoring program will track the presence of the species during the next water sharing plan period.

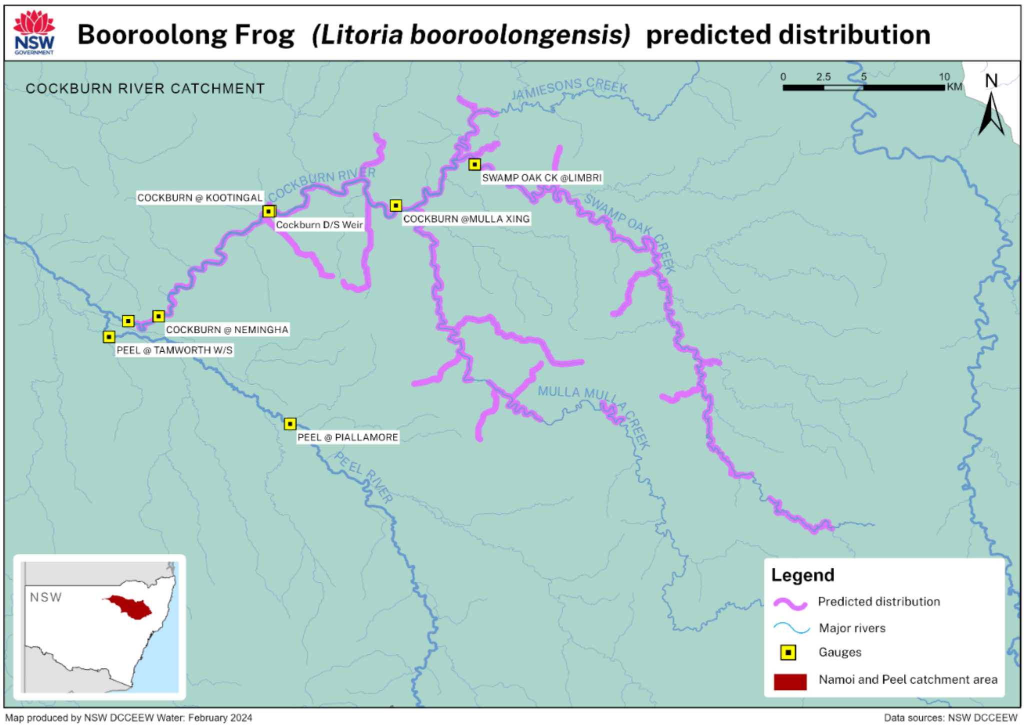

Figure 4 Predicted distribution of the Booroolong frog (Litoria booroolongensis) within the Cockburn River water source based on historic data (2000-2017). Data source (DCCEEW – BCS data).

1.6 Preliminary water requirements of the Booroolong frog

Aim 2: define the preliminary environmental water requirements for the Booroolong frog in the Cockburn water source.

1.6.1 Defining water requirements

The influence of river flows on a species population is used to develop an understanding of water requirements. River flows are required to support frog reproduction and tadpole development, provide food resources, and maintain suitable habitats for all life stages (Coleman *et al.*, 2024) (Figure 5).

This section provides a preliminary set of water requirements based on available information which can be used to guide the protection of key flows for the Booroolong frog within the Cockburn River water source. They are guided by the peer reviewed article on stream frog water requirements in NSW (Coleman *et al.*, 2024) and will be updated with targeted monitoring during the life of the water sharing plan.

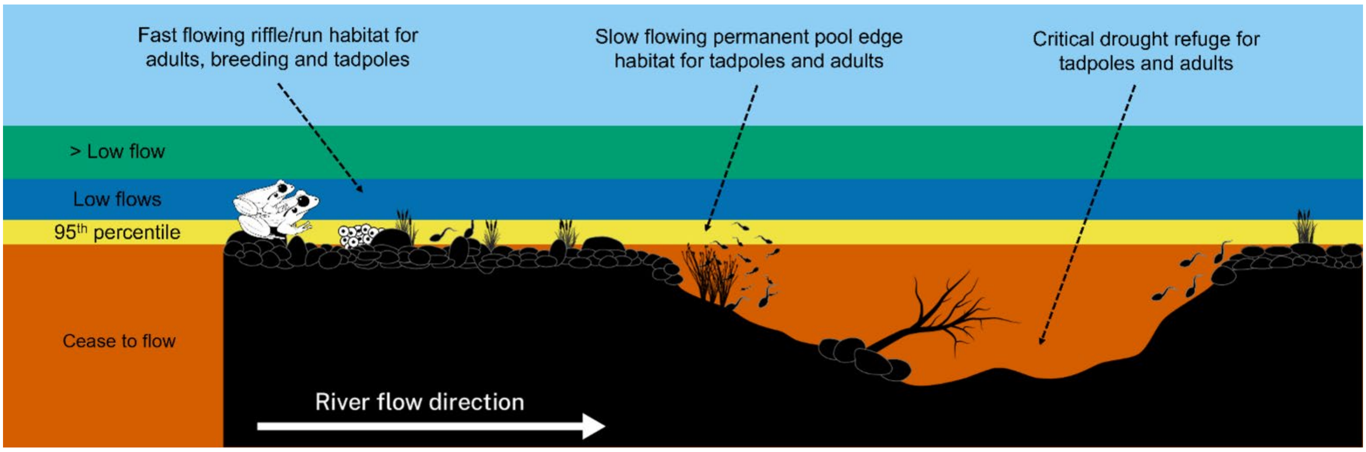

Figure 5 Conceptual model for the endangered Booroolong frog. The diagram highlights the significance of the 95th percentile flows for breeding, tadpoles and adult habitat.

1.6.2 Water dependence of the Booroolong frog

The Booroolong frog is considered an obligate stream breeding frog, which requires continuous stream flows to ensure the protection of flowing water habitats (such as riffles) and pools which should support the completion of the reproductive life-cycle (Table 1). Coleman *et al.*, (2024) highlight that extended cease-to-flow periods will limit reproductive success due to reduce egg-laying habitat in riffles, resulting in a subsequent reduction in the abundance of juveniles and adult frogs. The Northern population of the Booroolong frog, including in the Cockburn River water source has severely declined after prolonged stream drying (North West Ecological Services, 2015) and the influence of climate change on stream drying is a listed threat to this species (Threatened Species Scientific Committee, 2021). Cease-to-flow periods are also likely to reduce tadpole survivorship as they require 2.5 months to mature into frogs and prefer flowing riffles and pools. Therefore, low flows are the most important flow category, or water requirement to avoid extended cease-to-flow periods.

Table 1. Additional information on the flow or water dependent connection as well as water management threats for the Booroolong frog.

Description of flow, water-dependent or stream connection	Threats (water, flow and stream management)	Literature
No detail	Altered stream flows and stream drying associated with severe droughts and extended cease to flows	OEH (2012)
Failure to locate the Booroolong frog along ephemeral streams, and the decline of this species from streams that dried during recent severe droughts, demonstrates the reliance of this species on permanent water	No detail	Hunter & Smith (2006)
Reliability of flows is considered a key factor in habitat suitability	Drought and long periods of low flows are a threat	North West Ecological Services (2015)
The primary habitat requirements for the Booroolong frog are extensive rock bank structures along permanent rivers	Flow modification is a threat, particularly modification to low and base flows	Gillespie & Hines (1999)
Associated with shallow slow flowing cobble riffles and rapids. Eggs are laid in shallow slow flowing riffles	High flows can disturb eggs and breeding sites. River regulations and cold water pollution	NCMA (2009)
Tadpoles commonly found in shallow flowing sections of streams: runs, riffles and shallow stream flowing inlets. Adults found mid-stream basking or under rocks on the banks of flowing streams.	No detail	Anstis, Alford & Gillespie (1998) Anstis *et al.*, (1998)
No detail	Flow alteration to low and base flows are considered a significant risk to stream frogs.	Hunter & Gillespie (2014)
Strong association with flowing rocky streams often seen on rocks and next to stream throughout the day	No detail	Clulow *et al.*, (2006)

1.6.3 Defining low flows

A "low flow" means different things to different interest groups. The International Glossary of Hydrology (WMO, 2012) defines low flow as 'flow of water in a stream during prolonged dry weather'. However, this distinction doesn't discriminate between low flows and droughts. Low flows are generally a seasonal phenomenon, and an integral component of the flow regime. They are normally derived from groundwater discharge or from surface water sources like lakes, upland swamps and marshes which provide consistent inflows that can sustain flows in rivers for long periods after a rainfall pulse flow has travelled downstream.

In previous studies, low flows have been calculated using a variety of methods (Smakhtin, 2001), including but not limited to: low flow domains, flow duration curves and percent exceedances, and low-flow frequency analyses based on an annual scale. In NSW, low flows have primarily been calculated using flow duration curves and percent exceedances. The NSW River Flow Objectives, which were endorsed by the NSW Government in 1999 define very low and low flows as:

- very low flows: flows below the level naturally exceeded on 95% of all days with flow (95th percentile)
- low flows: flows below the level naturally exceeded on 80% of all days with flow (80th percentile).

The focus on natural flows is based on the large body of work establishing the significance of natural flows for aquatic ecosystems (Poff et al., 1997; Lytle & Poff, 2004). Haeusler & Reinfelds (2016) also identified the 94th - 96th percentile of natural flows as an appropriate low flow or minimum flow required to provide a small refuge of all hydraulic conditions within cobble bed flowing water habitats (such as riffles) in several NSW rivers. Protecting, or maintaining these minimum flows is critical to reduce the frequency and duration of cease-to-flow events. This flow is considered an appropriate flow to ensure survival of aquatic biota like the Booroolong frog, which are adapted to live and breed within faster-flowing waters most affected by low flow conditions and water extraction.

1.6.4 Determining preliminary water requirements for the Booroolong frog

Flow thresholds of interest

The minimum flow requirement for protecting the core habitat of the Booroolong frog, flowing cobble bed riffles, was based on the NSW River Flow Objectives and the work by Haeusler & Reinfelds (2016). The minimum flow requirement is considered the 95th percentile of flowing days based on the observed flow record due to the lack of modelled natural flows for this assessment. We also provide an analysis of the 80th percentile, often considered a baseflow threshold in NSW water sharing plans, and the 87.5th percentile flow threshold (between the 95th and 80th percentile) which would provide ideal outcomes for the Booroolong frog by protecting more flowing habitat and reducing very low and cease to flow events during drought.

Timing or seasonality

The provision or protection of low flows are particularly important during the breeding months (Spring - Summer) when Booroolong frogs come to sit on cobbles within the flowing riffle zone of the river to mate and lay their eggs. The Booroolong tadpoles require appropriate river flows for a minimum of 2.5 months of river flows to allow them to fully develop into juvenile frogs (Anstis, 2017). Therefore, the flowing water habitats are most important during these periods, which are defined within Table 2.

Preliminary water requirements

Based on the available information at the time of writing this report, we consider the minimum water requirement for the Booroolong frog to be the 95th percentile of natural flows between 1 October – 28 February for breeding, and the 15 December – 15 May for tadpole development. However, we have used the 95th percentile of flowing days from the observed flow record in the absence of modelled natural flows for all gauges within the water source (Table 2).

Table 2 Water requirements of the Booroolong frog during specific life stages for relevant flow gauges within the Cockburn River water source (ML/day) (Figure 4). *This is a new gauge and the flow percentiles are based on a small amount of data, during a relatively wet period. This needs to be considered in any water management decisions.

Flow gauge	Flow record used	Life stage	Timing	Minimum flow (ML/d) requirement 95th percentile	Ideal flow (ML/d) requirement 87.5th percentile	Low flow (ML/d) requirement 80th percentile
419114 Cockburn River DS of Kootingal Bridge + 419099 Cockburn River at Kootingal	25/2/2006 to 30/06/2023	Adult breeding (Tadpole development)	1 Oct – 28 Feb (15 Dec – 15 May)	1.8	3.0	5.0
419099 Cockburn River at Kootingal	25/2/2006 to 2/01/2020	Adult breeding (Tadpole development)	1 Oct – 28 Feb (15 Dec – 15 May)	1.7	2.4	3.9
419114 Cockburn River DS of Kootingal Bridge*	3/01/2020 to 30/06/2023	Adult breeding (Tadpole development)	1 Oct – 28 Feb (15 Dec – 15 May)	6.6	20.6	32.3
419016 Cockburn River at Mulla Crossing	16/07/1973 to 30/06/2023	Adult breeding (Tadpole development)	1 Oct – 28 Feb (15 Dec – 15 May)	2.1	4.6	7.9
419054 Swamp Oak at Limbri	21/05/1974 to 30/06/2023	Adult breeding (Tadpole development)	1 Oct – 28 Feb (15 Dec – 15 May)	1.5	2.7	4.1

1.7 River flows in the Cockburn water source

There are 4 gauges in the Cockburn River water source:

- Cockburn River at Kootingal (419099)
- Cockburn River downstream of Kootingal Bridge weir (419114)
- Cockburn River at Mulla Crossing (419016)
- Swamp Oak Creek at Limbri (419054).

The Cockburn River downstream of Kootingal Bridge weir gauge (419114) is a new gauge with only 3 years of data as it replaced gauge 419099. Hydrographs for 4 key gauges are shown in Figure 6, for the period of the water sharing plan (water year 2013 to water year 2023). The most recent years on record (2021-2023) was one of the wettest periods across the Northern Murray Darling Basin (Figure 6 and Figure 7).

To show flow metric data for the full period of record for the Cockburn River at Kootingal we have combined flow data from 2 gauges (419099 and 419114). By adding the records together at the time of activation of the new gauge we can see the entire record from 2006 to 2023 which captures both dry and wet periods (Figure 7). However, the new gauge is more accurate at lower flows than the deactivated gauge 419009. This may impact the calculation of some low flow metrics such as the number of cease-to-flow days (<1 ML) (Figure 8) and the 95th percentile flows (Figure 9). It was also activated during a relatively wet period compared to the historic gauge 419099, for this reason we have included metrics for the combined gauges alongside each individual gauge in the calculation of the environmental water requirements (Table 2).

The period of record for the Cockburn River at Kootingal (419099 and 419114) is still relatively short. Both the Swamp Oak Creek at Limbri (419054) and Cockburn River at Mulla Crossing (419016) flow gauges have data from the mid 1970's to present, whilst he Kootingal gauges only cover the period from 2006 onwards. Both of the flow gauges with longer records (419054 and 419016) have a significant step change in flow rates (high and low flows) after 1990. The step changes indicates that the system has experienced a hydrological shift and drying of the catchment, with less flows consistently occurring after 1990 (Appendix A: Figure 13 and Figure 14).

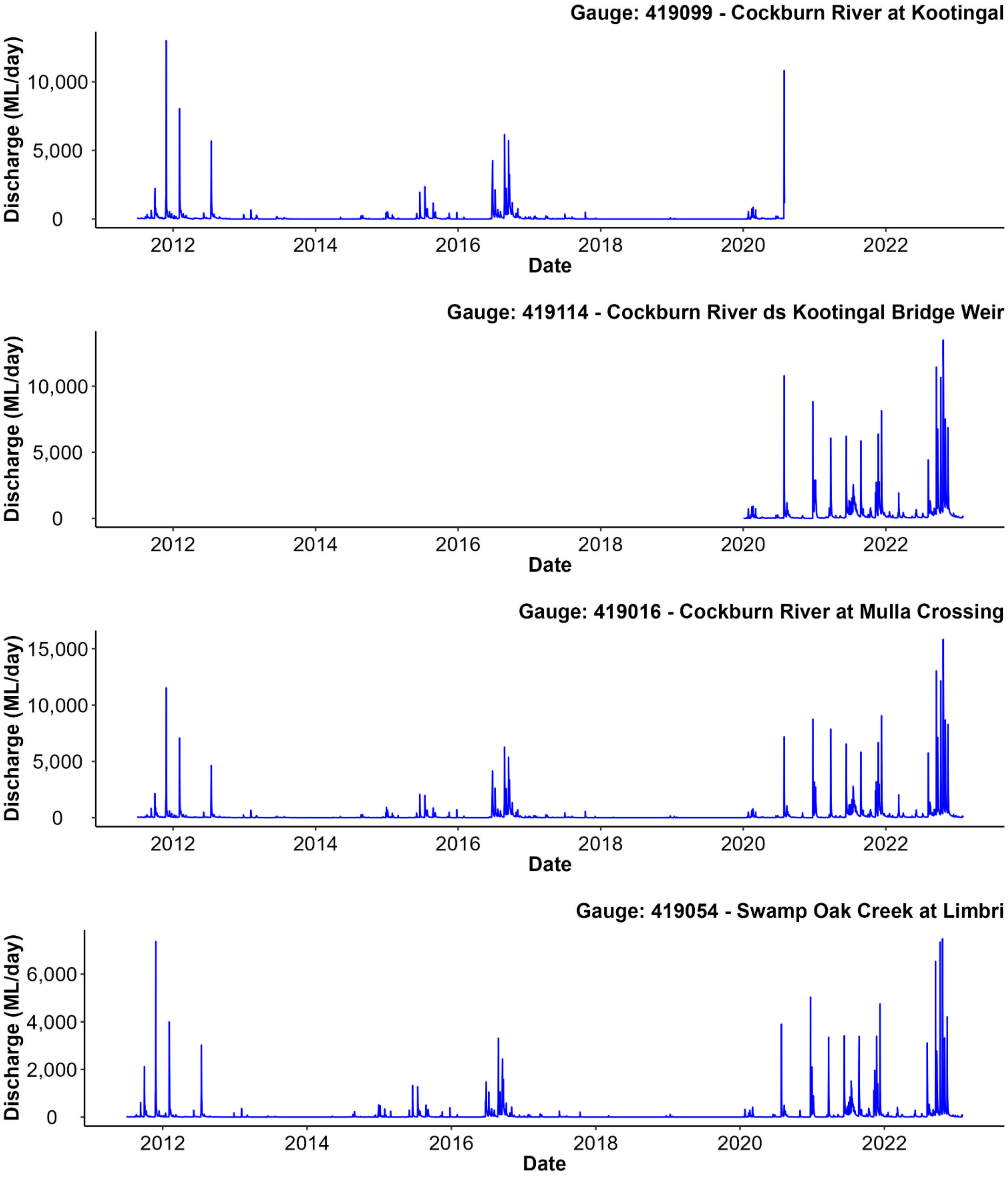

Figure 6 Mean daily discharge (ML/day) since the commencement of the water sharing plan (01/07/2012 – 30/06/2023) at different gauges within the Cockburn River water source.

1.7.1 Changes to total annual volume

Annual total volumes and the whole period of record at each of the gauge locations were highly variable (Figure 7). Total annual volumes for the current water sharing plan period (2012-2022) were some of the highest and lowest annual volumes on record (Figure 7).

Figure 7 shows the annual total annual volume for the Cockburn River at Kootingal (combined 419099/419114, 2006 - 2022), Cockburn River at Mulla Crossing (419016, 1974-2022) and Swamp Oak Creek at Limbri (419054, 1975-2022). The blue shaded area shows the current water sharing plan period (2012 – 2022 water years). The flow data from gauges 419099 and 419114 have been combined to represent flows at the Cockburn River at Kootingal, as the old gauge 419099 was discontinued during early 2020 and the new gauge has replaced it but only has data for 3 years (2019 – 2022 water years), indicated by the 2 shades of blue 419099 (dark blue), 419114 (light blue.)

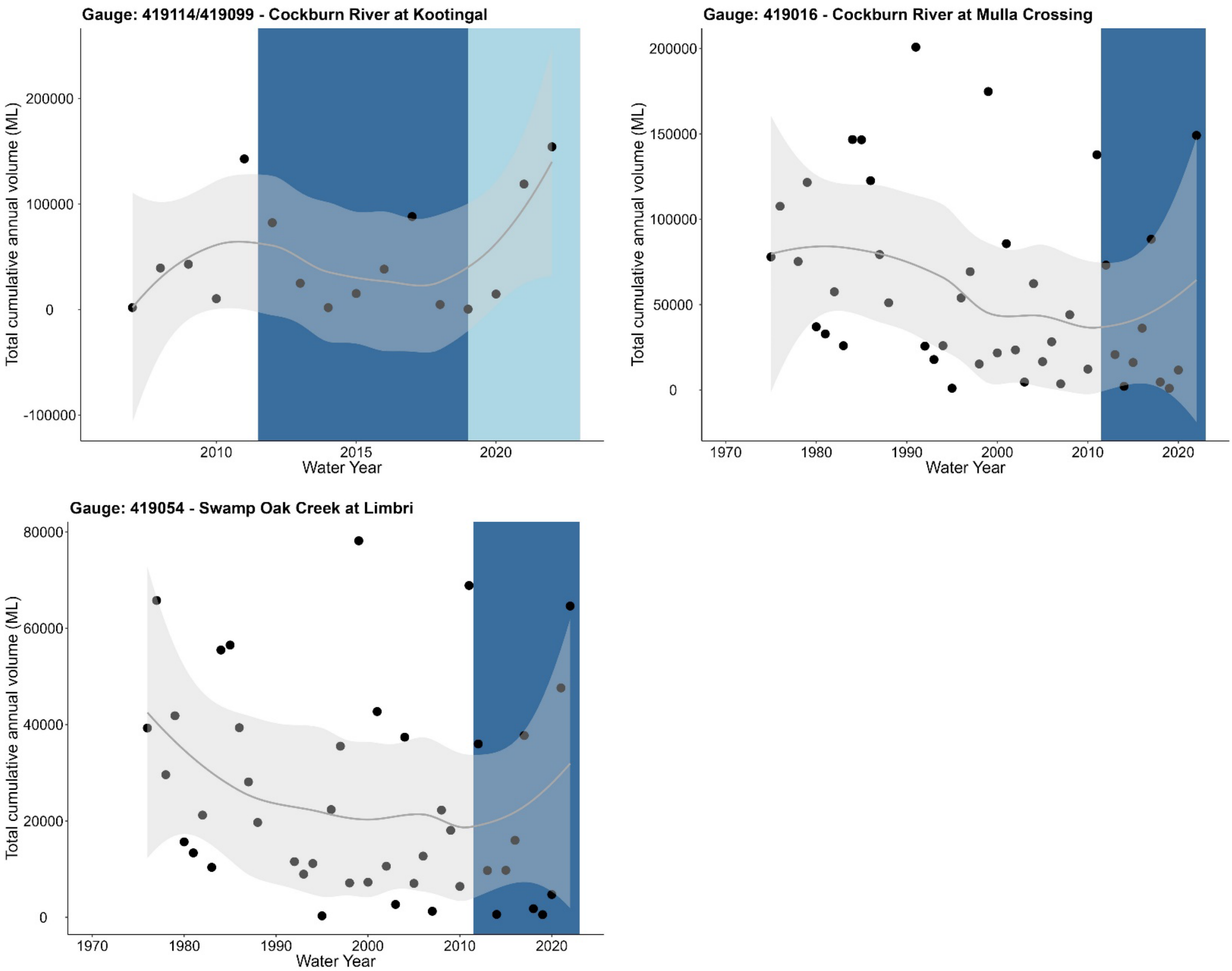

Figure 7 Total annual volume (ML) for the whole period of record at 3 gauge sites in the Cockburn River water source.

1.7.2 Changes to cease to flows

It is important to highlight that cease to flows are a natural component of the flow regime in the Cockburn River water source. However, increases to their frequency or duration can impact on the health of a river by reducing quality and availability of aquatic habitats. In this report we consider anything below 1 ML/d a cease to flow from an ecological perspective, as it is unlikely to provide flows that are ecologically meaningful for flow dependent organisms.

There is insufficient data to determine long-term changes in the number of cease-to-flow days at the Cockburn River at Kootingal gauges (combined data 419009/419114), since the period of record only covers between 2006 to 2022. Based on the available period of data, the number of cease-to-flow days remains variable from year to year since 2006, but has not increased noticeably. The biggest impact appears to be during 2019 which was the driest period on record at this gauge, with almost the entire year (>300 days) having less than 1ML/day.

Figure 8 shows the number of cease to flow days (<1ML/day) for the Cockburn River at Kootingal (combined 419099/419114, 2006 - 2022), Cockburn River at Mulla Crossing (419016, 1974-2022) and Swamp Oak Creek at Limbri (419054, 1975-2022). The blue shaded area shows the current water sharing plan period (2012 – 2022 water years). The flow data from gauges 419099 and 419114 have been combined to represent flows at the Cockburn River at Kootingal, as the old gauge 419099 was discontinued during early 2020 and the new gauge has replaced it but only has data for 3 years (2019 – 2022 water years), indicated by the 2 shades of blue 419099 (dark blue), 419114 (light blue.)

The Kootingal gauges (419009/419114) have a relatively short period of record compared to the other two gauges in the water source: the Cockburn River at Mulla Crossing 419016 and Swamp Oak Creek at Limbri 419054, which both have data from the 1970s onwards. These gauges are upstream of most of the extraction within the catchment and provide insight into the climatic changes occurring within the catchment, as well as impacts from basic landholder rights and small entitlement usage. Both 419016 and 419054 gauges show an increasing trend in the number of days that the river has ceased to flow (<1 ML/day) (Figure 8, Appendix A). This suggests that the catchment is drying and the amount of time that the river ceases to flow is increasing which is likely to impact the recovery of the Booroolong frog as well as other environmental values within the catchment.

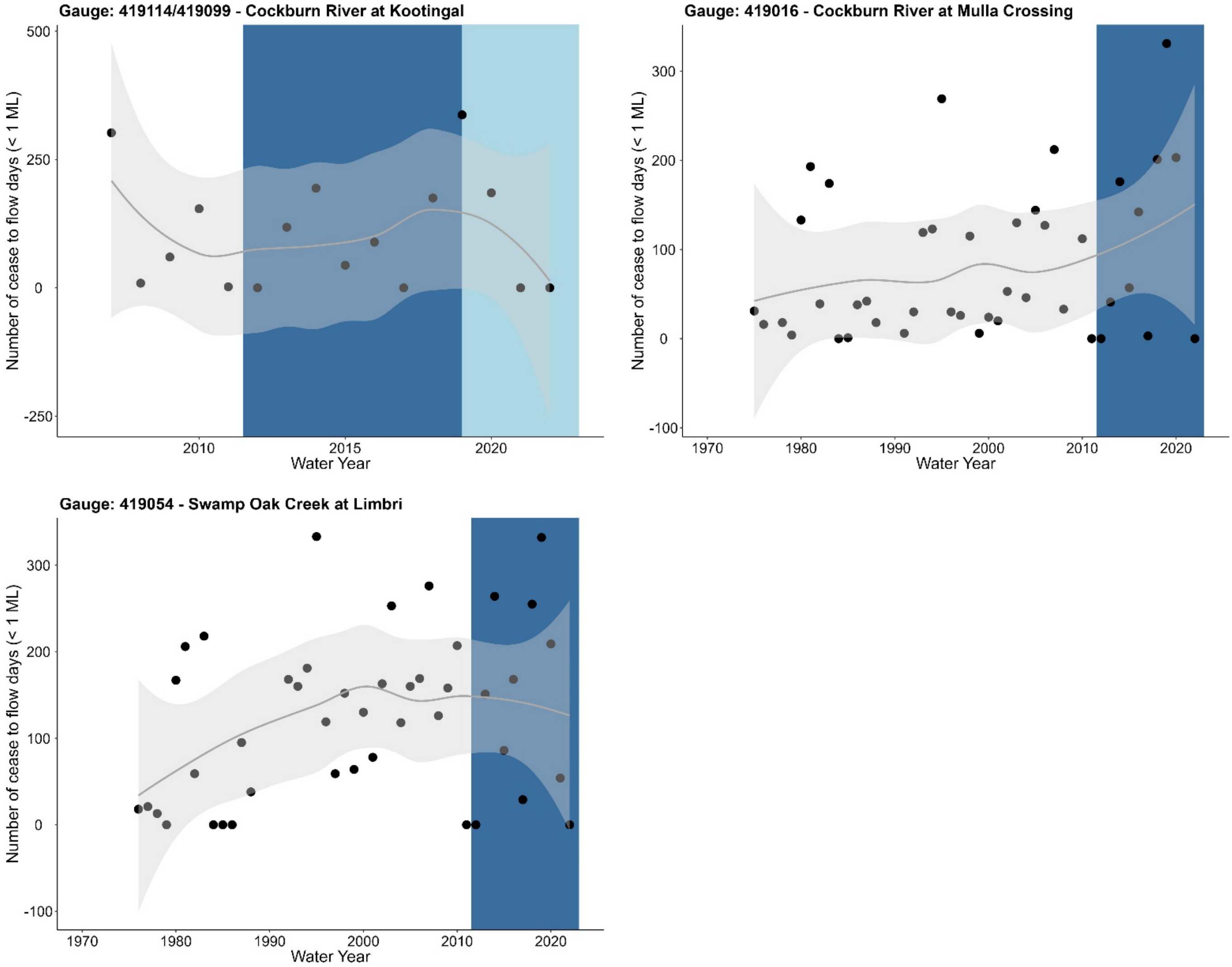

Figure 8 Number of cease to flow days (days under 1 ML) for the whole period of record at 3 gauge sites in the Cockburn River water source.

1.7.3 Changes to low flows (95th percentile)

Figure 9 shows the annual 95th percentile for the Cockburn River at Kootingal (combined 419099/419114, 2006 - 2022), Cockburn River at Mulla Crossing (419016, 1974-2022) and Swamp Oak Creek at Limbri (419054, 1975-2022). The blue shaded area shows the current water sharing plan period (2012 – 2022 water years). The flow data from gauges 419099 and 419114 have been combined to represent flows at the Cockburn River at Kootingal, as the old gauge 419099 was discontinued during early 2020 and the new gauge has replaced it but only has data for 3 years (2019 – 2022 water years), indicated by the 2 shades of blue 419099 (dark blue), 419114 (light blue.) The green box indicates the period prior to 1990 (gauge 419016) and 1986 (gauge 419054) when there was a significant step change in the hydrology of flows at gauge 419016 and 419054 (Table 3).

The low flows, as represented by the 95th percentile flow (including zero flows) (Figure 9) is often 0 ML/day, meaning that the river ceases to flow most years, which is common for intermittently flowing rivers in the Northern Murray-Darling Basin. However, at the 2 gauges with relatively long-term records (419016 and 419054) there is a noticeable point around 1990 and 1986 respectively, where the 95th percentile declines and rarely exceeds 0 ML/day (Figure 9 and Table 3).

Prior to 1990, at the Cockburn River gauge at Mulla Crossing 419016 there were 76% of years where the 95th percentile was greater than 0 ML/day. However, after 1990, this fell to 56% of years where the 95th percentile was greater than 0 ML/day. At the Swamp Oak Creek at Limbri 419054 gauge, there were 77% of years where the 95th percentile was greater than 0 ML/day prior to 1986. This fell to 44% in the 37 years after 1986 to 2023. This suggests that the catchment has experienced a climate shift, with periods where the river ceases to flow becoming more prevalent and low flows reducing.

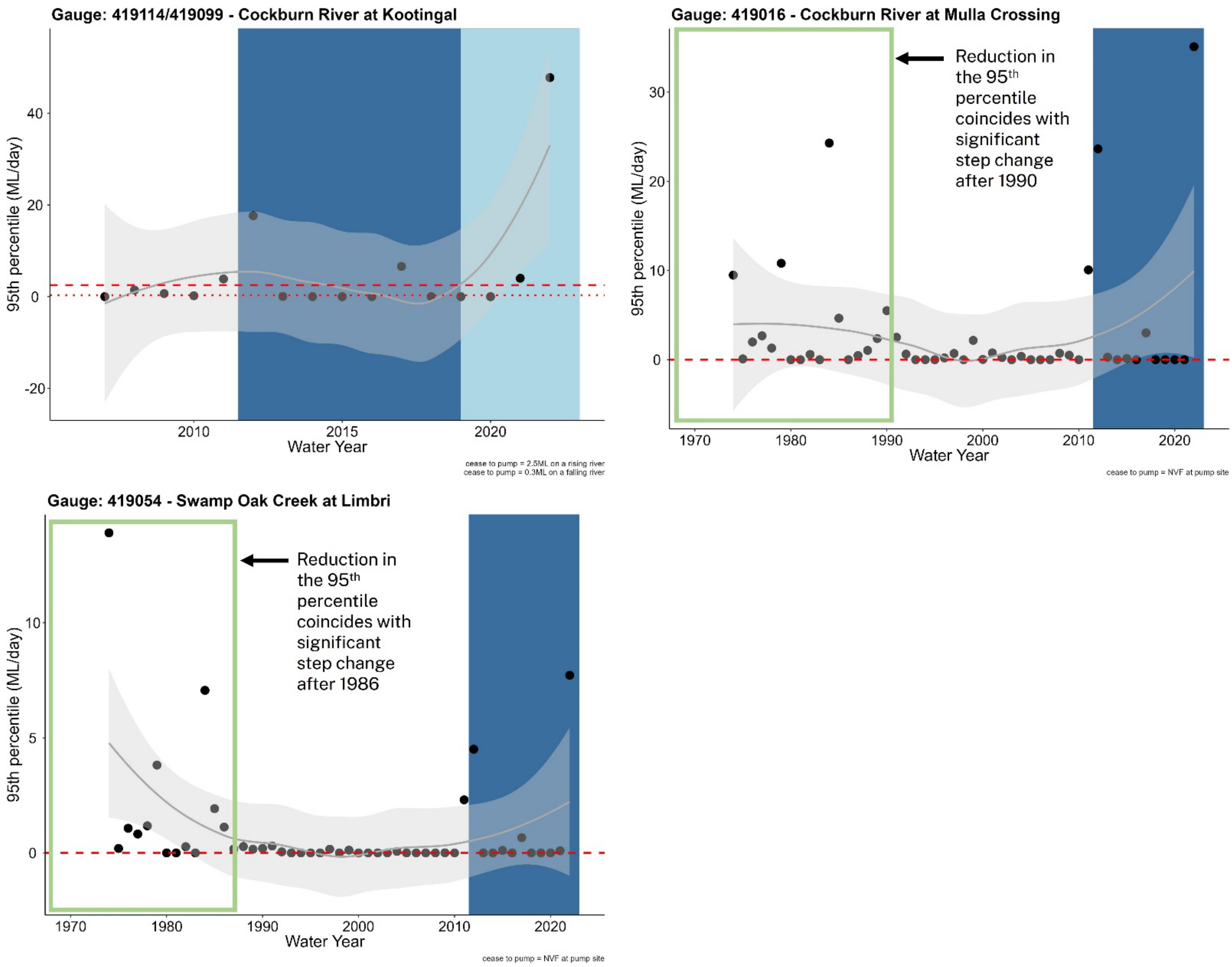

Figure 9 The 95th percentile (ML/day) for the whole period of record at 3 gauge sites in the Cockburn River water source.

1.7.4 Changes to 80th percentile

At the gauges with the longest period of record (Cockburn River gauge at Mulla Crossing 419016 and the Swamp Oak Creek at Limbri 419054) the base flows, as represented by the 80th percentile flow (including zero flows) (Figure 10) are often greater than 1 ML/day prior to 1990 and 1986 respectively, occasionally exceeding 5ML/day. At the Cockburn River gauge at Mulla Crossing 419016 there were 82% of years where the 80th percentile was greater than 1 ML/day. However, after 1990, this fell to 69% of years where the 80th percentile was greater than 1 ML/day. At the Swamp Oak Creek at Limbri 419054 gauge there were 77% of years where the 80th percentile was greater than 1 ML/day. However, after 1986, this fell to 64% of years where the 80th percentile was greater than 1 ML/day. This decline in 80th percentile flows is particularly pronounced during the millennium drought (2001 - 2009). This downward trend in 80th percentile flows shows that low flows in these rivers are declining and even during the current water sharing plan period (2012-2022) there were 7 out of 10 years at 419154 and 5 out of 10 years at 419016 where the 80th percentile fell to less than 1 ML/day.

Figure 10 shows the annual 80th percentile for the Cockburn River at Kootingal (combined 419099/419114, 2006 - 2022), Cockburn River at Mulla Crossing (419016, 1974-2022) and Swamp Oak Creek at Limbri (419054, 1975-2022). The blue shaded area shows the current water sharing plan period (2012 – 2022 water years). The flow data from gauges 419099 and 419114 have been combined to represent flows at the Cockburn River at Kootingal, as the old gauge 419099 was discontinued during early 2020 and the new gauge has replaced it but only has data for 3 years (2019 – 2022 water years), indicated by the 2 shades of blue 419099 (dark blue), 419114 (light blue.) The green box indicates the period prior to 1990 (gauge 419016) and 1986 (gauge 419054) when there was a significant step change in the hydrology of flows at gauge 419016 and 419054 (Table 3). After the step change, the 80th percentile was frequently much lower than before the step change.

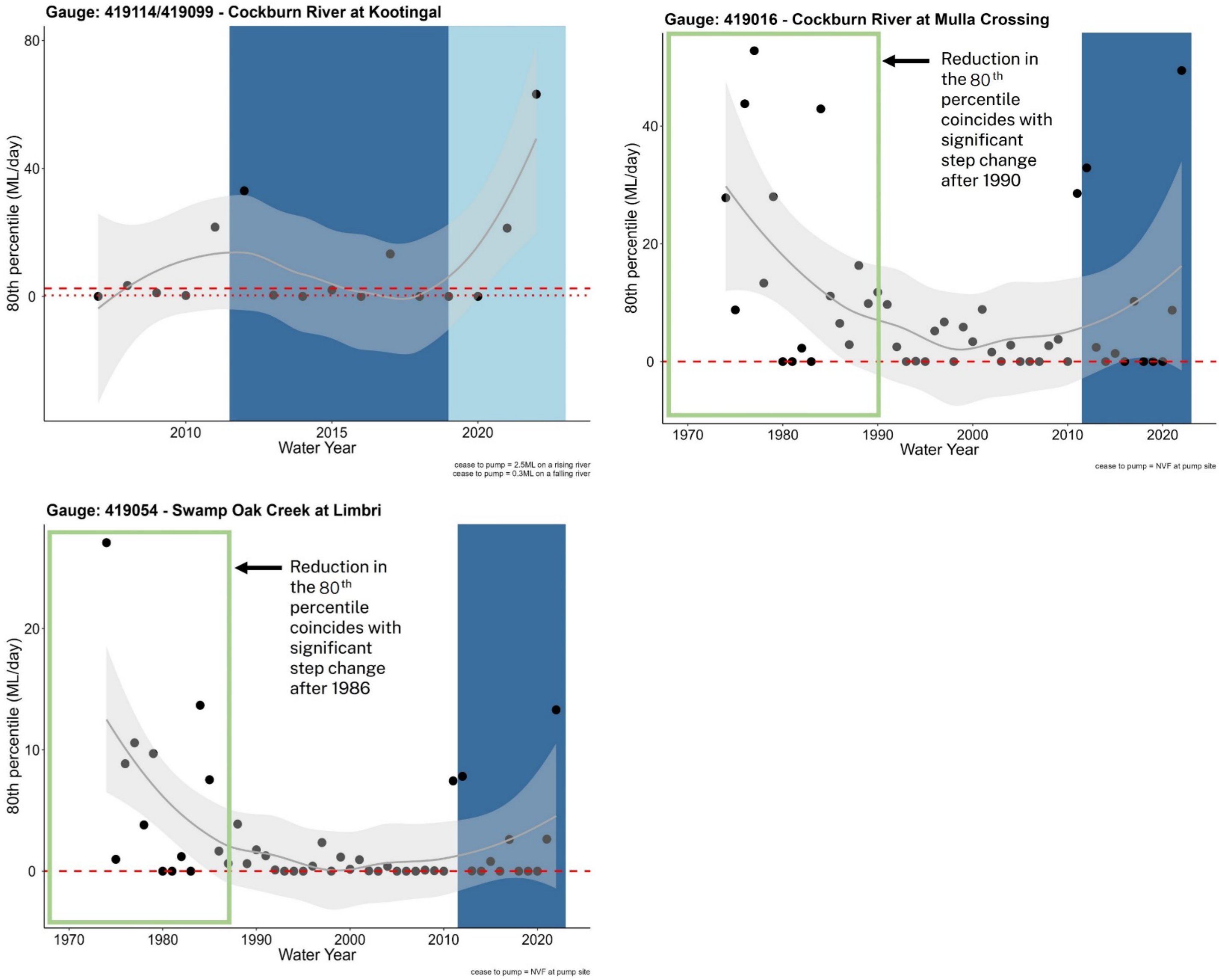

Figure 10 The 80th percentile (ML/day) for the whole period of record at 3 gauge sites in the Cockburn River water source.

2 Conclusions and recommendations

Based on the information presented in this report, we provide the following conclusions, which are supported by recommendations to protect flows for the Booroolong frog in the Cockburn River source.

Aim 1: Identify the current and historic distribution of the Booroolong frog in the Cockburn River water source.

The distribution of the Booroolong frog has significantly contracted to a few small pockets in the upper reaches of the Cockburn River water source. This includes a reintroduction site on a tributary of the Cockburn River. The 2019 drought caused significant contraction to the species and future droughts remain a significant risk to the species' persistence within the catchment.

A current environmental DNA monitoring program under the Environmental Outcomes Monitoring and Research Program, led by the NSW DCCEEW Water Group, aims to confirm the current distribution within the Cockburn River water source as a baseline post the 2019 drought, and track changes from the start of the new water sharing plan to the plan evaluation in the 7th year of the plan. This will help evaluate whether the objectives of the water sharing plan have been met during the next term.

Aim 2: Define the preliminary environmental water requirements using available information for the Booroolong frog in the Cockburn River water source.

Using the available literature and expert opinion, the environmental water requirements for the Booroolong frog have been defined based on the need for low flows in flowing habitats (such as riffles) during the breeding season and tadpole development period. Low flows are defined in this report as flows between the 95th and 80th percentile and are most important between 1 October to 15 May. The specific flow rates in ML/d are provided in Table 2. We recommend the protection of at least the ideal flow rates (87.5th percentile) be considered during the remake of the current water sharing plan, to ensure that the water management rules consider the needs of the Booroolong frog and compliment the overall conservation aim of the NSW government for this species. It is important to note that the timing of flow protection is critical and may allow flexibility in decision making by allowing greater access outside of critical breeding periods. Retaining suitable levels of flow in the Cockburn water source will assist in building resilience of the Booroolong frog and other water dependent species (e.g. native fish such as the Eel-tailed catfish) to the reductions in stream flows occurring in a changing climate. Improving the protections of low flows to meet the flow requirements of the Booroolong frog is also consistent with Priority 3 and 4 and associated actions of the NSW Water Strategy.

Aim 3: Document changes to river flows in key areas where the Booroolong frog is predicted to occur within the catchment.

The hydrological regime in the Cockburn River water source appears to be drying, with trends in the data at gauges with the longest period of record showing increased duration of cease-to-flow events and reduced low flow thresholds. This change appears be most apparent from the mid 1980s to 1990s onwards. This reduction in flows is consistent with other research on the changes to stream flows in the Northern Basin which indicate increasing dry periods from the 1990s onwards (see Appendix A) (BOM, 2020). In the Northern Basin, stream flows have declined, and many streams have shifted from perennial to intermittent with reduced flow continuity since 2011 (Crosbie et al., 2022).

We recommend that the trend in drying presented here, and the potential impacts of future droughts be considered when deciding on management options for this water source. This is particularly important if extended periods of low rainfall occur, and flows are expected to cease for long periods of time like they did during the 2019 drought where the Cockburn River ceased to flow for almost the entire water year.

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4 Appendix A

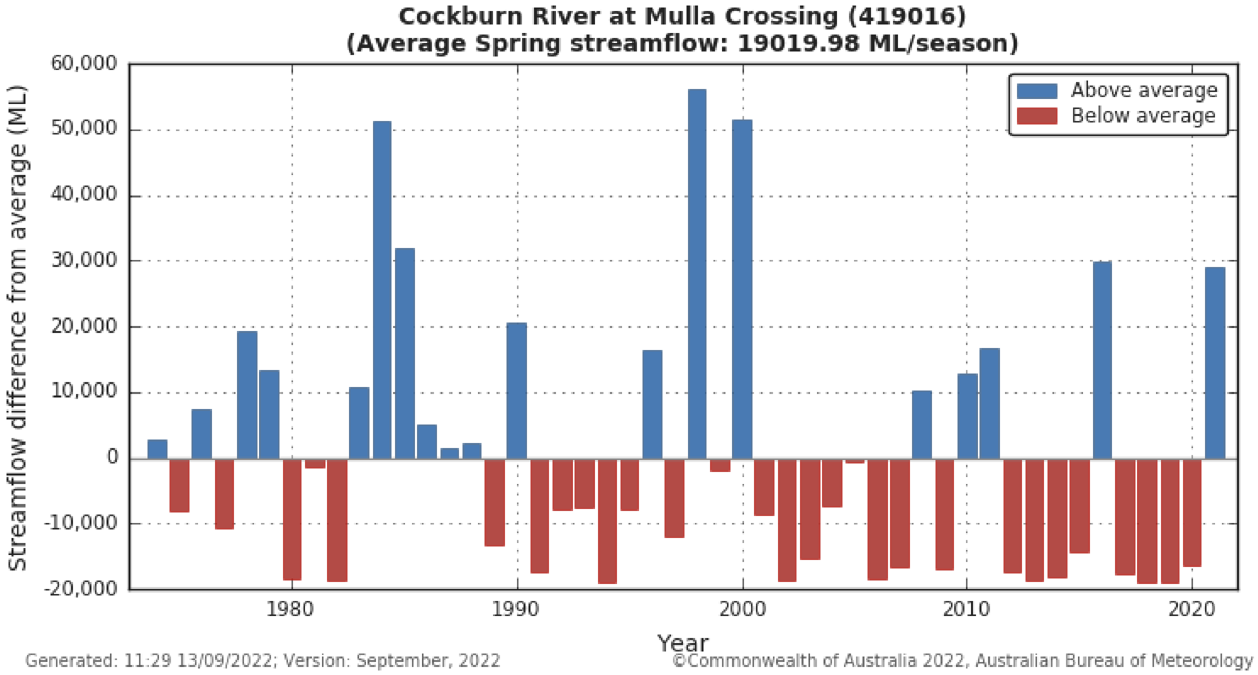

Figure 11 Changes to river stream flow during spring at the Cockburn River at Mulla Crossing (419016) flow gauge. Source: http://www.bom.gov.au/water/hrs/index.shtml

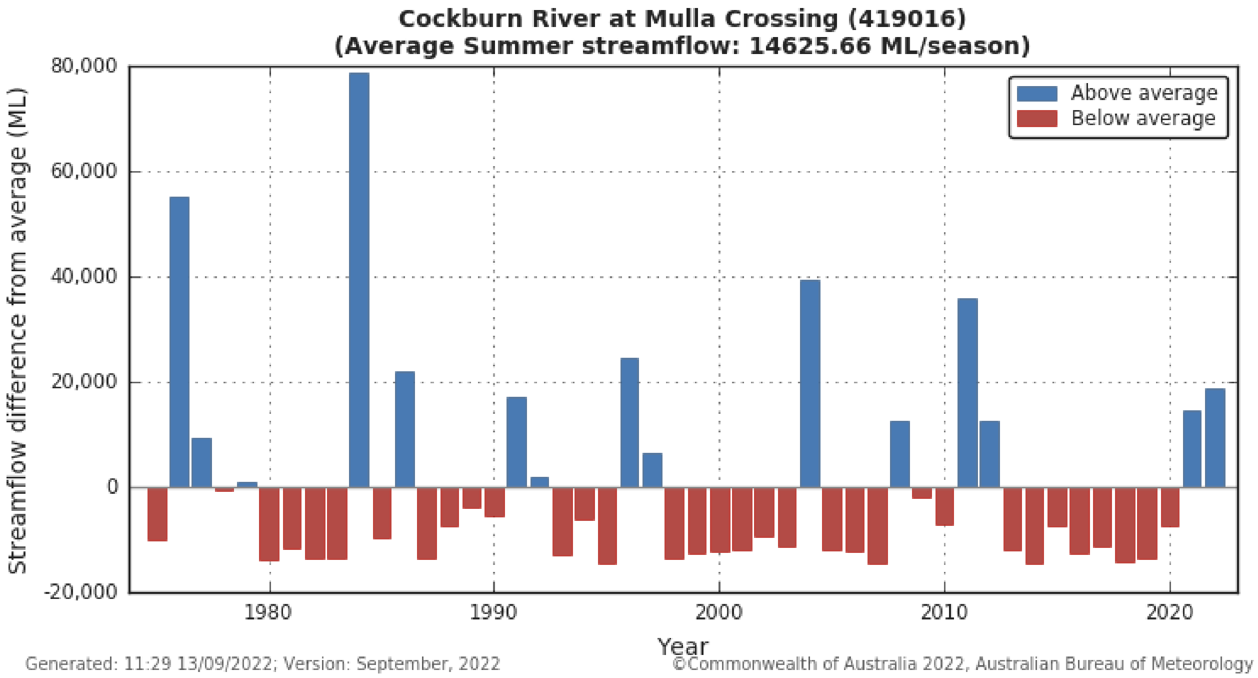

Figure 12 Changes to river stream flow during summer at the Cockburn River at Mulla Crossing (419016) flow gauge. Source: http://www.bom.gov.au/water/hrs/index.shtml

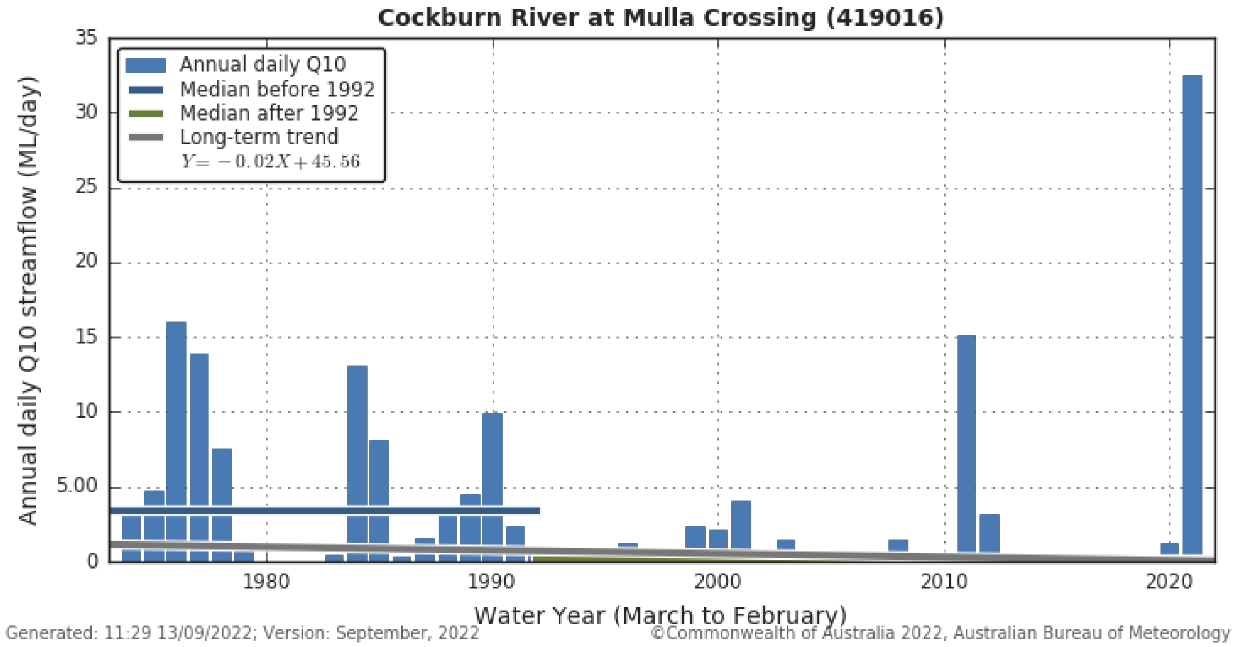

Figure 13 Significant changes to the annual Q10 or 90th percentile at the Cockburn River at Mulla Crossing (419016) flow gauge. Source: http://www.bom.gov.au/water/hrs/index.shtml.

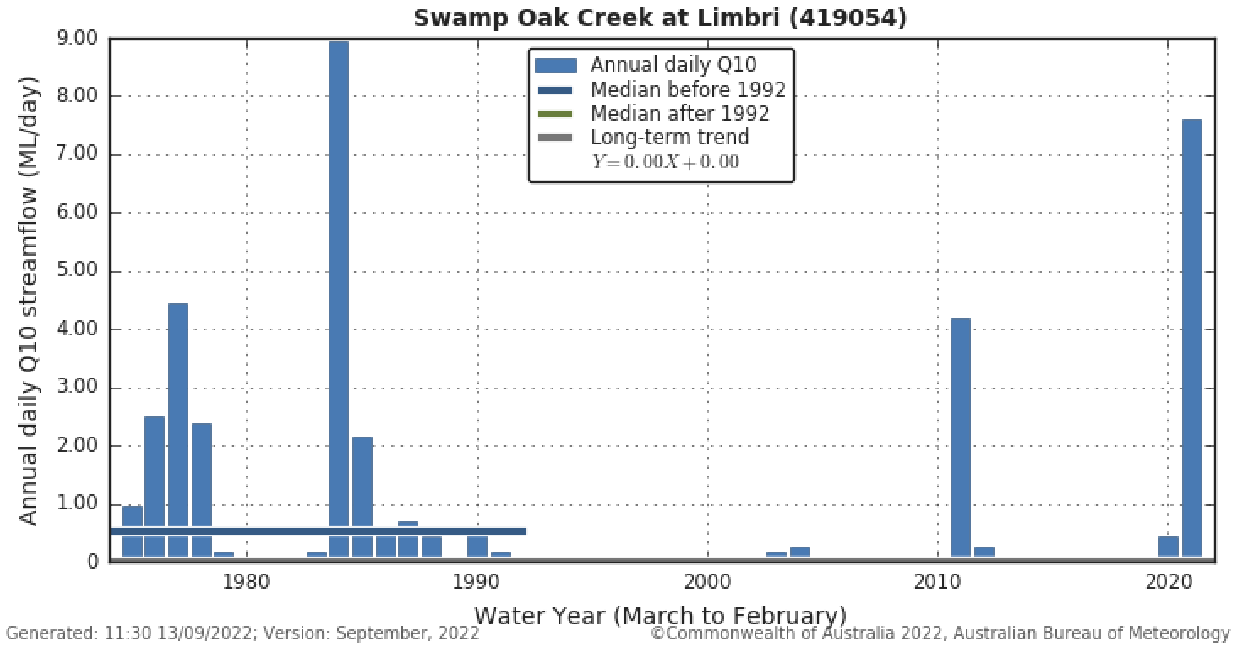

Figure 14 Significant changes to the annual Q10 or 90th percentile at the Swamp Oak Creek at Limbri (419054) flow gauge. Source: http://www.bom.gov.au/water/hrs/index.shtml.

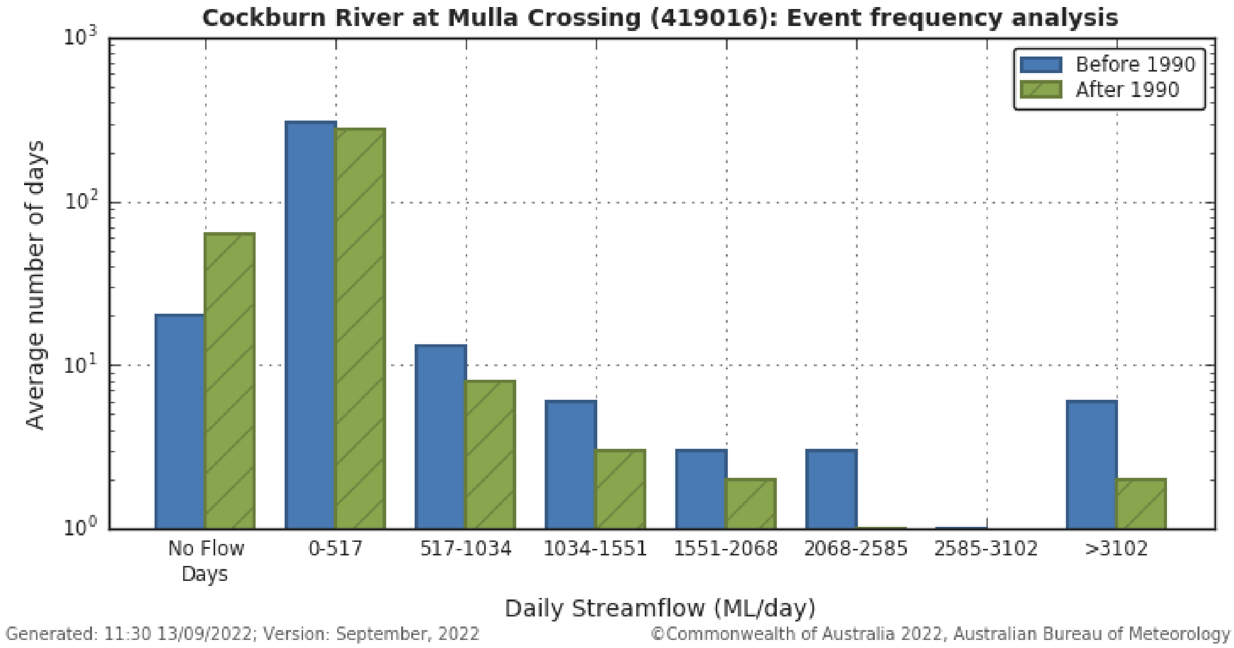

Figure 15 Changes to the average number of days within different flow categories before and after 1990 at the Cockburn River at Mulla Crossing (419016) flow gauge. Source: http://www.bom.gov.au/water/hrs/index.shtml.

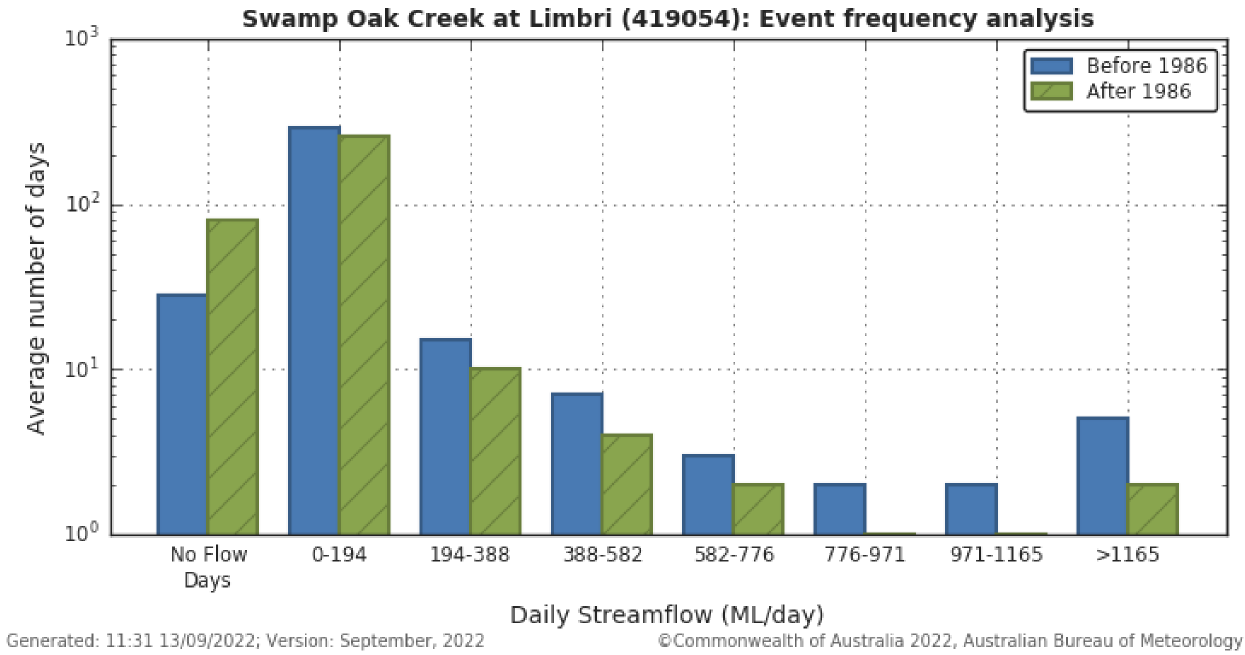

Figure 16 Changes to the average number of days within different flow categories before and after 1986 at the Swamp Oak Creek at Limbri (419054) flow gauge. Source: http://www.bom.gov.au/water/hrs/index.shtml

Table 3. Trend summary for changes to daily flows in the Cockburn River at Mulla Crossing (419016) and Swamp Oak Creek at Limbri (419054). Source: http://www.bom.gov.au/water/hrs/index.shtml.

Flow gauge	Test for	Test name	Description	Level of significance (p)	Result	Pass/Fail
419016	Randomness	Median crossing	Tests for randomness of time series data	0.466 (P crit = 0.01)	Random	Pass
419016	Randomness	Rank-difference	Tests for randomness of time series data	0.286 (P crit = 0.01)	Random	Pass
419016	Trend	Mann-Kendall	Tests whether there is a trend in the time series data	0.013 (P crit = 0.1)	Significant	Pass
419016	Step change	DF CUSUM	Tests for step change and the year of change	N/A	1990	N/A
419016	Step change	Rank-sum	Tests whether the median in two different time periods are different or not	0.002 (P crit = 0.1)	Significant	Pass
419054	Randomness	Median crossing	Tests for randomness of time series data	0.768 (P crit = 0.01)	Random	Pass
419054	Randomness	Rank-difference	Tests for randomness of time series data	0.617 (P crit = 0.01)	Random	Pass
419054	Trend	Mann-Kendall	Tests whether there is a trend in the time series data	0.037 (P crit = 0.1)	Significant	Pass
419054	Step change	DF CUSUM	Tests for step change and the year of change	N/A	1986	N/A
419054	Step change	Rank-sum	Tests whether the median in two different time periods are different or not	0.047 (P crit = 0.1)	Significant	Pass