Reconnecting River Country Program Lower Murrumbidgee Waterbird Environmental Benefits Analysis
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Cover photo: Gayini wetlands

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Table of contents

Table of figures

Table of tables

Executive Summary

The Lower Murrumbidgee Waterbird Environmental Benefits Assessment (EBA) project is part of the NSW *Reconnecting River Country Program* (the program) which aims to improve wetland and floodplain connectivity in southern NSW. The program is in development, and led by the NSW Department of Climate Change, Energy, the Environment and Water (NSW DCCEEW). This report presents a qualitative assessment of likely outcomes for waterbirds from delivering water for the environment under a range of new flow limit options in the Murrumbidgee River at Wagga Wagga: 32,000 ML/day (W32), 36,000 ML/day (W36) and 40,000 ML/day (W40). Modelled flow regimes for each flow limit option (hereafter referred to as flow scenarios) were assessed against a base case flow scenario representing the current flow limit, 22,000 ML/day at Wagga Wagga (W22). Potential waterbird outcomes in the lower Murrumbidgee (Lowbidgee) were assessed by considering observed waterbird responses to a range of historical flows in the lower Murrumbidgee River at Hay and comparing these to predicted flow outcomes at Hay under the flow scenarios.

- Key findings from analysis of observed flows and waterbird responses: Large wader responses included breeding at a range of flow thresholds from 13,000+ to 28,000+ ML/day at Hay.
- The majority of waterbird breeding responses were associated with flows in the August-October time period.
- Large waders were the dominant response group, breeding during all recorded breeding events and at all flow thresholds.
- There does not appear to be any strong trends in guild responses to different flow thresholds.
- There is a general trend of higher waterbird abundances occurring with higher flows.
- 51 Eastern Australia Waterbird Survey (EAWS) sites receive water across the range of thresholds. 50% of these receive water at relatively low thresholds of 13000+ to 19,000+ ML/day, which correspond with flows influenced by the program.
- 14 NSW DCCEEW long-term survey sites) receive water at flow thresholds ranging from 13000+ to 21000+ ML/day, which correspond with flows influenced by the program.

Potential benefits to waterbirds under each flow option:
Potential benefits to waterbirds under the program include increases in the number of flow events for all scenarios (W32, W36, W40) compared to the W22 (base case), at a wide range of flow thresholds. This is likely to benefit all waterbirds, particularly large waders and may provide increased opportunities for breeding. The occurrence of wetland-inundating flows in the Lowbidgee increases with flow limit option from W32 to W40, with W40 having the largest number of additional wetland-inundating flows relative to the base case. Extended flow events, at all flow volumes, may increase nesting or breeding success where inundation duration is extended and breeding is initiated. This is likely to benefit both large waders and piscivores through the extended provision of suitable nesting habitat and foraging areas.

Many of the waterbird wetland sites that were surveyed were modelled to receive water at relatively low flow thresholds of less than 21000 ML/day at Hay, which corresponds with flows that could be delivered under raised flow limits at Wagga Wagga. This will be beneficial to waterbirds through the provision of potential nesting and foraging areas, but also through the maintenance of waterbird habitat, including riparian and floodplain vegetation.

Overall, program benefits for waterbirds in the Lowbidgee are expected to increase with flow limit option from W32 to W40, with the highest flow limit option (W40) having the greatest potential benefits.

Background

The Lower Murrumbidgee Waterbird Environmental Benefits Assessment (EBA) project is part of the NSW *Reconnecting River Country Program* which aims to improve wetland and floodplain connectivity in southern NSW. The EBA project is focused on the Murrumbidgee River and River Murray systems. Quantitative assessment of the likely benefits to waterbirds in the Mid-Murrumbidgee is presented in Bino et al. 2022b. In this report we qualitatively assessed the likely benefits to waterbirds of relaxed constraints for environmental flows in the lower Murrumbidgee Wetlands (Lowbidgee) downstream of Hay, in the Murrumbidgee Catchment.

Four flow scenarios were investigated as part of this project to determine the potential benefits for waterbirds in the Lowbidgee Wetlands. The potential benefits of increased limits for environmental flows of 32,000 ML/day, 36,000 ML/day and 40,000 ML/day for the Murrumbidgee River at Wagga Wagga were investigated and compared to the current flow limit of 22,000 ML/day.

The current flow limit at Wagga Wagga in the Murrumbidgee River is designed to avoid impacts on agricultural land. Should the program proceed to delivery, it is expected that relaxation of constraints to permit a higher flow limit would allow more frequent inundation of Lowbidgee wetlands, providing benefits for a range of wetland-dependent species including waterbirds (NSW Department of Planning and Environment 2023a). The Lowbidgee is a critical wetland area for aggregating waterbird breeding regularly supporting large >5,000 nest rookeries at several sites (Brandis et al. 2020).

A qualitative assessment was undertaken due to the difficulty in accurately linking inundated areas to flow gauges in the Lowbidgee at this point in time. Flow delivery infrastructure on parts of the Lowbidgee floodplain plays an important role in determining which areas of the floodplain are inundated during low or moderate flows, as opposed to direct river and overbank flows during large flood events.

Methods

To understand potential benefits and the way in which waterbirds may respond to changes in flows under the flow limit options, the waterbird assessment first compared observed data, both hydrological and waterbird, and then applied observed trends to the modelled hydrological timeseries of river flows developed for each flow limit option (hereafter referred to as flow scenarios).

Hydrological data

Modelled hydrological timeseries of river flows for the historical period 1895 to 2020 were developed for each flow limit option to represent a likely regime of river flows with flow limits at Wagga Wagga relaxed to different thresholds (NSW Department of Planning and Environment 2023a). Each flow scenario includes managed environmental water deliveries up to the different flow limits as well as unregulated flows (such as large natural floods), consumptive water deliveries and other regulated system flows. Current operational conditions (aside from flow limits) were applied to the whole time 120-year frame for each scenario. This modelled flow data was analysed by NSW DCCEEW to identify years in which an event with characteristics of relevance to waterbirds occurs and align with the hydraulic inundation modelling. Those characteristics include flow magnitude, minimum event duration and timing window within the water year (either full year 1 July to 30 June, or 1 August to 30 October). The analysis provides a count of:

- number of years with an event that meets the minimum flow threshold and event duration requirements, for the base case scenario.
- number of years an event was added that meets the minimum flow threshold and event duration requirements, in the flow option scenarios.
- number of years an event was extended, using specified extension duration in days, in the flow option scenarios. Includes extension of any event that meets the flow threshold, not just ones that meet the specified main event consecutive duration requirements.
- number of years an event no longer meets the full consecutive duration requirement. Event may still occur, but just for a shorter number of days.

These counts were provided for a range of flow thresholds that were linked to relevant flow thresholds at Hay in the Murrumbidgee River and Yanco Creek System hydraulic floodplain inundation modelling (DPE 2023) as well as relevant thresholds for the flow outcomes at Hay (Table 1 and Table 2).

The flow characteristics were provided for each of the four flow scenarios and observed flow data for Hay (M/Bidgee DS Hay Weir, 410136) for 1983-2020 (Table 1).

Table 1 Modelled flow scenarios: flow limits at Wagga Wagga and corresponding likely flow outcomes at Hay.

Modelled Scenario	Flow limit at Wagga Wagga (ML/d) (M/Bidgee River at Wagga Wagga)	Approximate flow for individual events at Hay (ML/d) based of 75th percentile (M/Bidgee DS Hay Weir)
W22 (base case)	22,000	14,000
W32	32,000	20,000
W36	36,000	22,000
W40	40,000	24,000

Table 2 Flow likely to be influenced by the program at Hay with the exception of >28,000 ML/d.

Minimum Flow threshold (ML/d)	Description
13,000 +	Includes environmental water delivery event peaks likely to occur under all flow options including base case
19,000 +	Includes environmental water delivery event peaks likely to occur under all flow options but not base case
21,000 +	Includes environmental water delivery event peaks likely to occur under higher flow limits (W36, W40)
23,000 +	Includes environmental water delivery event peaks likely to occur under the highest flow limit (W40)
25,000 +	Includes environmental water delivery event peaks that may rarely occur under the highest flow limit (W40)
28,000 +	Flow peaks outside of flow limit options

Waterbird data

Waterbird data were collated from the Eastern Australia Waterbird Survey (EAWS) (Kingsford et al. 2020), Waterbird Breeding Database (Brandis 2010), and NSW DCCEEW (formerly the Department of Planning and Environment) Spring Waterbird Survey data (NSW DPE Unpublished data 2008-2020). Waterbird data included records of abundance, species diversity and breeding for aggregating species. These included:

Australian white ibis	Little egret	Great cormorant	Australian pelican
Glossy ibis	Intermediate egret	White-necked heron	Pied cormorant
Royal spoonbill	Great egret	Australasian darter	Little black cormorant
Straw-necked ibis	Cattle egret	White-faced heron	
Yellow spoonbill	Nankeen night heron	Little pied cormorant	

Records of waterbird breeding (1980-2020) were matched with observed flows as represented in DNA plots (NSW DCCEEW provided). The size of breeding events were categorised as either minor (<10,000 total nests) or major (>10,000 total nests). Breeding species diversity was compiled for each recorded breeding event.

Spatial analyses

Waterbird sites (EAWS and NSW DCCEEW) were overlaid with hydraulic floodplain inundation modelling (NSW Department of Planning and Environment 2023b) to give an indication of which sites may receive water under different flow thresholds.

Results

Relationship with observed waterbird data

From 1980-81 to 2020-21 there were 26 recorded waterbird breeding events in the Lowbidgee including Redbank and Gayini (Figure 2). Nesting, when considering all waterbirds, occurred 62.5% of the time (1981-2021), 1 in 1.6 years. Major nesting responses (>10,000 total nests across the Lowbidgee) occurred 20% of the time (1981-2021), 1 in 5 years. Minor nesting response (<10,000 nests across the Lowbidgee) occurred 45% of the time, 1 in 2.26 years (Figure 3). Australian white ibis and Straw-necked ibis were the most common species to breed, nesting in 55% and 40% of years respectively (Figure 4).

The breeding data available includes records for two key feeding guilds: large waders and piscivores (Table 3).

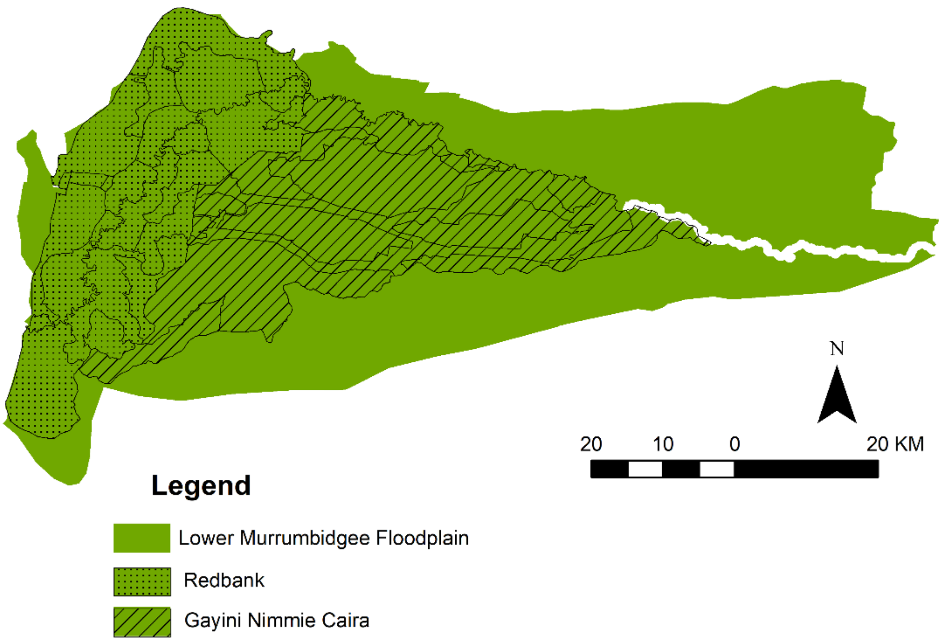

Figure 1 Map showing Lowbidgee Floodplain and Redbank and Gayini Nimmie Caira areas within the floodplain boundary.

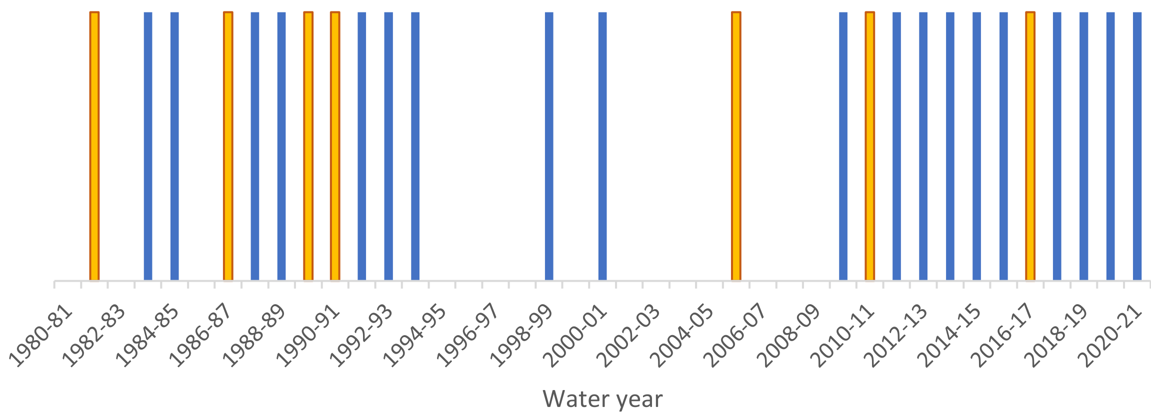

Figure 2 Records of years with breeding 1980-2020 – combined data from NSW DCCEEW and Waterbird Breeding Database (Brandis 2010) and EAWS. Blue columns indicate water years with minor nesting, orange columns indicate water years with major nesting.

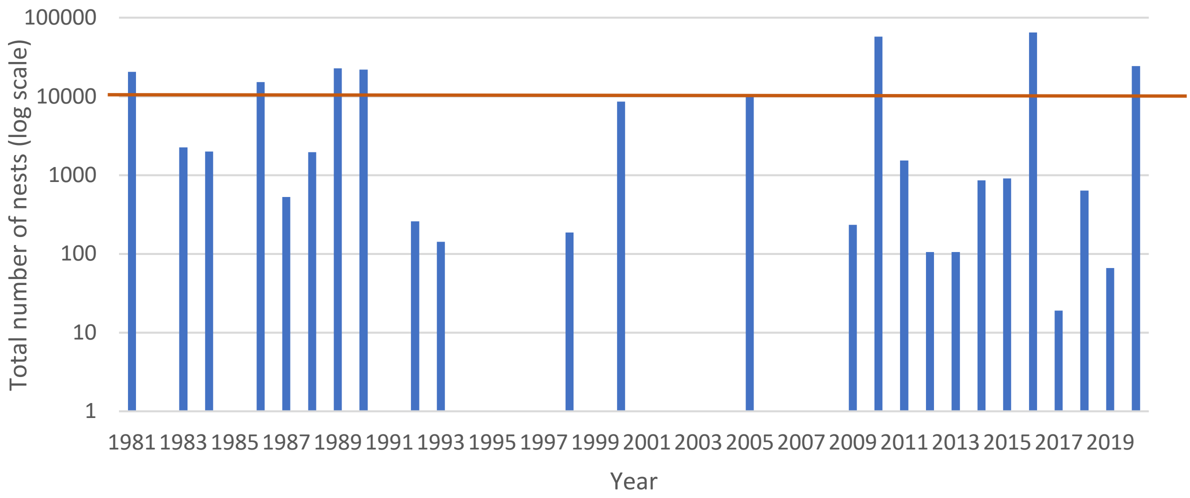

Figure 3 NSW DCCEEW waterbird breeding data records 1981-2020 - breeding abundance. Orange line represents 10,000 nest threshold for major breeding. >10,000 nests – major breeding, <10,000 nests - minor breeding.

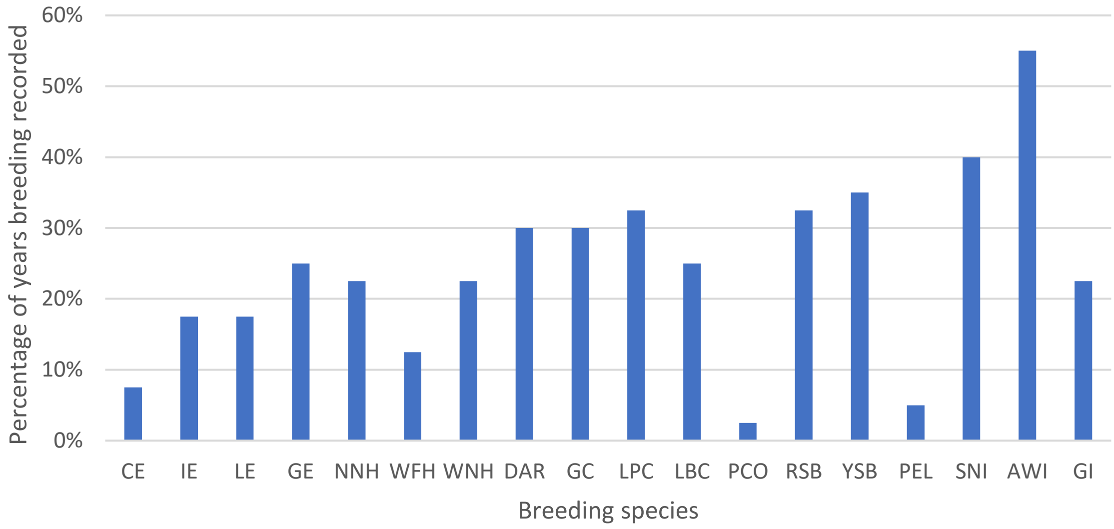

Figure 4 Using NSW DCCEEW spring survey data, combined data across multiple sites, percentage of years in which breeding in different species was detected over the 1981-2021 period. See Table 3 for species and guild.

Table 3 Aggregating waterbird species used in qualitative assessment.

Species	Common Name	Waterbird Code (Figure 3)	Feeding guild
Threskiornis Molucca	Australian white ibis	AWI	Large wader
Plegadis falcinellus	Glossy ibis	GLI	Large wader
Platalea regia	Royal spoonbill	RSP	Large wader
Threskornis spinicollis	Straw-necked ibis	SNI	Large wader
Platalea flavipes	Yellow spoonbill	YSP	Large wader
Egretta garzetta	Little egret	LE	Large wader
Ardea intermedia	Intermediate egret	IE	Large wader
Ardea alba	Great egret	GE	Large wader
Bubulcus ibis	Cattle egret	CE	Large wader
Nycticorax caledonicus	Nankeen night heron	NNH	Large wader
Phalacrocorax carbo	Great cormorant	GC	Piscivore
Ardea pacifica	White-necked heron	WNH	Piscivore
Anhinga novaehollandiae	Australasian darter	DAR	Piscivore
Egretta novaehollandiae	White-faced heron	WFH	Piscivore
Microcarbo melanoleucos	Little pied cormorant	LPC	Piscivore
Pelecanus conspicillatus	Australian pelican	PEL	Piscivore
Phalacrocorax varius	Pied cormorant	PCO	Piscivore
Phalacrocorax sulcirostris	Little black cormorant	LBC	Piscivore

There were seven major waterbird breeding events during 1980-2020. Of these, three events (1989, 1990 and 2016) occurred when flow events greater than 28,000+ ML/day occurred during August – October (Figure 5b, c), while one (2000) included flows taking place outside these months (Figure 5a, c). Of the remaining three breeding events, two (1981, 2005) occurred when flow did not reach between 13000 to 28000+ ML/day for at least 10 consecutive days (Figure 5), and one occurred when the maximum yearly flow event was greater than 13,000+ ML/day August – October for 10 days with additional flows up to 21,000+ ML/day outside this time period (Figure 5).

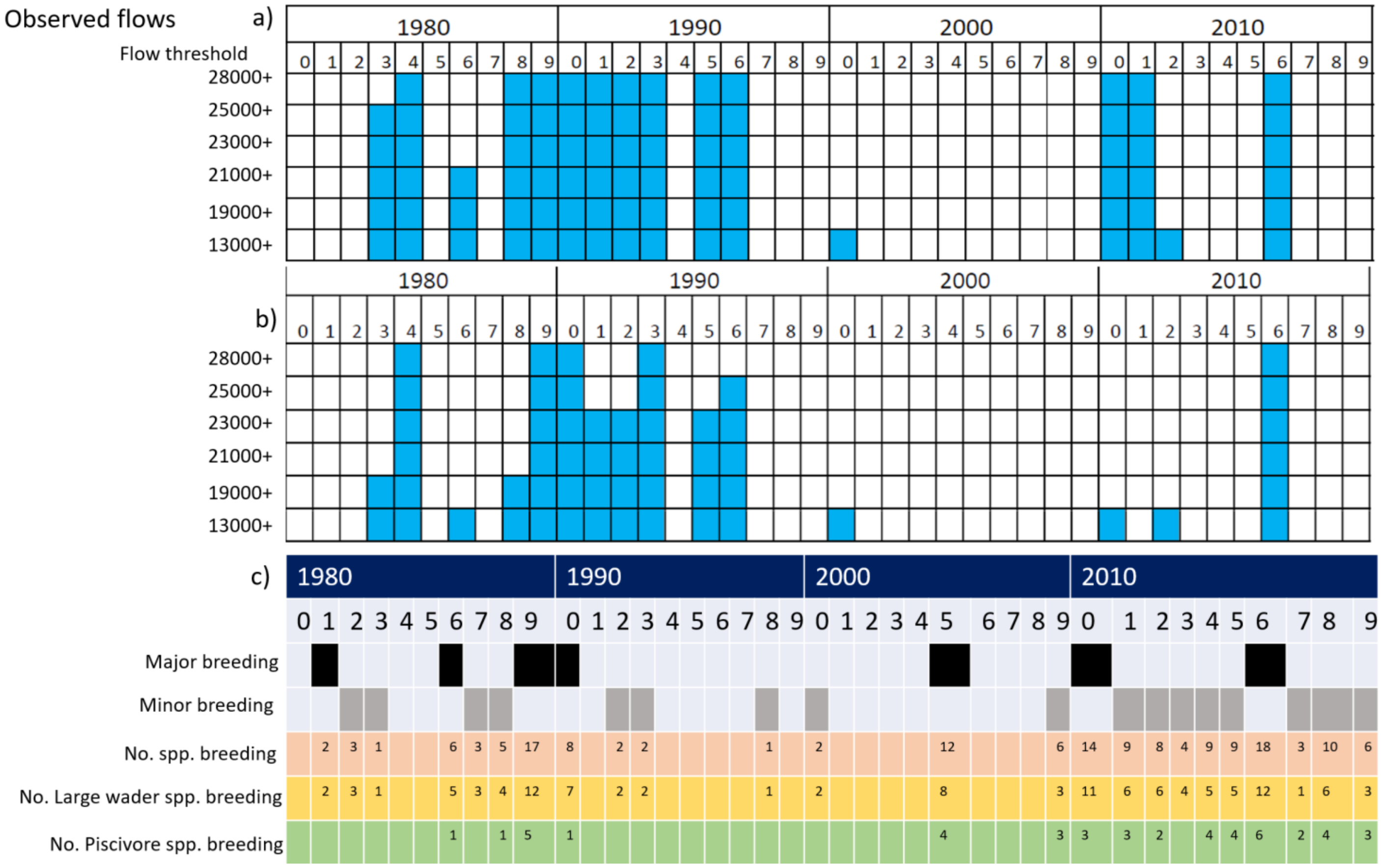

Figure 5 Comparison of waterbird breeding data (NSW DCCEEW 1990-2020) with 'observed flows' and associated thresholds a) 'anytime' of the year and b) August to October. c) identifies major (>10,000 nests) and minor (<10,000 nests) breeding events, the total number of species breeding during each event and the breakdown into guilds – large wader and piscivores.

Slightly more than half (57%) of major waterbird breeding occurred when flows thresholds reached 28,000+ ML/day for ten consecutive days at Hay.

Major breeding that occurred when there was no observed flows for 10 consecutive days within the 13,000+ to 28,000+ ML/day at Hay thresholds, included 1981-1982 when total annual flows at Hay were much lower than those measured at Maude (Figure 6; Hay is upstream of Maude, flow records at Hay began in 1982), and in 2005-2006 during a relatively dry period which may have influenced waterbirds to breed on a smaller flow event (Figure 6). The nesting that occurred in 2005 was not thought to be a successful (Spencer pers. comm.) potentially due to insufficient flows and inundation.

There were 17 minor waterbird breeding events during 1980-2020. Ten of these (1982, 1987, 1988, 2009, 2003, 2004, 2005, 2017, 2018, 2019) were associated with flows less than 13,000 ML/day at Hay. However, there were small flows during these years, with possible durations of <10 days (Figure 7). The remaining seven minor breeding events were associated with a range of flow thresholds from 13,000+ to 28,000+ ML/day (Figure 5).

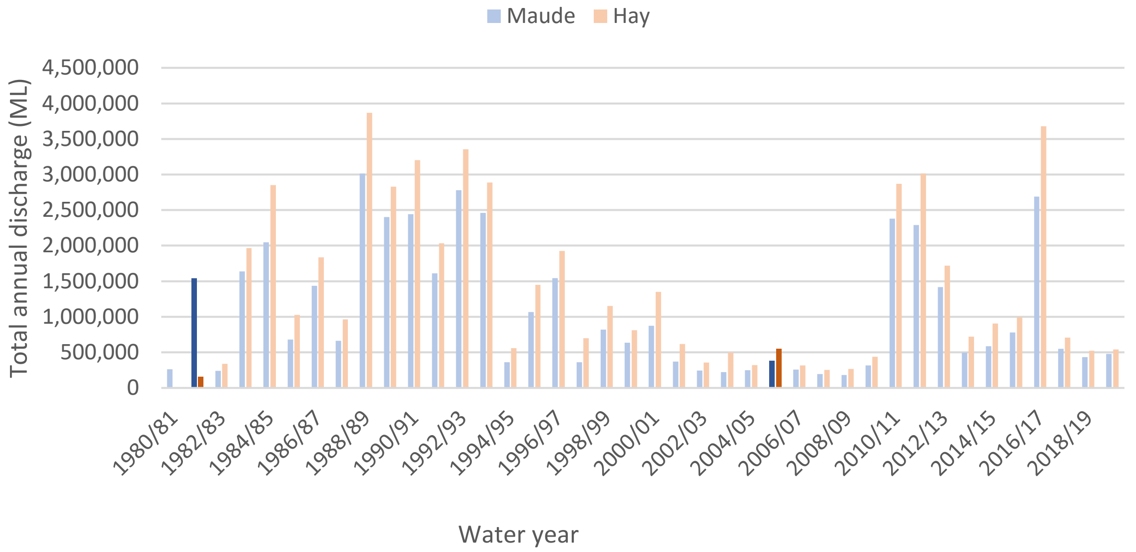

Figure 6 Total annual flows (June-July) at Hay (orange) and Maude (blue) – flow associated with major waterbird breeding events in darker colours.

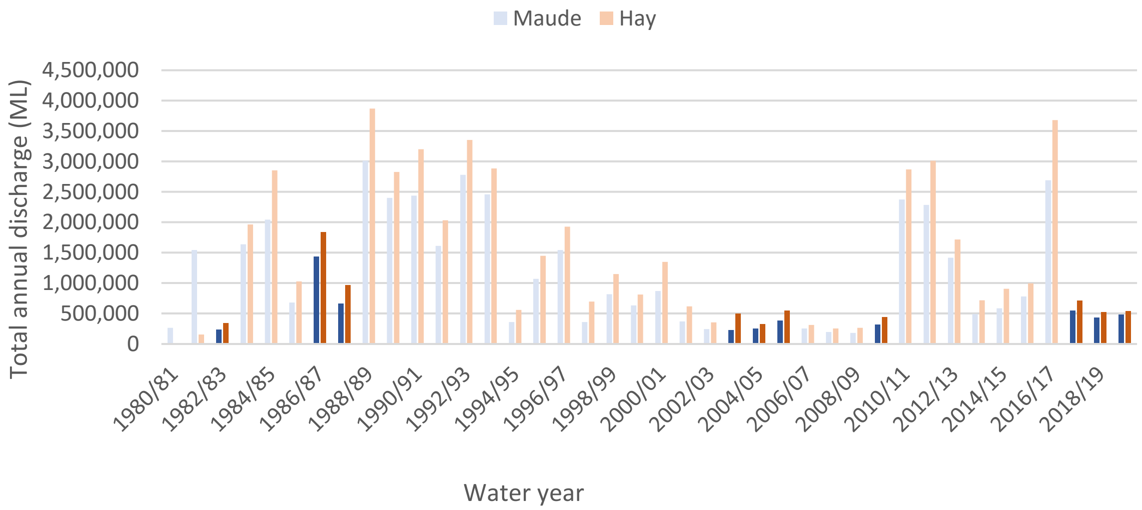

Figure 7 Total annual flows (June-July) at Hay (orange) and Maude (blue) – flow associated with minor waterbird breeding events in darker colours.

There do not appear to be any strong patterns in flow events at different flow thresholds and the size of waterbird breeding responses. The more general trend is that major breeding events (~60%) were more often associated with flow events at thresholds >28,000 ML/day that occurred in August-October, whereas fewer major breeding events were associated with events at smaller flow thresholds (Figure 8). This pattern is also consistent with lower flow events at different thresholds that occurred anytime during the water year (July-June), with more major breeding events associated with larger flows during this time period.

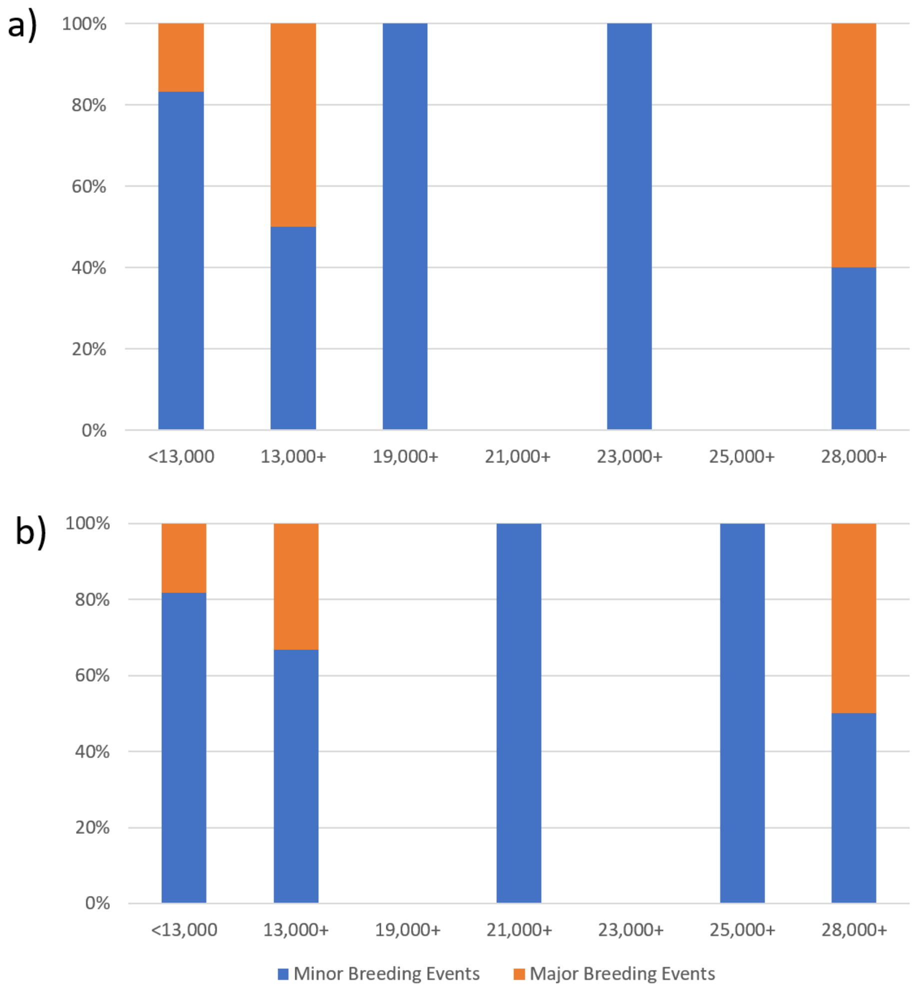

Figure 8 Composition of breeding response size to events of 10 days or more at flow thresholds ML/day a) in period August – October and b) anytime during the water year (July-June, including events shown in a).

Breeding species diversity

Large waders were the dominant response group, breeding during all recorded breeding events and at minimum ten-day events at all flow thresholds (Figure 9). However, there does not appear to be any strong trends in guild responses to events at different flow thresholds (Figure 10).

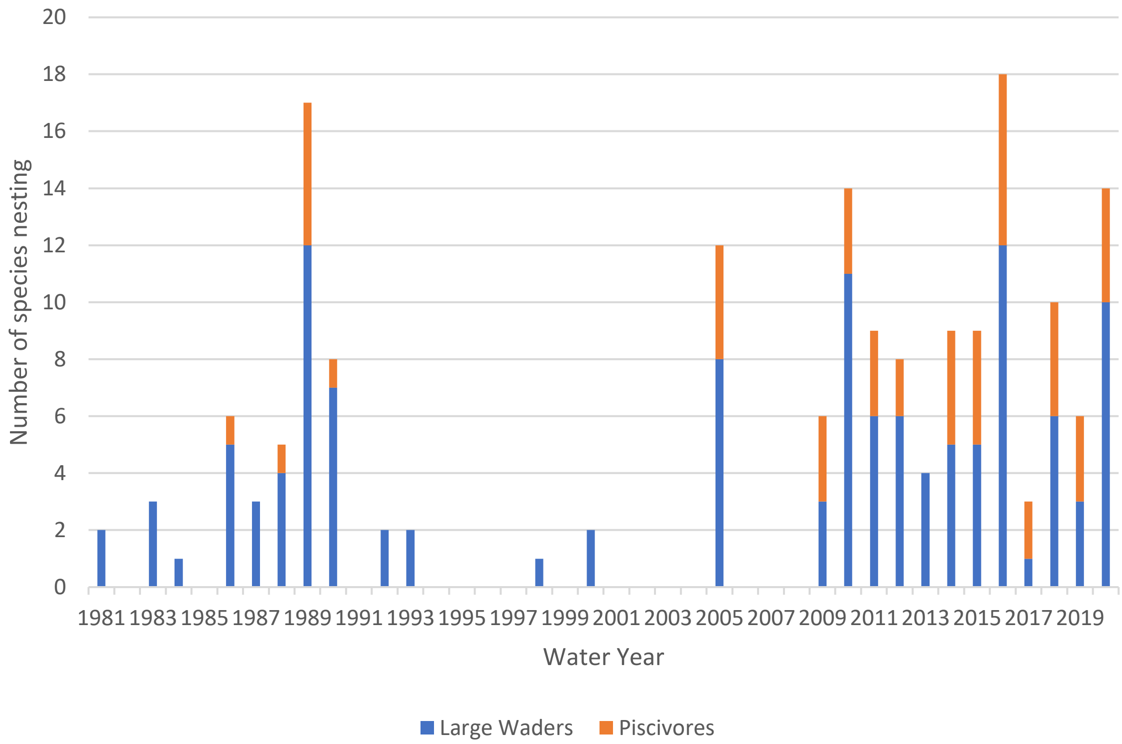

Figure 9 Composition of detected breeding events by guild – Large waders and Piscivores (NSW DCCEEW data).

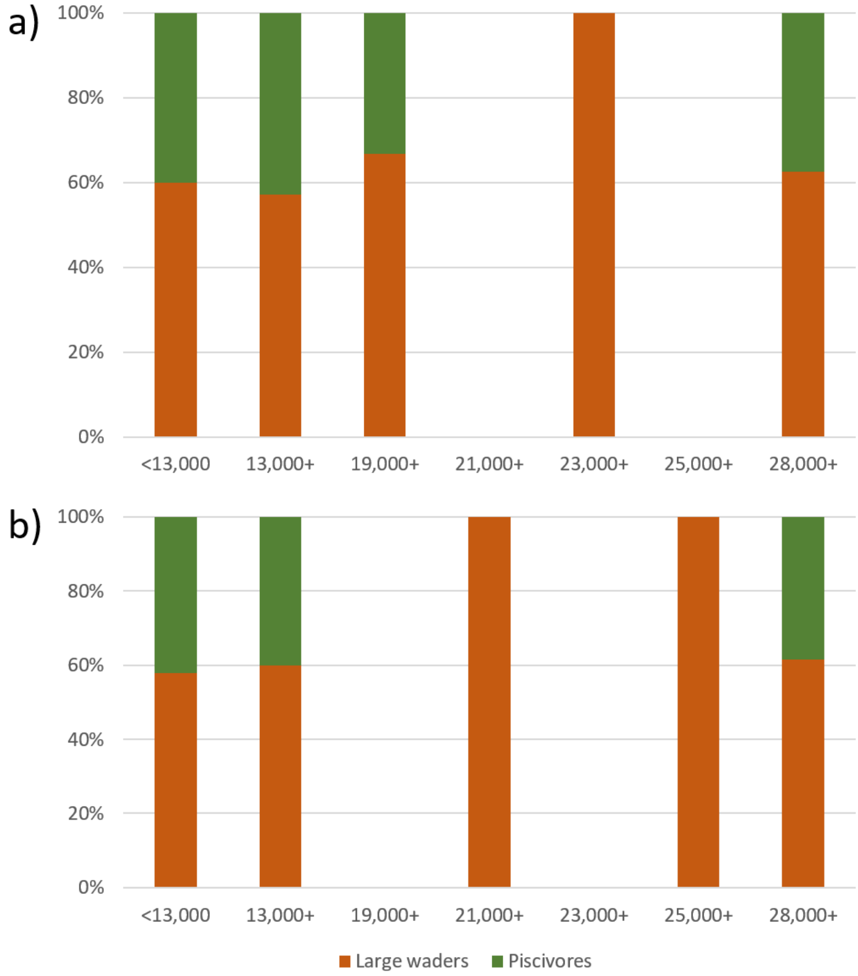

Figure 10 Composition of breeding responses by guild and events of 10 days or more at flow thresholds ML/day a) in August - October, b) anytime in the water year (June-July, including events shown in a; NSW DCCEEW waterbird data).

Species diversity and abundance

Using EAWS data for the period 1983-2020, which includes a large range of waterbird species, the most abundant species observed included grey teal (643,421 individuals 1983-2020) straw-necked ibis (192,752), and Eurasian coot (172,839) with over a total of 150,000 individuals (Figure 11).

Comparing flows at Hay (Figure 12) and observed DNA plots (Figure 13) and waterbird abundances there was a general trend of higher waterbird abundances occurring with higher flows and thresholds.

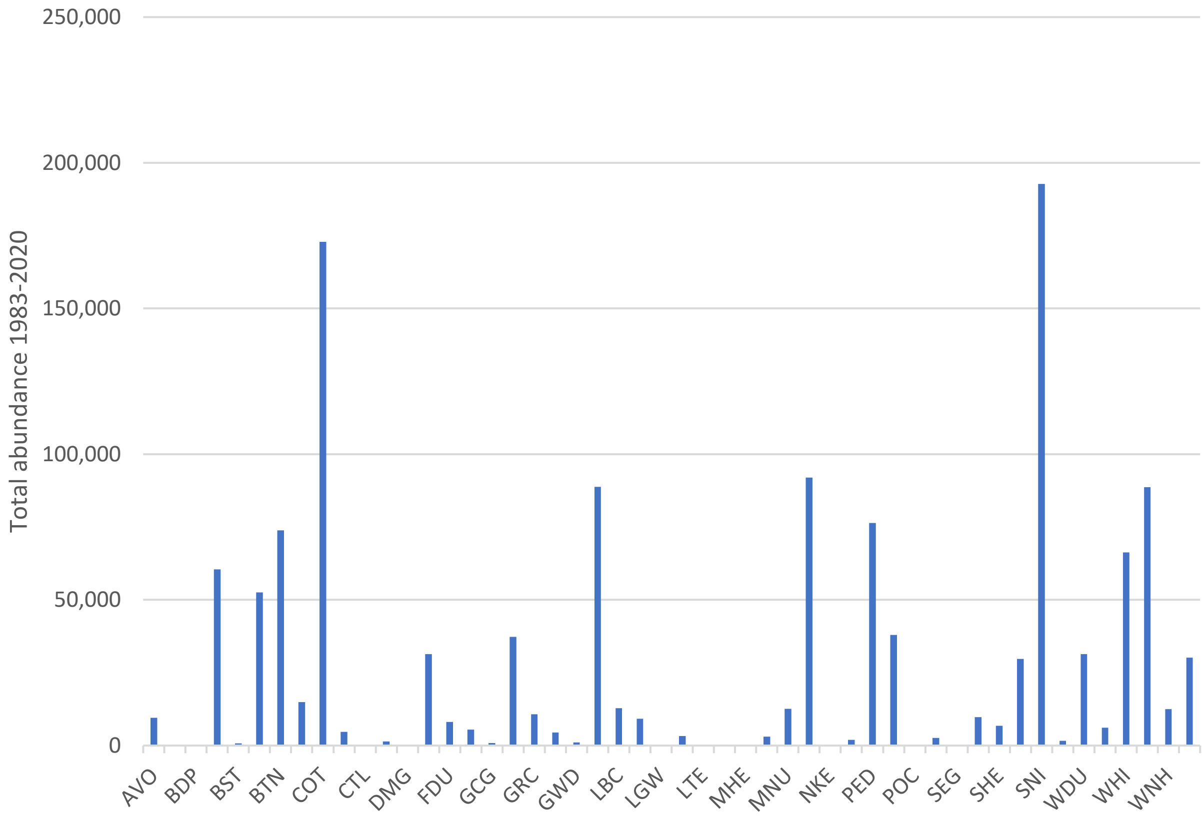

Figure 11 Waterbird species abundances in the Lowbidgee (total per species across all Lowbidgee EAWS sites, Figure 18). Excluding Grey teal (Anas gracilis) total abundance 643,421 for figure scaling. See Table 4 for species.

Table 4 Code, common name and scientific names of waterbird species observed in the Lowbidgee during Aerial Surveys 1983-2020).

Code (Figure 11)	Common name	Scientific name
AVO	Red-necked Avocet	*Recurvirostra novaehollandiae*
BDP	Banded Lapwing	*Vanellus tricolor*
BST	Banded Stilt	*Cladorhynchus leucocephalus*
COT	Eurasian Coot	*Fulica atra*
CTL	Chestnut Teal	*Anas castanea*
DMG	Domestic Goose sp.	*Anser sp.*
FDU	Freckled duck	*Stictonetta naevosa*
GCG	Great crested grebe	*Podiceps cristatus*
GWD	Plumed whistling-duck	*Dendrocygna eytoni*
LBC	Little black cormorant	*Phalacrocorax sulcirostris*
LGW	Large Waders unidentified	
LTE	Little egret	*Egretta garzetta*
MHE	Dusky moorhen	*Gallinula tenebrosa*
MNU	Australian Shelduck (Mountain Duck)	Tadorna tadornoides
NKE	Nankeen (Rufous) Night Heron	*Nycticorax caledonicus*
PED	Pink-eared Duck	*Malacorhynchus membranaceus*
POC	Pied Oystercatcher	*Haematopus longirostris*
SEG	White-bellied Sea-Eagle	*Haliaeetus leucogaster*
SHE	Purple swamphen	*Porphyrio porphyrio*
SNI	Straw-necked Ibis	*Threskiornis spinicollis*
WDU	Wood (Maned) Duck	*Chenonetta jubata*
WHI	Australian White Ibis	*Threskiornis molucca*
WNH	Pacific (White-necked) Heron	*Ardea pacifica*

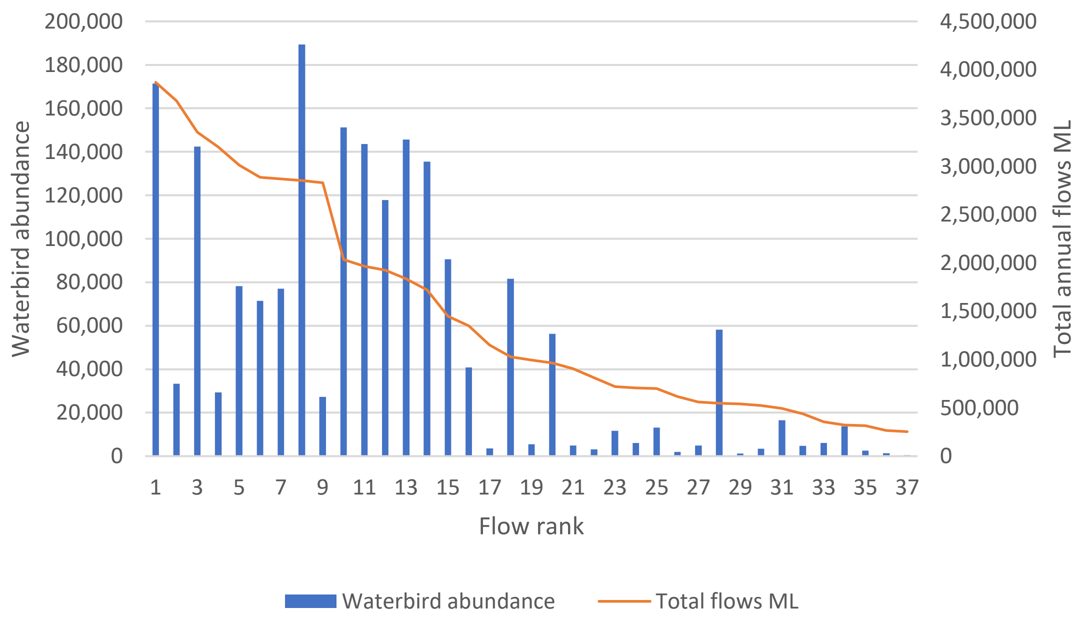

Figure 12 Ranked flows (by total annual flow ML) and associated waterbird abundances.

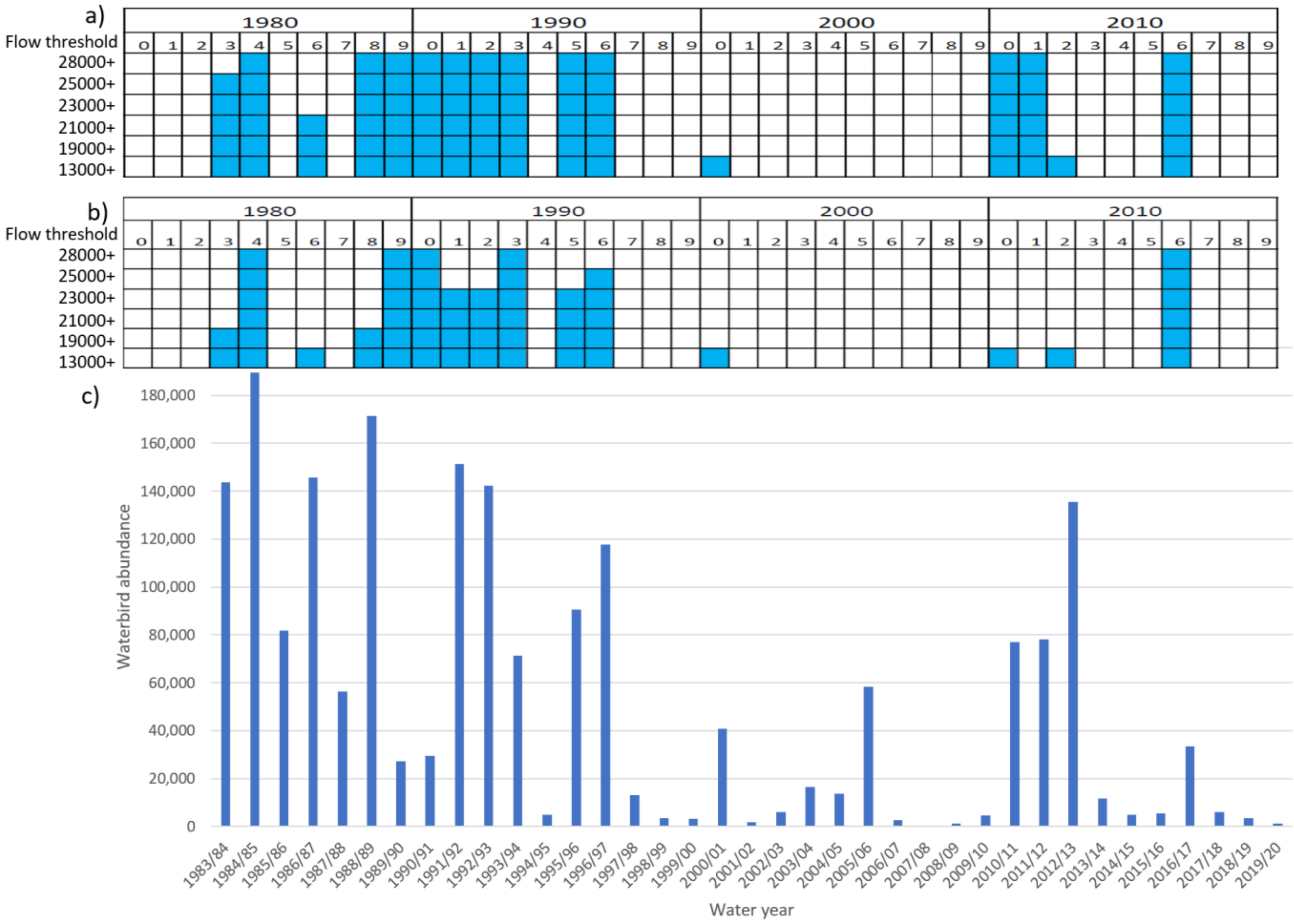

Figure 13 Temporal matching between observed flows in a) anytime during the water year, b) Aug.-Oct. and c) total waterbird abundance (EAWS data).

Potential outcomes under Reconnecting River Country Program flow options

All flow options (W32, W36 and W40) resulted in increased years with flows at all thresholds (13000+ to 28000+ ML/day at Hay) relative to the base case (W22). However, the potential response of waterbirds is determined by the seasonal delivery of flow and flow volumes. The majority of observed waterbird breeding responses were associated with flows in the August-October time period. The general trend in observed data from 1983 - 2020 was that major breeding events (~60%) were more often associated with flow events at thresholds >28,000 ML/day that occurred in August-October. These flow rates are above the highest flow option and are often associated with natural flows within the system and are not a target of the program. The program would have the greatest influence on flow below 28,000 ML/d at Hay (Table 2). These are small to medium wetland inundation flows which will support potential resilience of waterbird and waterbird habitats, including nesting and roosting vegetation, and may provide additional foraging areas.

The W32 option resulted in more years with small wetland connecting flows (>13000 ML/day) both during August – October (10 years) and at anytime during the year (8 years). Small wetland connecting flow thresholds were generally associated with minor waterbird breeding responses. The seasonal timing of flows (August – October) is more likely to result in larger waterbird responses as it inundates habitat for spring breeding. The increase of flows for smaller wetland inundating thresholds may also support higher waterbird abundance as seen by the trend of higher waterbird abundances occurring with higher flows and thresholds in the observed data.

The W36 flow option resulted in an increase in years with small wetland connecting flows >13,000 ML/day, and a smaller increase in years with higher wetland connecting flows (19000+ to 28000+ ML/day). Waterbird responses to W36 would likely be similar to that of W32, with a slight increase in the possibility of major breeding events with increased years with larger flows.

The W40 flow option had the greatest increase in years (~10 years) with flows of 19000+ to 28000+ ML/day with delivery anytime during the year. Increases in years with flows in this range may result in increases in waterbird breeding, more likely to be minor breeding events than major ones. However, the number of years with these flow thresholds was less for delivery in August-October. This is unlikely to result in significant changes to opportunities for waterbird breeding. However, increases in small and moderate events may result in opportunities for smaller breeding events and provided areas for foraging.

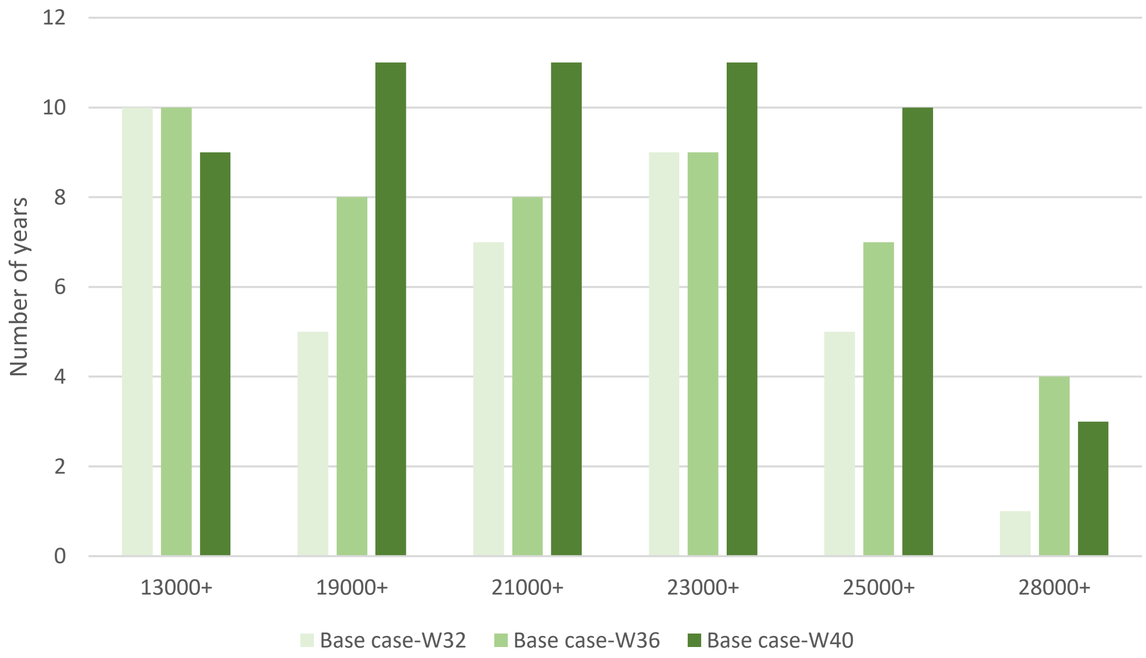

Figure 14 Additional number of years with a 10-day flow duration delivered in August-October for each flow option compared to the base case W22 for each flow threshold (1890-2020).

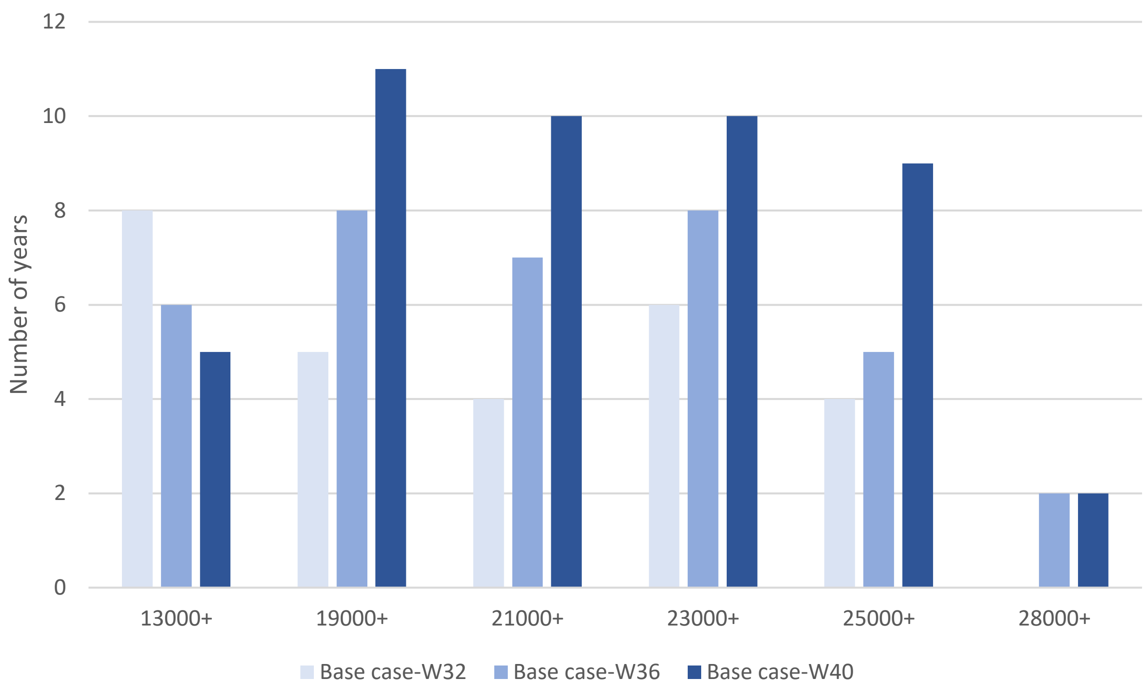

Figure 15 Additional number of years with a 10-day flow duration delivered anytime during the year for each flow option compared to the base case W22 for each flow threshold (1890-2020).

Although the program is not targeting large wetland connecting flows (>28,000 ML/d) that have been seen to have a strong influence of large waterbird breeding events, the increase in small to moderate wetland connecting flows may be important, particularly during extended dry periods. When looking at historical climatic dry periods in the modelled time series, such as the Federation Drought (1895-1902), the World War II drought (1937-1945) and the Millennium drought (1997-2009), there are additional events and duration extensions of small to medium wetland inundating flows under the higher flow options. This can be seen in both the August-October time period (Figure 16) and anytime of year (Figure 17). This indicates the program could provide opportunities for minor breeding events where there otherwise might have been none, or potentially increase the success of those that start through increasing the size and/or the duration of the flow that is supporting the event leading to increased inundated area and potential habitat and foraging.

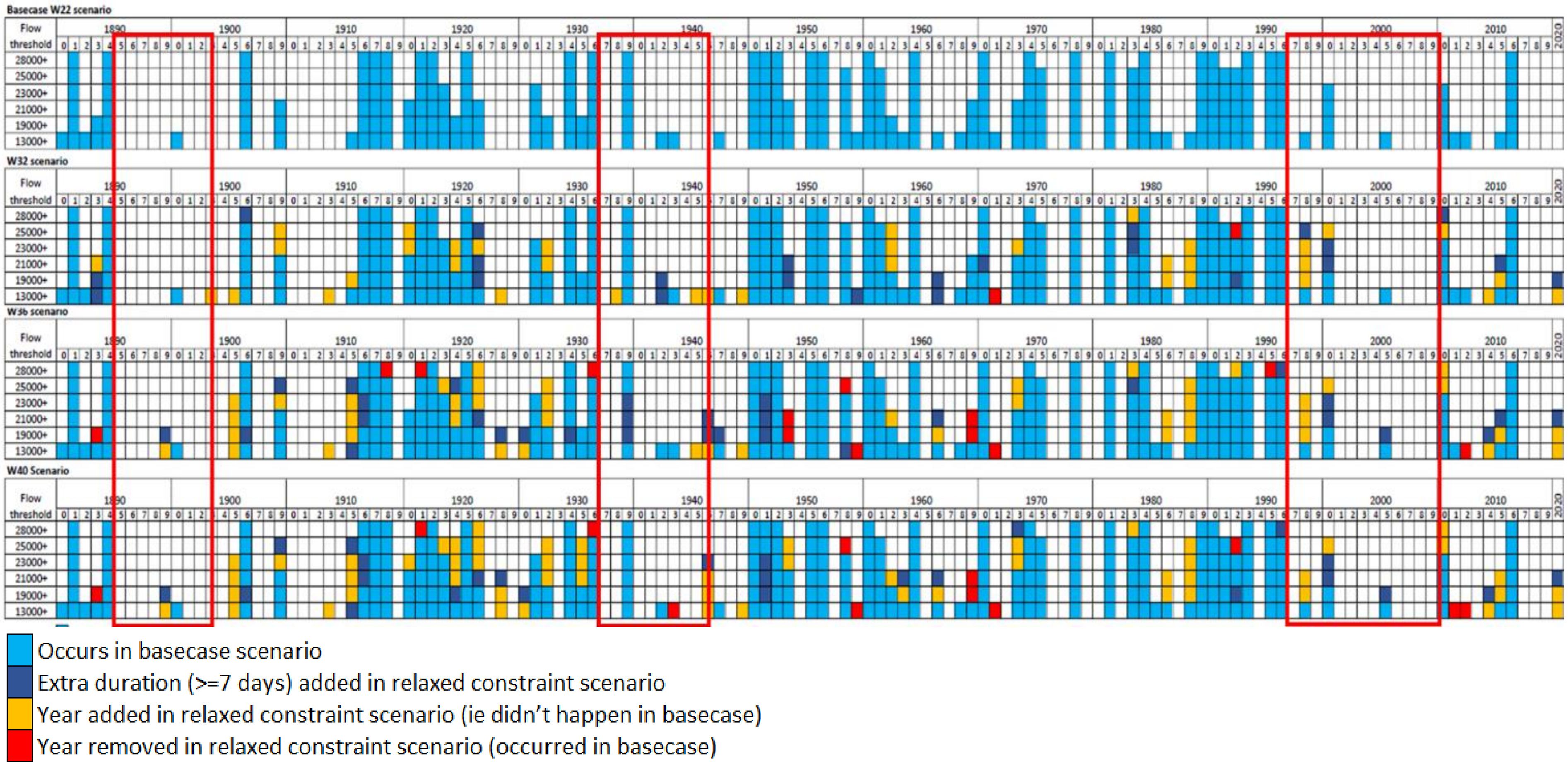

Figure 16 August-October DNA plot for 10 day events with serious drought periods outlined in red.

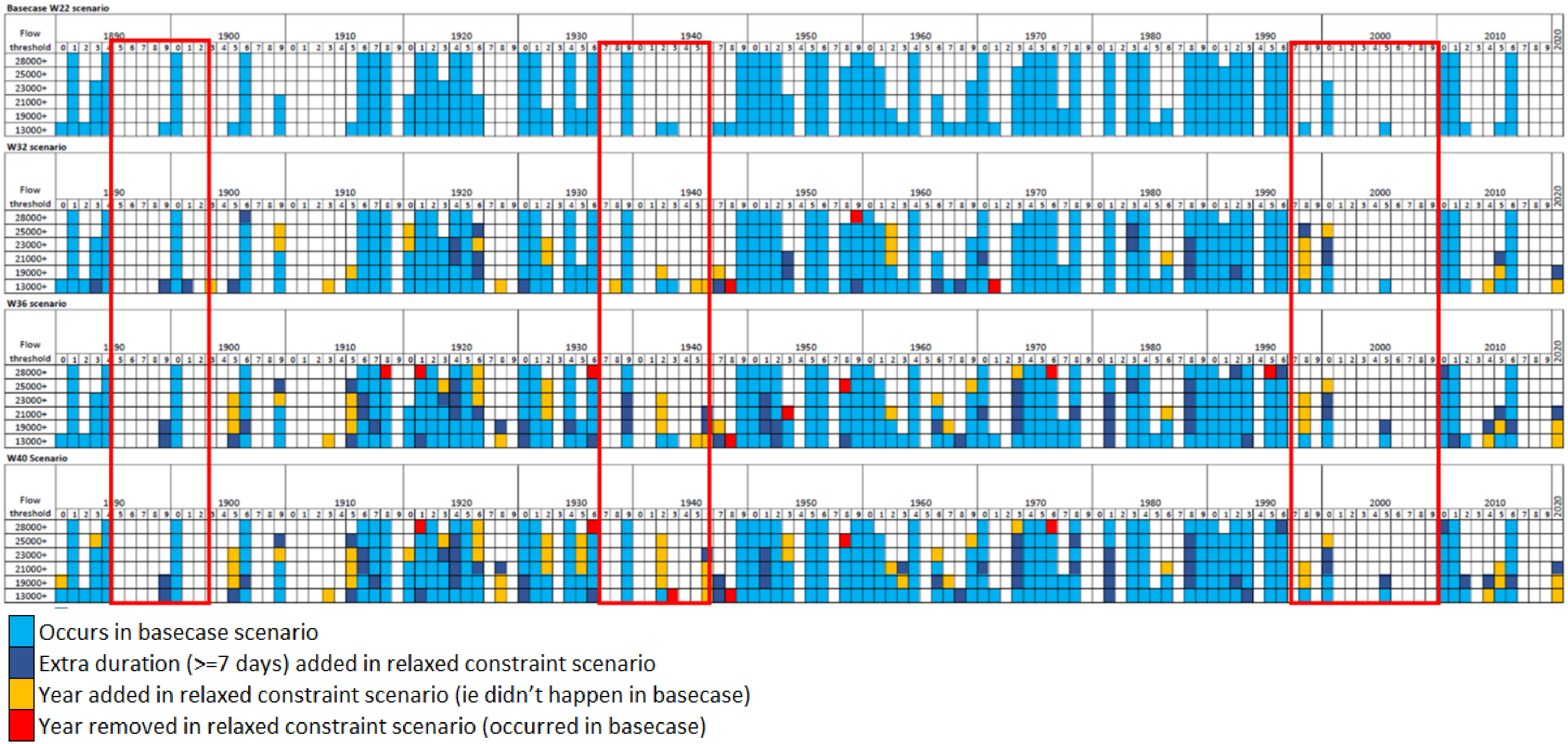

Figure 17 Anytime DNA plot with serious drought periods outlined in red.

Spatial analyses of waterbird sites

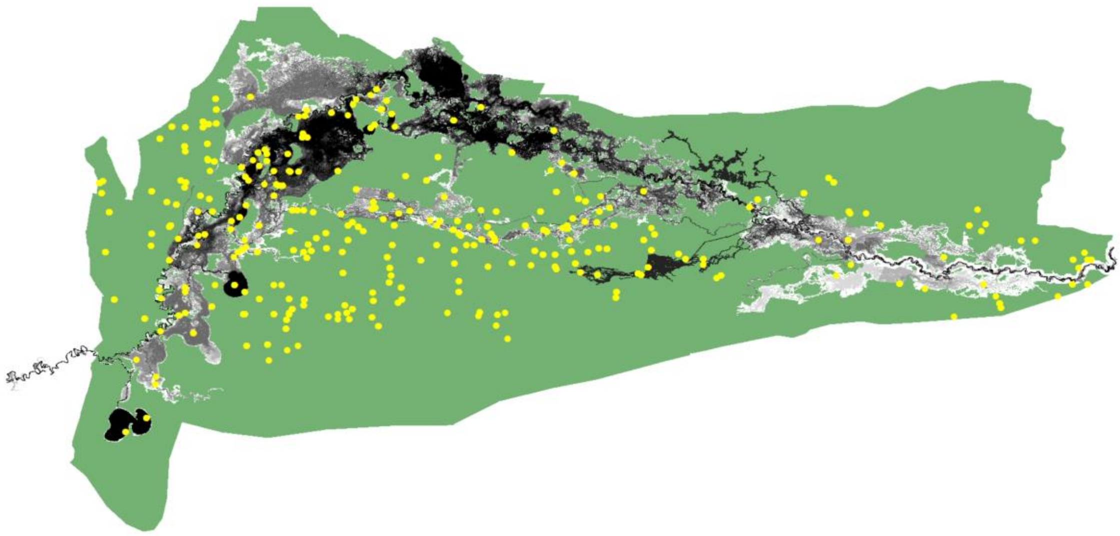

Figure 18 Lowbidgee floodplain (green area) – yellow dots locations of Aerial Survey waterbird data 1983-2020. Modelled inundation extents based on program hydraulic modelling (white, black, grey).– NSW DCCEEW supplied.

There were 356 locations in the Lowbidgee where waterbird data had been recorded as part of the EAWS 1983-2020 (Figure 18). Of this total, up to 51 locations would receive water under differing flow thresholds and are within the area of influence for the program (Table 5, Figure 19).

Table 5 Number of EAWS waterbird sites that would receive water at each flow threshold and the potential number of additional years they may be inundated.

Hydraulic floodplain inundation model thresholds (ML/d)	Count of inundated EAWS waterbird locations	Cumulative total of inundated EAWS waterbird locations	W32 Aug-Oct. additional years of inundation	W32 Anytime additional years of inundation	W36 Aug-Oct additional years of inundation	W36 Anytime additional years of inundation	W40 Aug-Oct additional years of inundation	W40 Anytime additional years of inundation
13000	19	19	10	8	10	6	9	5
15000	2	21						
17000	4	25						
19000	2	27	5	5	8	8	11	11
21000	5	32	7	4	8	7	11	10
23000	8	40	9	6	9	8	11	10
25000	2	42	5	4	7	5	10	9
27000	6	48						
29000	3	51	1	0	4	2	3	2

Figure 20 shows which NSW DCCEEW waterbird survey sites will receive water under different flow thresholds within the program area of influence. Note that some survey sites do not appear to receive water when located at a known wetland site. This is due to the location of the GPS point being at the edge of the wetland and not in the wetland itself.

These have been identified in Table 6. Including these sites, 14 (54%) NSW DCCEEW survey sites will receive water with threshold ranging from 13000+ to 21000+ ML/day. As seen in the Potential outcomes under Reconnecting River Country Program flow options section there is also likely to be an increase in the frequency that these small the medium wetland inundating thresholds are met or exceeded increasing waterbird habitat and foraging areas.

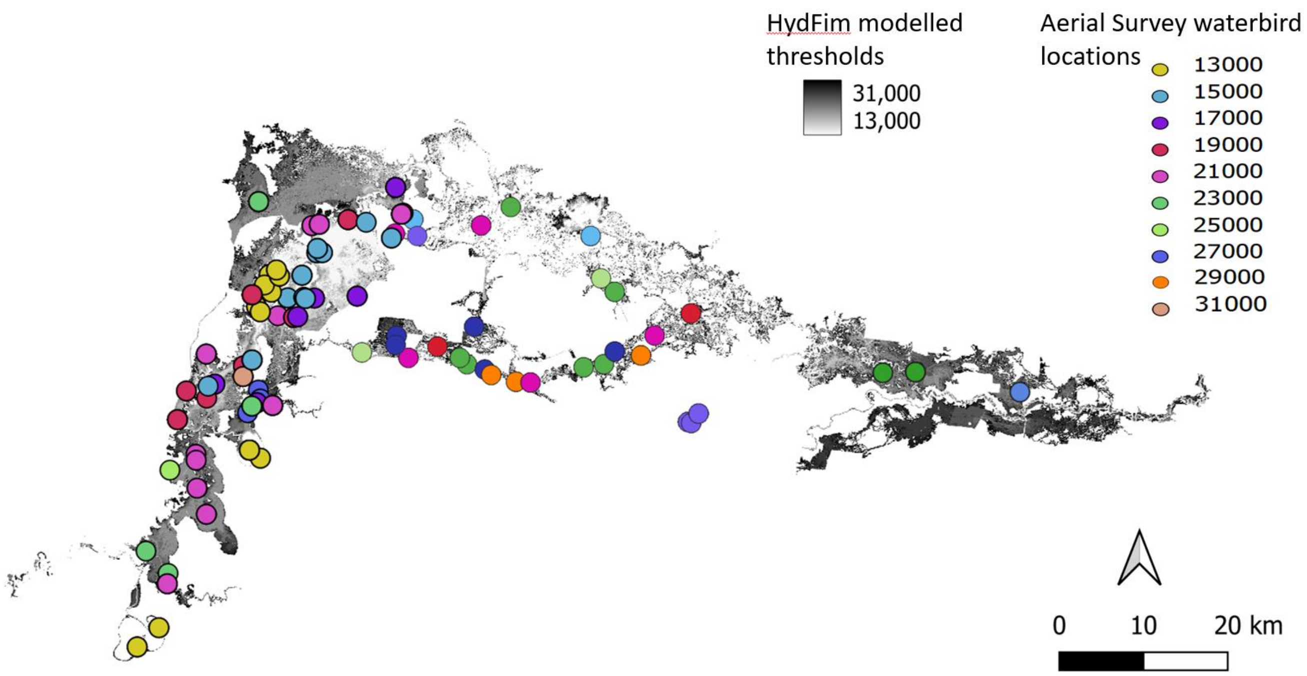

Figure 19 EAWS waterbird sites that will receive water at varying flow thresholds (ML/day).

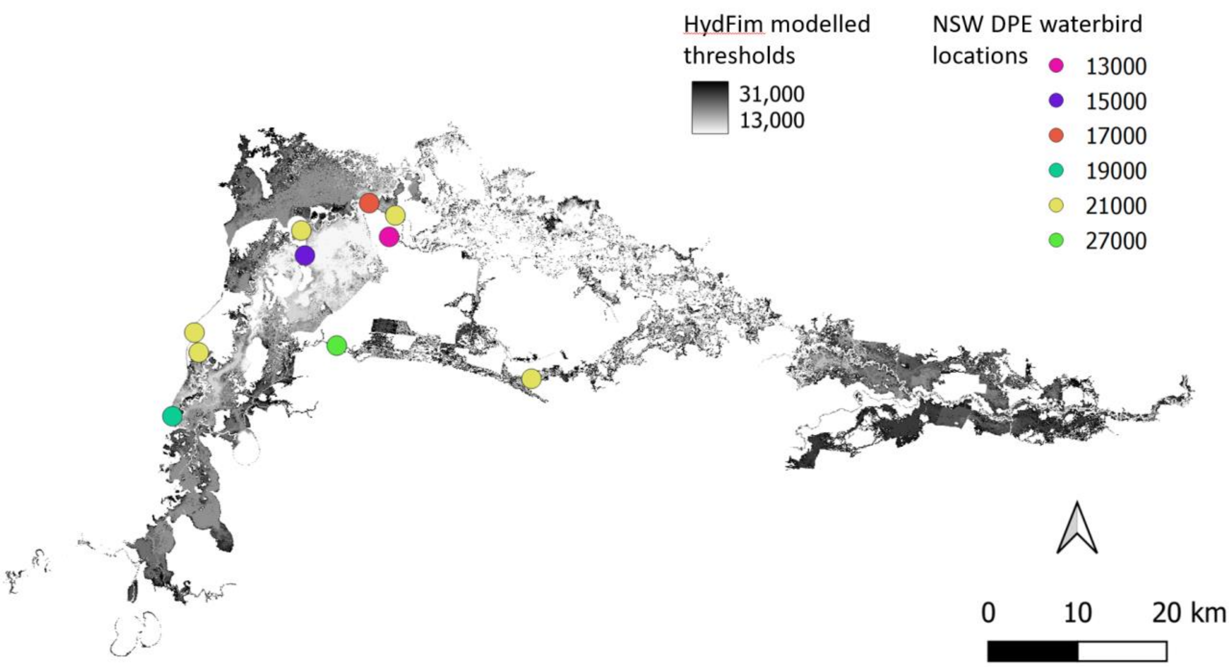

Figure 20 NSW DCCEEW Waterbird Survey Sites that will receive water at varying thresholds (ML/day).

Table 6 NSW DCCEEW waterbird sites that may become inundated under different flow thresholds within the program area of influence.

Site Name	Location	Flow threshold (ML/d) site inundated	Flow threshold (ML/d) at sites with edge GPS locations
Bala Rookery (Eulimbah)	Gayini Wetlands		17,000
Monkem Creek	Monkem Grange, Wagourah Road	27,000	
Nap Nap Swamp	Nap Nap		23,000
Telephone Creek	Gayini Wetlands	21,000	
Murrundi Swamp	Murrundi	19,000	
Narwie West Swamp	Narwie	21,000	
Steam Engine Swamp	Wynburn	21,000	
Mercedes Swamp	Yanga National Park	21,000	
Piggery Lake	Yanga National Park		13,000
Shaws Swamp	Yanga National Park	17,000	
Two Bridges Swamp	Yanga National Park	15,000	
Waugorah Lagoon	Yanga National Park	13,000	
Waugorah Lake	Yanga National Park	21,000	
Yanga Lake	Yanga National Park		13,000

Summary

Key findings included:

- Observed data indicates that large wader responses included breeding at a range of flow thresholds from 13000+ to 28000+ ML/day at Hay.
- The majority of waterbird breeding responses were associated with flows in the August-October time period.
- There is an increase in events at all thresholds (13,000+ to 28,000+ ML/day) in all flow scenarios compared to W22 (base case) including in the August-October time period.
- Large waders were the dominant response group, breeding during all recorded breeding events and at all flow thresholds.
- There does not appear to be any strong trends in guild responses to different flow thresholds.
- There is a general trend in observed data of higher waterbird abundances occurring with higher flows.
- There is an increase in the number of 10-day events at higher flow thresholds in all flow scenarios (W32, 36, W40) compared to W22 (base case). The number of additional events generally increases with flow limit option from W32 to W40, with the W40 scenario having the largest number of additional events overall
- 51 EAWS sites will receive water across the range of thresholds. 50% of these will receive water at relatively low thresholds 13000+ to 19,000+ ML/day, which are within the range of flows influenced by the flow options.
- 14 NSW DCCEEW long-term waterbird survey sites will receive water with threshold ranging from 13000+ to 21000+ ML/day.

Potential benefits

All scenarios, W32, W36 and W40 predict an increase in the number of flow events compared to W22 (base case) cross all flow thresholds from 13000+ to 28000+ in the Murrumbidgee River at Hay. This is likely to benefit all waterbirds, particularly large waders and may provide increased opportunities for breeding. W40 additionally provides additional flow events at higher thresholds which provides greater opportunity for larger breeding events.

Table 7 Summary of potential waterbird benefits for each flow option.

Flow option	Waterbird Benefits
W32	Potential increase in number of small wetland connecting flows. Potential increase in number of opportunities for minor aggregating waterbird breeding events, particularly in extended periods of dry. Greater waterbird habitat and foraging areas.
W36	Potential increase in number of small (>13,000 ML/d) and higher (25,000 ML/day) wetland connecting flows. Potential increase in number of opportunities for minor aggregating breeding events, particularly in extended periods of dry. Minor increase in the chance of major aggragating waterbird breeding events. Greater waterbird habitat and foraging areas, larger spatial extent than W32.
W40	Greatest increase of wetland connecting flows, both smaller and higher, of all scenarios compared to W22 (base case). Greatest increase in the chance of minor aggregating waterbird breeding events. Greatest increase across the scenarios for possibly major waterbird breeding events. Greatest additional inundation of waterbird habitat and foraging areas of all flow options.

Extended flow events, at all flow volumes, may increase nesting or breeding success where inundation duration can be extended and breeding initiated. This is likely to benefit both large waders and piscivores through the extended provision of suitable nesting habitat and foraging areas.

Many of the waterbird survey sites (EAWS and NSW DCCEEW, Figure 19, Figure 20) are modelled to receive water at relatively low flow thresholds <21000 ML/day. The potential increase in the events that inundate them under the flow options will be beneficial to waterbirds through the provision of potential nesting and foraging areas, but also through the maintenance of waterbird habitat, including riparian and floodplain vegetation.

Waterbird responses

Waterbirds are highly mobile organisms and their responses to flows and inundation at a wetland or floodplain, may be influenced by habitat availability (breeding, foraging and roosting) at a larger, landscape scale beyond the Lowbidgee floodplain. There may be waterbird benefits at other wetlands in the landscape under the Reconnecting River Country Program including the Murray and mid-Murrumbidgee (Bino et al. 2022a, Bino et al. 2022b) Waterbird responses and the magnitude of the response are also influenced by population sizes, timing of flows and life history stages e.g., breeding. These caveats should be considered when anticipating likely waterbird responses and when assessing outcomes of environmental water deliveries.

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