Department of Climate Change, Energy, the Environment and Water

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Border Rivers Regional Water Strategy

Detailed ecological analysis

November 2022

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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Contents

Introduction

The NSW Government is developing 12 regional water strategies and 2 metropolitan strategies that bring together the best and latest climate evidence, with a wide range of tools and solutions to plan and manage each region's water needs over the next 20 to 40 years.

The draft Border Rivers Regional Water Strategy, including a long list of options, was released in October 2020[1]. A rapid assessment process was used to review the long list of options and develop a high priority short list, as documented in the 'Border Rivers: Shortlisted Actions – Consultation Paper'[2] This included asking experts across NSW agencies what their initial assessment of risk or benefit for the environment was for each option[3].

Options that passed the rapid ecological and economic assessments were then examined to understand the risks and opportunities that they presented, particularly whether there was potential to affect economic and/or ecological values within the region. How short list options were developed for each Regional Water Strategy is described in the Options Assessment Process Overview[4], and the Regional Water Strategies guide[5]. Figure 1 provides an overview of the options assessment process.

Two shortlisted options were selected for ecological analysis. The ecological assessments in this report use river hydrology time series models to estimate how the options might affect current flow conditions in the Border Rivers region, as well as future conditions under different climate change scenarios. These results are compared to expert estimates of ecological risk or benefit in the earlier rapid assessment process and then discussed within the context of key regional water strategy challenges.

[1] DPIE (2020a). Draft Regional Water Strategy Border Rivers. October 2020 (www.dpie.nsw.gov.au/__data/assets/pdf_file/0003/327801/draft-br-strategy.pdf), and

DPIE (2020b). Draft Regional Water Strategy. Border Rivers: Long list of options, October 2020 (www.dpie.nsw.gov.au/__data/assets/pdf_file/0020/327800/draft-br-options.pdf).

[2] DPE (2022a). Border Rivers: Shortlisted Actions – Consultation Paper. Department of Planning and Environment, June 2022. (https://www.dpie.nsw.gov.au/__data/assets/pdf_file/0005/514085/short-list-actions.pdf).

[3] The rationale for these scores is described in this document, at Appendix A (p. 36).

[4] DPE (2022b). Options Assessment Process. Overview. April 2022 (www.dpie.nsw.gov.au/water/plans-and-programs/regional-water-strategies/identifying-and-assessing).

[5] DPIE (2020c). Regional Water Strategies. Sustainable and integrated water resource management for the benefit of present and future generations. Guide. September 2020 (www.dpie.nsw.gov.au/water/plans-and-programs/regional-water-strategies/identifying-and-assessing)

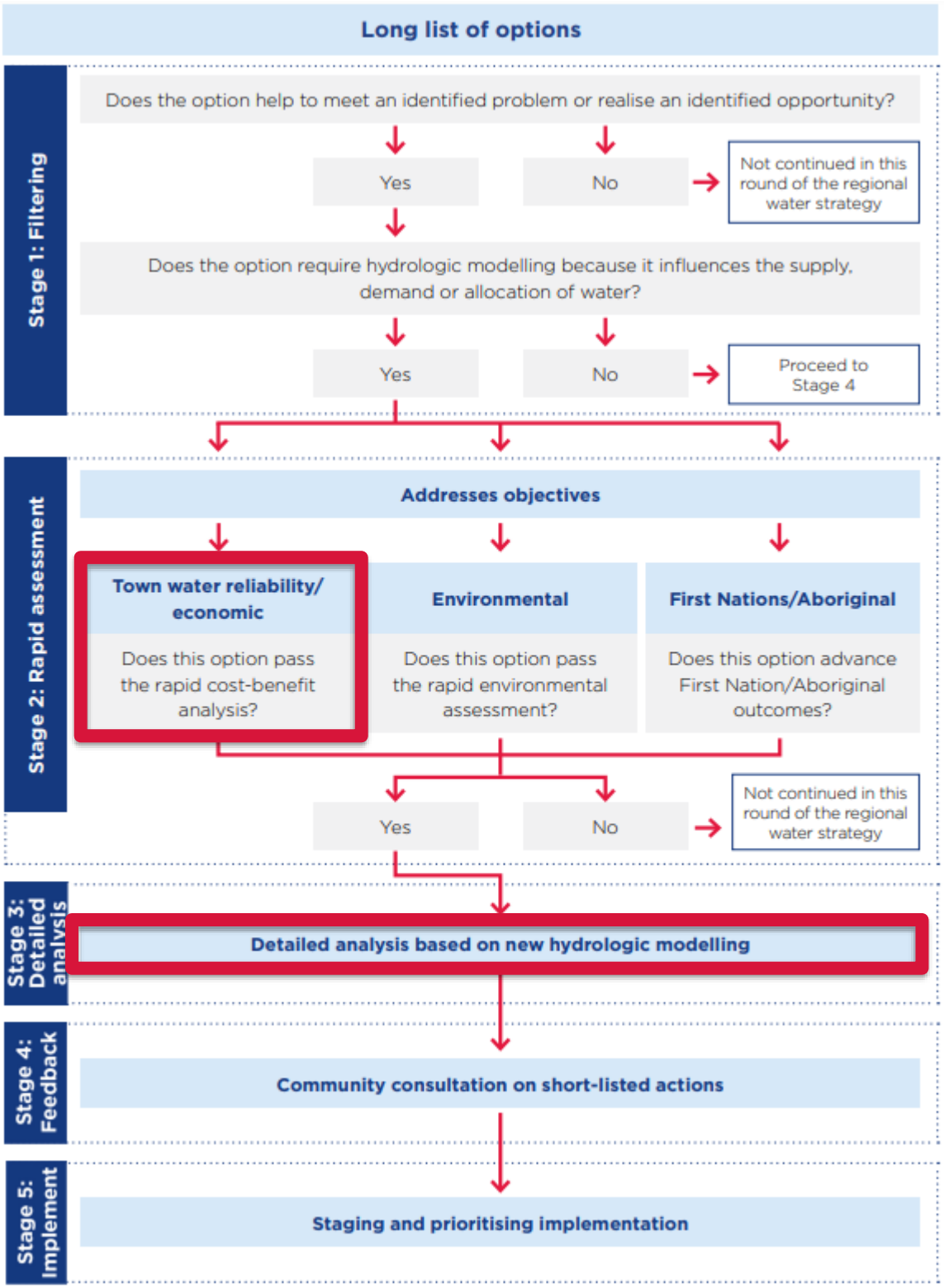

Figure 1: Options assessment process as outlined in the detailed economic assessment for the Gwydir region[6]. This document represents the environmental component of stage 3.

[6] DPE (2022c). Border Rivers Regional Water Strategy. Detailed economic analysis, July 2022.

Purpose of the ecological analysis

The NSW Government is developing 12 regional water strategies and 2 metropolitan water strategies that bring together the best and latest climate evidence with a wide range of tools and solutions to plan and manage each region's water needs over the next 20 to 40 years.

This ecological analysis describes the results of the hydrologic modelling for the relevant options put forward in the Draft Border Rivers Regional Water Strategy. The hydrologic modelling will cover the observed historical (instrumental), long-term paleoclimate (Stochastic or long-term variability) and climate change (NARCliM) model predictions. We have 10,000 years of data in each Stochastic and NARCliM data set.

This ecological analysis is an expansion and improvement on the ecological analyses that were done for the Border Rivers Regional Water Strategy consultation paper[7]. This analysis shows the effects of the options using Border Rivers Long Term Water Plan[8] flow metrics. How these options potentially impact future hydrology and the some of the key ecological assets in this region are reported. The differences between baseline conditions versus models where option effects were added were used to assess likely change. Two baseline conditions were developed. One assumed the flow variation observed under long-term variability using the Stochastic models. Additional baseline conditions were developed under future climate change using the NARCliM models. The average and extreme ecological effects of these options are reported and discussed in relation to the commentary in the rapid assessments.

Options modelled were:

1. Increase the reserve to 62.2 GL to provide a 2-year essential needs reserve across Glenlyon Dam and Pindari Dam (Option 30, Draft Border Rivers Regional Water Strategy).
2. Bulk conversion – convert all general security licences to high security licences (Option 44, Draft Border Rivers Regional Water Strategy).

[7] DPE (2022a). Border Rivers: Shortlisted Actions – Consultation Paper. Department of Planning and Environment, June 2022. (https://www.dpie.nsw.gov.au/__data/assets/pdf_file/0005/514085/short-list-actions.pdf).

[8] DPIE (2018). Border Rivers Long Term Water Plan. Parts A and B. NSW Department of Planning, Industry and Environment (https://www.mdba.gov.au/sites/default/files/pubs/draft-nsw-border-rivers-long-term-watering-plan-part-a-and-b-for-exhibition.pdf).

Key ecological values and assets

The NSW Border Rivers catchment supports a range of water-dependent ecosystems, including instream aquatic habitats, riparian forests, and floodplain watercourses, woodlands and wetlands. Notably, the Morella Watercourse/Boobera Lagoon/Pungbougal Lagoon wetland complex is nationally recognised in the Directory of Important Wetlands and comprises some of the few permanent waterbodies in the northern Murray-Darling Basin[9].

These ecosystems support a range of important ecological communities, including state and federally listed plant and animal species. River red gum (*Eucalyptus camaldulensis*), coolibah (*E. coolabah*) and river oak (*Casuarina cunninghamiana*), with weeping bottlebrush (*Callistemon viminalis*) understorey line many of the rivers in the region[10]. This also include the Macintyre River wetlands and floodplain, which are important breeding habitat for protected waterbirds including brolgas (*Grus rubicunda*), black-necked storks (*Ephippiorhynchus asiaticus*) and magpie geese (*Anseranas semipalmata*)[11].

The ecological condition of the Border Rivers catchment water-dependent ecosystems is largely driven by flows that connect instream benches, cut-off channels, anabranches, floodplains and wetlands. These flows support the ecological health of many waterholes, billabongs and wetlands, and support Murray cod and 15 other species of native fish including the vulnerable silver perch and endangered freshwater catfish, olive perchlet and purple-spotted gudgeon[12]. Flows that provide these connections also support necessary stream metabolic functions such as organic carbon transfer and nutrient cycling, trigger movement and breeding of native fish and waterbirds, and maintain vegetation condition and habitat.

Any improvements or impacts resulting from the options will take effect in a partially modified system, largely because of increased use of water for irrigation which expanded in the 1990s[13]. This system was ranked in overall better condition than many other Murray Darling Basin rivers as part of the 2008 Sustainable Rivers Audit, with the overall ecosystem score ranked as moderate[14]. A more recent surface water risk assessment suggests, however, a more mixed story. It indicates that in many sections of the Border Rivers, and especially in the regulated sections, there are risks in meeting environmental flow requirements. There is often a high risk in not meeting cease to flow, base-flow or low flows requirements, low to high risk in the capacity to meet fresh flows, and typically low to medium risks for high and infrequent flows [15]. Barriers to fish passage, cold water pollution

[9] CEWO (2012). Commonwealth Environmental Water Office Water Management Plan 2020–21, and DPE (2022c). NSW Border Rivers Long Term Water Plan Parts A and B (www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Water/Water-for-the-environment/border-rivers-long-term-water-plan-part-a-part-b-221304.pdf).

[10] MDBA (2012). Assessment of environmental water requirements for the proposed Basin Plan: Lower Border Rivers (in-channel flows). Murray–Darling Basin Authority, 2012 (www.mdba.gov.au/sites/default/files/archived/proposed/EWR-Lower-Border-Rivers.pdf).

[11] MDBA (2012). As previously cited.

[12] DPE (2022d). NSW Border Rivers Long Term Water Plan, as previously cited, and DPI (2015). Fish and Flows in the Northern Basin: responses of fish to changes in flow in the Northern Murray–Darling Basin – Valley Scale Report. NSW Department of Primary Industries (https://www.mdba.gov.au/sites/default/files/pubs/fish-and-flows-nb-stage-2-valley-scale.pdf).

[13] Kingsford, R. T. (1999). Managing the water of the Border Rivers in Australia: irrigation, Government and the wetland environment. *Wetlands Ecology and Management*, 7(1), 25-35.

[14] Davies et al. (2008). A report on the ecological health of rivers in the Murray-Darling Basin, 2004-2007. Murray–Darling Basin Commission (https://www.mdba.gov.au/sites/default/files/archived/mdbc-sra-reports/1-SRA_Report_1_tech_full.pdf).

[15] DPI (2018). Border Rivers Surface Water Resource Plan Risk assessment. Schedule D. NSW Department of Primary Industry, December 2018 (www.industry.nsw.gov.au/__data/assets/pdf_file/0017/206090/schedule-d-border-rivers-risk-assessment-part-one.pdf).

effects and numerous pump offtakes in the lower reaches compounding these low flow impacts and are very likely to cause loss in condition and often mortality of freshwater fish[16], [17].

Method and rationale behind the detailed ecological analysis

The flow regime is the one of the key determinants of river and floodplain wetland ecosystem health[18]. River ecosystems depend on a wide range of flow conditions to maintain the diversity of plants, animals and microorganisms over the long term. Periodically high flows support wide-scale movement of biota, provide water for vegetation along riverbanks and sustain off-river billabongs and pools (**Error! Reference source not found.** and Table 1). Smaller flows can stimulate breeding or dispersal, maintain healthy water quality and support population diversity.

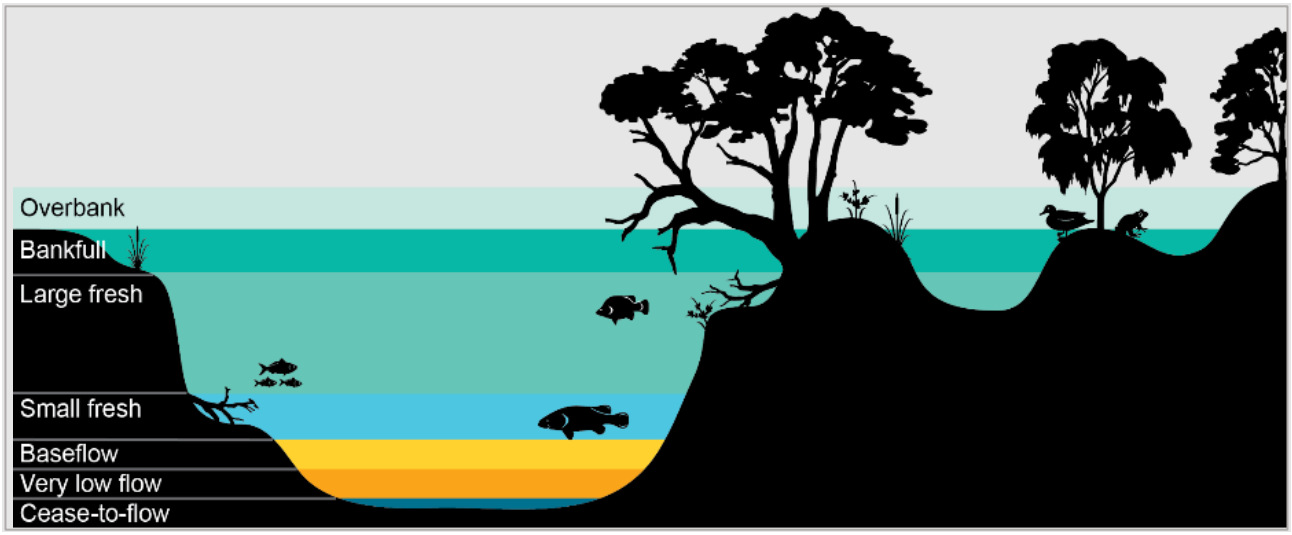

Figure 2. Conceptual model of commonly used ecological flow components

We used river hydrology models to estimate the effect that each option could have by looking at how their implementation could change commonly used ecological flow metrics, and metrics from the Border Rivers Long Term Water Plan (LTWP). The LTWP metrics represent the environmental flow regime requirements from no flows and low flows to high, infrequent flows. Long Term Water Plans were prepared as part of Basin Plan implementation. The ecological objectives of these plans are grouped into four themes: native fish, waterbirds, native vegetation and ecosystem function. The EWRs cover a range of flows and are determined by the specific flow or inundation needs of target plants, animals and processes. Critical flow components are described in terms of their timing, duration, frequency and maximum inter-flow or inter-event period for specific gauges within planning units.

[16] NSW Department of Primary Industries—Fisheries (2016) Fish Communities and Threatened Species Distributions of NSW. Published by the NSW Department of Primary Industries (www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/669589/fish-communities-and-threatenedspecies-distributions-of-nsw.pdf).

[17] Boys, C. A., Rayner, T. S., Baumgartner, L. J., & Doyle, K. E. (2021). Native fish losses due to water extraction in Australian rivers: Evidence, impacts and a solution in modern fish-and farm-friendly screens. *Ecological Management & Restoration*, 22(2), 134-144.

[18] Bunn, S. E., & Arthington, A. H. (2002). Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. *Environmental management*, 30(4), 492-507.


Weir River
Boggabilla Weir
Goondiwindi Weir
Goondiwindi
Boggabilla
Macintyre River
Boomi Weir
Boomi Regulator
Whalan Creek
Boomi River
Boobera Lagoon
Pungbougal Lagoon
Morella Watercourse
Macintyre Brook
Coolmunda Dam
Pike Creek
Severn River
Glenarbon Weir
Cunningham Weir
Dumaresq River
Glenlyon Dam
North Star
Mungindi Weir
Mungindi
Bonshaw Weir
Jennings
Mole River
Tenterfield
Croppa Creek
Croppa Creek
Crooble
Beardy River
Macintyre River
Ashford
Emmaville
Deepwater
Severn River
Pindari Dam
Glen Innes
Inverell
Copeton Dam
Euahlayi
Githabul
Kambuwal
Gomeroi
Kiwiambul
Ngarabal

Fi

We analysed the hydrologic time series model outputs for 19 flow gauges. These gauges provided a good representation of how flow conditions can change along the Border Rivers region when the inflows from different valleys are also changed. The gauges also reflect the geographic spread within the LTWP, which breaks the catchment up into 15 planning units, each referenced to a specific gauge.

We modelled the percentage change in flow metrics between the modelled scenarios and a 'base case' model. Base case models estimate current flow conditions based on flow data, patterns of rainfall, inflows and water use under the current water sharing plan rules. We used the base case model as a benchmark of current conditions, and then estimated how flows would change under the different options scenarios.

The extent and direction of percentage change was then classified on an eleven-point scale from 'extreme improvement' to 'extreme impact' (Table 3). Whether a percentage change was an improvement, or an impact varied depending on the flow metric. For example, a decrease in the 'mean duration of cease-to-flow events' metric is a beneficial outcome for the environment, whereas a decrease in the 'mean duration of fresh events' metric is a detrimental outcome. Our interpretation of beneficial or detrimental change for each metric is explained in Table 2.

This approach captures many of the potential ecological changes associated with an option, but we acknowledge that there are many that cannot be detected. For example, any increase in supply or reliability of water for agricultural use enabled within a storage can also result in further downstream use and diversion of water that is associated with native fish mortality caused by pumps and off-river channels[19] .

Because of the considerable detail within the Long-Term Watering Plan and the need to present a communicable level of detail some metrics were often aggregated. For example, for small freshes, the frequency for all classes of fresh from SF1 to SF3 were combined.

Some of these metrics sound like they are the same, but are not, and are based on the logic of the Long-Term Watering Plans. In particular, the 'frequency of over-extended time between events' metrics tell a complementary story to frequency metrics. This is because a frequency requirement can be met, but because flow components (such as freshes and base flows) can preferentially cluster together during specific flow sequences, there can be different flow sequences where the time between these components are too far apart.

For consistency, this report uses the metrics that were developed as part of the 2018 version of the Border Rivers Long-Term Watering Plan[20] which were used in the consultation report. The 2022 version of the Long-Term Watering Plan[21] was revised during the Border Rivers Regional Water Strategy reporting process.

[19] Boys et al. (2021), as previously cited.

[20] DPIE (2018). Border Rivers Long Term Water Plan. Parts A and B. NSW Department of Planning, Industry and Environment (https://www.mdba.gov.au/sites/default/files/pubs/draft-nsw-border-rivers-long-term-watering-plan-part-a-and-b-for-exhibition.pdf).

[21] DPE (2022c). NSW Border Rivers Long Term Water Plan Parts A and B (www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Water/Water-for-the-environment/border-rivers-long-term-water-plan-part-a-part-b-221304.pdf).

Table 1. Generic ecological flow component definitions and codes used in the 2018 Border Rivers Long Term Watering Plan[22]

Flow components (code)	Description
No flow, or cease-to-flow (CF)	Partial or total drying of the channel. Stream contracts to a series of disconnected pools. No surface flows. For a specific gauge this can sometimes be a non-zero reading as it ties back to no flow conditions at the target location.
Very Low Flows (VF)	Minimum flow in a channel that prevents a cease to flow. Provides connectivity between some pools.
Base Flows (BF)	Provides connectivity between pools and riffles and along channels. Provides sufficient depth for fish movement along reaches.
Small fresh (SF)	Improves longitudinal connectivity. Inundates lower banks, bars, snags and in-channel vegetation. Trigger for aquatic animal movement and breeding. Flushes pools. May stimulate productivity/food webs.
Large fresh (LF)	Inundates benches, snags and inundation-tolerant vegetation higher in the channel. Supports productivity and transfer of nutrients, carbon and sediment. Provides fast-flowing habitat. May connect wetlands and anabranches with low commence-to-flow thresholds.
Bankfull Flows (BK)	Inundates all in-channel habitats and connects many low-lying wetlands. Partial or full longitudinal connectivity. Drown out of most small in-channel barriers (e.g., small weirs).
Overbank flows (OB)	Overbank flows are used to describe flows when they are above bankfull. These provide lateral connectivity with floodplains and wetlands. They support nutrient, carbon and sediment cycling between the floodplain and channel, and promote large-scale productivity
Anabranch flows (AB)	Flows along anabranches that improve connections along rivers and between rivers and their floodplains also improve river system health[23]. Often important for the provision of refugia, and in maintaining the diversity and abundance of waterbird species.

[22] DPI (2018). Border Rivers Surface Water Resource Plan Risk assessment. Schedule D. NSW Department of Primary Industry, December 2018 (www.industry.nsw.gov.au/__data/assets/pdf_file/0017/206090/schedule-d-border-rivers-risk-assessment-part-one.pdf).

[23] McGinness, H. (2007). Spatial heterogeneity and hydrological connectivity in a dryland, anabranching floodplain river system. PhD thesis, University of Canberra.

Table 2. Ecological flow metrics derived from the Border Rivers Long Term Watering Plan metrics in Table 1 that were used for comparing base case and scenario models.

Ecological flow metric	Description	Beneficial % change
No flow (CF) frequency	The number of no flow periods (or cease-to-flow periods, as defined in the LTWP) per 130 years, where the no flow (or cease-to-flow) event is defined for each planning unit in the LTWP up to a maximum duration of 60 days. The frequency of no flow events is originally calculated for the 10,000-year modelling period, but then expressed as the number of events/ 130 years (the length of the reference Instrumental period).	Decrease
No flow (CF) duration	The average duration of no flow events (days)	Decrease
Very Low flow (VF) - frequency of years not met	The number of years (per 130 years) the specified minimum number of days per year for very low flows (as defined in the LTWP) is not met.	Decrease
Base flow (BF) - frequency of years not met	The number of years (per 130 years) the specified minimum number of days per year for base flows (BF1-BF2 as defined in the LTWP) is not met.	Decrease
Small Fresh (CF) (frequency of over-extended time between events)	The number of events (per 130 years) where the specified maximum allowable years between small fresh events (for SF1-SF3 as defined in the LTWP) is exceeded.	Decrease
Large fresh (LF) (frequency of over-extended time between events)	The number of events (per 130 years) where the specified maximum allowable years between large fresh events (for LF1-LF6 as defined in the LTWP) is exceeded.	Decrease
Bankfull (BK) (frequency of over-extended time between events)	The number of events (per 130 years) where the specified maximum allowable years between bankfull events (BK1-BK3 as defined in the LTWP) is exceeded.	Decrease
Overbank flows 1 (OB 1, frequency of over-extended time between events)	The number of events (per 130 years) where the specified maximum allowable years between large fresh events (for OB1-OB5 as defined in the LTWP) is exceeded.	Decrease
Anabranch flows 1 (AB 1, frequency of years not met)	The number of years (per 130 years) the specified minimum number of days per year for anabranch flows (AB1, as defined in the LTWP) is not met.	Decrease

Ecological flow metric	Description	Beneficial % change
Anabranch flows 2 (AB 2, frequency of over-extended time between events)	The number of events (per 130 years) where the specified maximum allowable years between anabranch flows (AB2, as defined in the LTWP) is exceeded.	Decrease

Table 3 Categories that were used to classify potential improvements or impacts that could occur under shortlisted options and commitments.

Stage 1 category	Stage 2 category	Estimated percentage change in hydrology/ecology
Major/extreme impact	Extreme impact	More than 30% change in a detrimental direction
	Major impact	More than 20% change in a detrimental direction
Minor/moderate impact	Moderate impact	More than 10% change in a detrimental direction
	Minor impact	More than 3% change in detrimental direction
No/little change	Little impact	Less than 3% change in a detrimental direction
	No change	0%, rounded to the nearest whole percentage point
	Little improvement	Less than 3% change in a beneficial direction
Minor/moderate improvement	Minor improvement	More than 3% change in a beneficial direction
	Moderate improvement	More than 10% change in a beneficial direction
Major/extreme improvement	Major improvement	More than 20% change in a beneficial direction
	Extreme improvement	More than 30% change in a beneficial direction

Climate models used in the ecological analysis

In addition to the Long-Term Watering Plan metrics, this assessment uses enhancements to river hydrology models that enable us to assess option effects under past and future flow regimes. We have used two different modelling approaches to develop the flow regimes. These two modelling approaches improves our confidence that we are considering a more accurate range of possible past and future flow scenarios in the assessment. The two approaches were Stochastic flow modelling and NSW and ACT Regional Climate Modelling (NARCliM) models.

Long-term historic climate projections (Stochastic data) assume that our future climate is like what the science is indicating our long-term paleoclimate was like and are based on a 10,000-year dataset. Stochastic modelling is based on an extended historical climate record that has integrated weather data, data from tree rings, ice cores, cave deposits and coral growth. The modelling has then enabled the generation of a

dataset covering up to 10,000 years, which enables us to describe patterns of natural variability and extremes (drought and flood) in our regions since the last major global climate shift with more certainty than was previously possible.

Dry climate change scenario (NARCliM modelling) assumes that there is a dry, worst-case climate change scenario in the future and is also based on a 10,000-year dataset. NARCliM uses results from four broad scale Global Climate Models (GCMs) and combines these with information on local topography and coastal processes to develop finer resolution Regional Climate Models (RCM). The regional models provide forecasts on a range of climate characteristics including temperature, rainfall and soil moisture for areas of 100 km^2. The NARCliM project is a NSW Government led partnership that now includes the ACT and South Australian Governments and the Climate Change Research Centre at the University of NSW.

Ecological analyses

Convert all general security licences to high security licences (Option 44).

Option description

Under this option all the existing general security A and B entitlement (nominal 264 GL/year, average take of 93 GL/year) is converted in bulk to 85 GL of high security entitlement, thereby using the existing Glenlyon and Pindari Dams to create additional high security entitlement to the maximum extent possible. The assessment assumes cotton production using the general security water is replaced by higher value permanent plantings (pecans) using the converted high security entitlement. This option represents the maximum increase in economic output that could be created using the existing infrastructure.

Summary of results

- Many extreme impacts including on cease to flow, base-flow or low flows requirements and fresh flow requirements already considered to be impacted under the surface water risk assessment[24].
- This analysis showed an even greater increase in the frequency of no flow periods, which is likely to be damaging to riverine communities. This would result in decreased condition of flow-dependent communities, and increased mortality of flow-dependent fauna and flora. The most extreme impacts were in lowland river sections
- There was an extreme overall impact on freshes, and the most extreme impacts were in lowland river sections. This would reduce the opportunities for fish recruitment and reduce the frequency of important processes that enable river productivity (such as flushing carbon sources off benches).
- Extreme impacts on some anabranch flows were also observed, especially at Boomi which could also impact on system productivity, such as for waterbirds.
- Lowland areas designated by Macintyre River sites Boomi, Terrewah, Kanowna and Goondiwindi generally showed the most extreme impacts.

Interpretation of results, and comparison with the rapid assessment

In the rapid assessment of the long options (option 31 in the list below), the option “Investigation of licence conversions” was trending around an average that fell between ‘Minor / Moderate impact’ and ‘Major / Extreme impact’. However, the general concerns that environmental water targets would be met less and that the impacts would be greater in the lowland sections of the Border Rivers are well supported.

Extreme impacts generally resulted for the frequency of no flow events, specially under the climate change scenario, although some extreme improvements were also observed. The duration of these events tended

[24] DPI (2018). Border Rivers Surface Water Resource Plan Risk assessment. Schedule D. NSW Department of Primary Industry, December 2018 (www.industry.nsw.gov.au/__data/assets/pdf_file/0017/206090/schedule-d-border-rivers-risk-assessment-part-one.pdf).

to be longer, although there were minor to moderate improvements at some sites. The most impacted sites included the more downstream sites at Macintyre River at Terrewah, Kanowna and Goondiwindi. These all had very large percentages increases in no flow events, by moving from between 0.3 - 1.3 to between 5-7 no flow events per 130 years under the climate change scenario. By contrast, upland sites tended to show more of an improvement, with, for example, Roseneath in the upper reaches showing a decrease in no flow events, from 3 to 2 no flow events per 130 years.

Impacts on higher flows were generally concentrated in the lower reaches. Upland sites showed extreme improvements for freshes. Severn River at Ashford, the Dumaresq River at Bonshaw, Roseneath and Glenarbon and the Macintyre River at Holdfast all showed improvements in fresh flows by 20% or more (average 55%). However, freshes, especially small freshes in the lower reaches were the most impacted. Small fresh impacts doubled for the Macintyre River at Boomi, Terrewah, Kanowna and Goondiwindi under the climate change scenario. Similarly, anabranch flow 2 frequency failures at for the Macintyre at Boomi increased by 100 and 78% under the Stochastic and NARCliM scenarios respectively. Bankfull flow impacts where they occurred were also very concentrated in the lower reaches. Sites on the Macintyre River at Boomi and Terrewah averaged about a 63% impact, whereas upland sites recorded essentially no change.

Overbank flows were, however, more impacted in the upper reaches. The number of times overbank 1 events were too far apart for the Severn River Ashford and Macintyre at Holdfast increased by 25 and 59 %, and 10 and 12 % for the Stochastic and NARClim scenarios respectively.

Extreme impacts also occurred at some sites for base flows, but the overall average effect was minor or nil for stochastic and climate change scenarios respectively. Most sites were not significantly impacted above the 3% threshold, apart from Macintyre River at Kanowna and the Boomi weir sites which showed the greatest change with a 37 and 50% increase in baseflows under the Stochastic scenario (from 65 to 89 days, and 42 to 62 per year). While this does not appear to be a large proportional change, these results are likely to be dominated by losses in base flows during low flow sequences.

The concentration of impacts in the lower river sections and the least impact on bankfull flows suggests a flow regime more dominated by operational deliveries in the upper to middle sections of this river system. Such flow regime changes have well documented impacts on the biodiversity of Murray Darling Basin rivers[25]. This would impact the river ecology that is already impacted by reduced and modified flows, and especially in the lower reaches during low flow sequences. As examples and given the stated intent of the impacted environmental metrics (Table 1, [26]), it is likely it would reduce the replenishment of riparian and wetland plant communities, lead to increased fish mortality due to refugia drying up and impact the recruitment of waterbirds reliant on anabranch flows.

Table 4. Modelled ecological change (average (minimum to maximum)) by impact category under Option 44 Convert all general security licences to high security licences. *

	Stochastic	NARCliM
Metric	Average (Min-Max)	
No Flows (frequency)	extreme impact (extreme improvement - extreme impact)	extreme impact (extreme improvement - extreme impact)

[25] Mallen-Cooper, M & Zampatti, B. (2018). History, hydrology and hydraulics: Rethinking the ecological management of large rivers. *Ecohydrology*, 11(5), e1965 (https://onlinelibrary.wiley.com/doi/pdf/10.1002/eco.1965).

[26] From DPIE (2018). Border Rivers Long Term Water Plan. Parts A and B. NSW Department of Planning, Industry and Environment (https://www.mdba.gov.au/sites/default/files/pubs/draft-nsw-border-rivers-long-term-watering-plan-part-a-and-b-for-exhibition.pdf).

No Flows (duration)	major impact (moderate improvement - extreme impact)	moderate impact (minor improvement - extreme impact)
Very Low Flows	minor impact (moderate improvement - extreme impact)	minor impact (minor improvement - extreme impact)
Base Flows	minor impact (moderate improvement - extreme impact)	no effect (moderate improvement - extreme impact)
Small Freshes	extreme impact (extreme improvement - extreme impact)	extreme impact (extreme improvement - extreme impact)
Large Freshes	extreme impact (extreme improvement - extreme impact)	extreme impact (extreme improvement - extreme impact)
Bankfull Flows	no effect (minor improvement - moderate impact)	no effect (minor improvement - minor impact)
Overbank Flows 1	no effect (minor improvement - major impact)	minor impact (no effect - extreme impact)
Overbank Flows 2	minor improvement (minor improvement - minor improvement)	no effect (no effect - no effect)
Anabranch Flows 1	no effect (no effect - minor impact)	no effect (no effect - minor impact)
Anabranch Flows 2	major impact (minor improvement - extreme impact)	major impact (no effect - extreme impact)

*Notes: (i) The ecological effect is calculated as the percentage change against the base case for long term variability (Stochastic) and future climate change (NARCliM) scenarios; (ii) All results are from averaged effects over time for each site, so the ranges represent the range of time-averaged values across sites, not the entire variability represented over time at the site or regional level and (iii) The changes within little impact to little improvement correspond to changes at or less than 3% and are not considered significant. Changes greater than 3 up to 10, 10 to 20, 20 to 30, and greater than 30% are categorised as minor, moderate, major and extreme respectively.

Increase the reserve across Glenlyon and Pindari Dams (Option 30)

Option description

At the start of each water year the Department of Planning and Environment assesses the water available in Glenlyon Dam and Pindari Dam plus likely inflows and determines how much water needs to be set aside for essential needs and how much can be allocated to water licences. After essential environmental flow requirements, the first allocation is water for towns, domestic and stock and high security licences for the current year, then an allocation is set aside for these for the next year. Only after this essential requirement is provided can water be allocated to general security licences.

The allocation set aside for next year for high priority purposes is called the reserve. It includes water for the high priority purposes plus an amount for delivery of that water down the river. Normally one year's reserve is provided but it can be longer. It is designed to provide the water for the high priority purposes through the worst drought in a 120-year historic record but is insufficient for more extreme events that could occur in future.

Currently, we set aside 41 GL of water in the storages to support essential needs. The reserve is fixed and is based on the lowest recorded 18-month inflow (December 1979 to May 1981) when the water sharing plan was made in 2009, and average delivery losses. The most recent drought was worse than this and our new climate modelling suggests we could have longer and more severe droughts than we have experienced in the historical record

Under this option 30, the reserve is increased by adding an additional years supply (62.2 GL to provide a 2-year essential needs reserve). This increased reserve would have been enough to continue supplying Mungindi and Boggabilla through the recent drought.

Summary of results

- Freshes were the most impacted environmental flow requirement and were especially impacted in upland sites, and, within this, most consistently impacted at the Dumaresq River at Roseneath
- No flow periods were also impacted in some sites, especially along the Macintyre River.
- With both these types of metric the changes were off a low base, but, given the risk assessment has already identified these flow classes as impacted, and the underlying time series data could reveal greater episodic impacts, these would require further investigation if this option was to progress.

Interpretation of results, and comparison with the rapid assessment

Increasing the reserve across Glenlyon Dam and Pindari Dam mostly affected freshes, with all-site effects averaging at no effect to minor effect, and mostly impacting freshes in the upland sites. The Noting again that the surface water risk assessment found that freshes are already impacted in this system. The most consistently impacted site was the Dumaresq River at Roseneath with an average across fresh classes of 54

and 15 % impacts under the Stochastic and NARCliM scenarios. This showed a 67 % increase in the number of over-extended periods between large freshes (LF2); off a base of about 3 events every 200 years.

There were some changes in the regularity of no periods in both directions, which could be significance for specific flow sequences, but the time-averaged changes do not suggest ecologically significant changes. For example, the Macintyre River at Holdfast had 57 and 13%, and the Macintyre River at Terrewa had 100 and 52% fewer no flow periods under the Stochastic and NARCliM scenarios. There were also some extreme impacts on no flow periods, and especially for the Dumaresq River at Bonshaw. However, all these impacts and improvements on no flows all tended to come off a low base condition. In the case of Dumaresq River at Bonshaw this base equated to about 6 no flow events every 10,000 years.

Table 5. Modelled ecological change (average (minimum to maximum)) by impact category under Option 30, Increase the reserve across Glenlyon Dam and Pindari Dam to 62.2 GL. *

	Stochastic	NARCliM
Metric	Average (Min-Max)	
No Flows (frequency)	minor improvement (extreme improvement - extreme impact)	minor improvement (extreme improvement - moderate impact)
No Flows (dur)	minor improvement (extreme improvement - minor impact)	no effect (moderate improvement - major impact)
Very Low Flows	no effect (minor improvement - no effect)	no effect (minor improvement - no effect)
Base Flows	no effect (no effect - no effect)	no effect (no effect - no effect)
Small Freshes	minor impact (extreme improvement - extreme impact)	no effect (major improvement - major impact)
Large Freshes	no effect (moderate improvement - extreme impact)	minor impact (minor improvement - extreme impact)
Bankfull Flows	No effect	no effect (no effect - no effect)
Overbank Flows 1	no effect (no effect - no effect)	no effect (no effect – minor impact)
Overbank Flows 2	no effect (no effect - no effect)	no effect (no effect - no effect)
Anabranch Flows 1	no effect (no effect - no effect)	no effect (no effect - no effect)
Anabranch Flows 2	no effect (no effect - no effect)	no effect (no effect – moderate impact)

*Notes: (i) The ecological effect is calculated as the percentage change against the base case for long term variability (Stochastic) and future climate change (NARCliM) scenarios; (ii) All results are from averaged effects over time for each site, so the ranges represent the range of time-averaged values across sites, not the entire variability represented over time at the site or regional level and (iii) The changes within little impact to little improvement correspond to changes at or less than 3% and are not considered significant. Changes greater than 3 up to 10, 10 to 20, 20 to 30, and greater than 30% are categorised as minor, moderate, major and extreme respectively.

How these results can inform Regional Water Strategy implementation

The detailed ecohydrology results and the rapid assessment results provide important and complementary information that inform the future implementation of the regional water strategy. Five challenges were identified as immediate priorities were identified in the final Border Rivers Regional Water Strategy[27]:

1. Increased surface water security risks for towns in the region
2. Risk of reduced water availability will impact the regional economy
3. Addressing barriers to Aboriginal water rights
4. Sustaining the health and resilience of aquatic and floodplain ecosystems
5. Improving connectivity to support downstream needs.

Meeting all these aims requires implementing options that benefit the environment as well as towns, agriculture and basic landholder rights.

The options that were submitted for ecohydrological analysis were designed to help meet the aims under options 1 and/or 2. If these options are implemented, they pose further challenges for achieving the priorities 3 and 5 (Table 6), and especially if they are implemented in isolation from more environmentally beneficial options identified by subject-matter experts (Table 7). Meeting challenges 4 and 5 would also underpin the aims for Aboriginal water rights described in the Regional Water Strategy, as access to natural waterbodies and decision-making in water management can only be ultimately fruitful if those waterbodies remain healthy.

These Regional Water Strategy challenges are also captured within the immediate priorities developed for the Border River Regional Water Strategy Implementation plan:

1. Supporting critical human and environmental needs before we go into the next drought, including:
    a. identifying, and acting on where new bores are required,
    b. providing operational clarity for the protection of critical environmental needs
    c. defining and codifying the operational triggers needed to provide system connectivity
2. Improving flows across floodplains, including
    a. Implementing the NSW Harvesting Policy
    b. Remediating unapproved floodplain structures
    c. Improving our ability to accurately modelling return flows from floodplains.
3. Implementing foundational work to do more with less water, including:

[27] DPE (2022). Regional Water Strategy. Border Rivers. Department of Planning and Environment. November 2022. (https://water.dpie.nsw.gov.au/__data/assets/pdf_file/0005/544235/final-border-rivers-regional-water-strategy.pdf)

a. Fast tracking regulatory frameworks for town stormwater harvesting

b. Finalising the climate vulnerability assessment for crops

c. Establishing enduring frameworks to ensure local Aboriginal people have a say in in water management and in the delivery of place-based cultural outcomes

Table 6. Summary of the ecological effects of Border River options submitted for ecohydrological analysis

Option	Summary of ecohydrological analysis	Assessment of effect in the rapid ecological assessment (Appendix A)
Option 44. Convert all general security licences to high security licences	Many extreme impacts, especially more no-flow periods, and fewer freshes in the lowland sections - Macintyre River sites Boomi, Terrewah, Kanowna and Goondiwindi. This would increase mortality of in-stream flora and fauna, reduce fish recruitment, and reduce the frequency of important processes that enable river productivity (such as flushing carbon sources off benches). Major impacts on some anabranch flows, especially at Boomi which would also impact waterbirds.	Could mean more water is being diverted to the upper catchment, reducing flows to lowlands. Need to ensure that it does not reduce Planned and Held Environmental Water availability. Potentially very significant impacts as General Security is allocated every two years, whereas High Security is annual (Option 31 in Table 8, which was originally framed much more generally as "Investigation of licence conversions").
Option 30. Increase the reserve across Glenlyon Dam and Pindari Dam to 62.2 GL	Freshes were the most impacted environmental flow requirement and were especially impacted in upland sites, and, within this, most consistently impacted at the Dumaresq River at Roseneath No flow periods were also impacted in some sites, especially along the Macintyre River.	If the new rules entail restricting flows to long sections of river when there is a real need to provide occasional flows to sustain refuge pools, then there will be severe impacts on threatened species and ecological communities. Need to maintain enough flow to sustain drought refugia and maintain ecological and geomorphic function through progressive drought stages. (In response to the original option 29 "New drought operational rules", which included "Improve water delivery and maintain effective reserves for high priority needs (regional towns, basic landholder rights and environment) during extreme events").

There are numerous options could help mitigate ecological impacts and would benefits challenges 3 and 5. In particular, options 10 and 23 in Table 7 would all help deliver "water to the end of the river system and connected valleys". All the options in Table 7 would improve "the health and resilience of aquatic and floodplain ecosystems".

Table 7. Options that, if implemented, are most likely to have the ecological benefits according to agency subject-matter experts.

Option	Short description[28]	Summary of comments subject-matter expert commentary
Option 10. NSW Fish Passage Strategy commentary	Ten priority weirs are proposed for remediation to facilitate fish access to an additional 660 km of the Macintyre and Dumaresq Rivers along the NSW-Queensland Border. Locations proposed are Macintyre blockbank A and Macintyre blockbank B; Boomi Weir; Goondiwindi Weir; Boggabilla Weir; Toomelah Weir; Glenarbon Weir; Cunningham Weir; Bonshaw Weir; Holdfast Crossing.	Improvements to longitudinal connectivity needed to allow breeding migrations and enable fish to escape to drought refuges. Benefits will only be realised if connectivity is not otherwise impacted by new infrastructure.
Option 11. Diversion screens to prevent fish extraction at pump offtakes	Install screens on major irrigation pumps and diversion channels to reduce the number of fish being extracted at pump sites. Is targeted at about 220 pump offtakes with a diameter greater than 200 mm in the Border Rivers system.	Should result in significant reduction in juvenile native fish mortality. This also has a significant benefit for irrigators with decreased maintenance requirements and increase efficiency.
Option 12. Cold water pollution mitigation measures	Cold water pollution from Pindari Dam affects over 100 km of the Severn and Macintyre Rivers. Although Pindari Dam has a variable level offtake to assist in mitigating cold-water pollution, the potential presence of toxic surface algae often prevents the positioning the variable level offtake so it can take warmer surface water. This option involves upgrading existing infrastructure, and operations to remove this limitation.	Depression of downstream water temperatures during Pindari Dam releases is a critical issue for fish in the Severn River. Operating protocols for Pindari Dam need to be improved. Need to prevent sudden, large drops in water temperature during releases. Potential for major improvements to river below Pindari dam.
Option 23. Improve connectivity with downstream systems	Improving connectivity to the Barwon-Darling River was a recommendation of: • the Independent Assessment of the 2018/19 Fish Deaths in the Lower Darling (Vertessy Report), • the Natural Resources Commission's review of the Barwon–Darling Water Sharing Plan and • the Independent Panel Assessment of the Management of the 2020 Northern Basin First Flush Event. Improving connectivity could be established by:	This is essential as it is currently very difficult to recommend end-of-system flows (EOSF) to ensure connectivity with lower sections of the Barwon-Darling because this depends on inflows from other major tributaries plus and the river channel being wet. Rules to meet EOSF will need to include modelling so that Border River's make a fair

[28] For more detail see DPIE (2020). Draft Regional Water Strategy. Border River: Long list of options. October 2020. NSW Department of Planning, Industry and Environment (www.dpie.nsw.gov.au/__data/assets/pdf_file/0020/327800/draft-br-options.pdf).

	• establishing additional end of system flow targets • implementing flow plan targets for unregulated water sources • using environmental water to achieve connectivity objectives using temporary water restrictions more frequently to achieve connectivity objectives • working with Queensland to enable more water to flow into NSW • reviewing water sharing rules in the northern tributary valleys to enable greater connectivity with downstream catchments.	contribution to aid downstream very low flows, base flows and freshes.
Option 24. Protecting ecosystems that depend on groundwater resources	Groundwater dependent ecosystems are classified broadly as terrestrial (vegetation communities), aquatic (wetlands and springs) or subterranean (aquifers and caves). These ecosystems support a variety of fauna and fora communities. During droughts when groundwater is needed to support communities, it is critical that groundwater dependent vegetation is also maintained. In this option, a series of projects would be initiated to advance our knowledge and management of groundwater dependent ecosystems	GDEs are still poorly understood and appreciated and so the proposed projects have the potential to better manage GDEs. GDEs may be under serious risk from falling groundwater levels because of severe drought & climate change. Need to consider stygofauna as part of this.

Appendix A. Rapid ecological assessment: key agency points

The rapid environmental assessment (Table 8) involved a high-level assessment of the environmental impact or improvement of each of the options in the long list of the draft Regional Water Strategy. The assessment was based on expert opinion of scientists from Department of Planning and Environment (DPE) Water – Water Science, DPE - Environmental and Heritage Group and Department of Regional NSW – DPI Fisheries.

The environmental assessment was undertaken separately by each agency and then the assessments are combined for an overall result for each option. In developing their rankings, the scientists were asked to consider how the option might impact:

- geomorphology (bed and bank erosion and sediment transport)
- floodplain and riparian vegetation
- wetland ecology
- fish breeding, recruitment and movement
- water quality (temperature, dissolved oxygen, nutrients, refuge pool conditions) river hydraulics (availability of flowing water and other diverse habitats)
- food web impacts (e.g., inputs of nutrients from overland and tributary flows, quality of water release from dams and weirs)
- availability of held environmental water and potential impacts on planned environmental water

The purpose of this was to assess whether the options that aimed to improve outcomes for the environment should proceed to the next stage. This assessment did not rule out options that were aimed at improving outcomes for towns or industries.

The ranking system the agencies were asked to apply were the stage 1 categories in Table 3.

A summary of the rapid ecological assessment outcomes can be found in Border Rivers: Shortlisted Actions – Consultation Paper[29]. A summary of the commentary by the agencies which informs how they came to score the options is provided in

Table 8 below.

Table 8. Rapid ecological assessment – agencies scores with key points made in their commentary against the options

[29] DPE (2022a). Border Rivers: Shortlisted Actions – Consultation Paper. Department of Planning and Environment, June 2022. (https://www.dpie.nsw.gov.au/__data/assets/pdf_file/0005/514085/short-list-actions.pdf)

Option Number	Option Name	Consensus from agency subject-matter experts	
Government commitment 1	Final business case for building a new dam on the Mole River	Major / Extreme impact	Will have major and extensive impacts on upstream ecology along with downstream connected communities and catchments, including undermining system scale connectivity, native fish species and Endangered Ecological Communities. Would expect less complex flow variability and detrimental impacts on aquatic biota. Likely to impact the Mole and Dumaresq Rivers that are core areas for endangered fish species.
Option 2	Raising Pindari Dam's full supply level	Minor / Moderate impact	Predicted to have major impacts on multiple aspects of catchment ecology and on connected catchments, in a system where current environmental water deliveries do not currently meet environmental requirement. Expect loss in flow variability (timing, magnitude), over-extended duration of some riparian zones in some locations but general reduction in flushing flows. Also expect extended periods of low/no flows downstream, reducing pool maintenance

Option Number	Option Name	Consensus from agency subject-matter experts	
Option 3	Raising Mungindi Weir	Major / Extreme impact	Will impound a much longer length of river, causing major alteration to instream environment by converting from a flowing river (lotic) to a still water body (lentic) impacting river mussels (*Alathyria jacksoni*), fish and other organisms. Toxic algae blooms will become more common and raised water levels are likely to kill many kilometres of riparian river red gums. There will be loss of longitudinal connectivity that disrupts fish movements and the critical transfer of energy and organisms along the river.
Option 4	Piping water to stock and domestic water users in the unregulated section of Boomi River	Minor / Moderate impact	More likely a 'moderate impact', assuming that none of the water savings will be returned to the Boomi River, but if these flows are returned it could result in a moderate benefit. In this worse scenario, could cause more no flows periods and impact end-of-system and riparian flows.
Option 5	Improve cross-border management of flows at major breakout points	Minor / Moderate impact	There are environmental benefits of water spilling into these anabranches and streams and so, while regulating these flows to keep them within major channels may be efficient for agriculture, this is unlikely to benefit river ecology. However, there could be some improvement in fish passage. Final effect would depend on scope and location of works and operations.

Option Number	Option Name	Consensus from agency subject-matter experts	
Option 6	Reliable access to groundwater by towns	Average at Minor / Moderate impact (slight trend)	Impacts are relative to the degree of extraction and connectivity with surface water systems. BR alluvium is considered a highly connected groundwater resource unit. BR alluvial supports significant GDEs of ecological value including EECs, threatened species, vegetation, and base flow ecosystems along extensive connected riparian corridors. Groundwater development impacts on stygofauna is a major knowledge gap.
Option 7	Intra- and inter-regional connections project investigation	Minor / Moderate impact	*Inter*-regional transfers will reduce available water to river ecosystems, especially during droughts when the ecosystems are stressed. *Intra*-regional transfers are likely to have a smaller environmental impact but alternative water sources for those towns during drought (e.g., groundwater stores) would reduce the need for these transfers and lessen the loss of water from natural ecosystems. If linked to development of dams or raising weirs then should be included for analysis in scope of those projects, as that would have a greater ecological impact.
Option 8	Inland diversions from the east	Major / Extreme impact	There is a serious risk of severely impacting on coastal and estuarine health with inter-basin transfers of biota. Inter-basin transfers could also detrimentally impact closely related organisms through genetic mixing, such as for eastern freshwater cod and Murray cod.

Option Number	Option Name	Consensus from agency subject-matter experts	
Option 9	Managing groundwater salinity	Minor / Moderate improvement	No commentary
Option 10	NSW Fish Passage Strategy	Major / Extreme improvement	Improvements to longitudinal connectivity needed to allow breeding migrations and enable fish to escape to drought refuges. Benefits will only be realised if connectivity is not otherwise impacted by new infrastructure.
Option 11	Diversion screens to prevent fish extraction at pump offtakes	Major / Extreme improvement	Should result in significant reduction in juvenile native fish mortality. This also has a significant benefit for irrigators with decreased maintenance requirements and increase efficiency.
Option 12	Cold water pollution mitigation measures	Major / Extreme improvement	Depression of downstream water temperatures during Pindari Dam releases is a critical issue for fish in the Severn River. Operating protocols for Pindari Dam need to be improved. Need to prevent sudden, large drops in water temperature during releases. Potential for major improvements to river below Pindari dam.
Option 13	Investigation of surface water quality mitigation measures	Minor / Moderate improvement	Benefits depend on scale and longevity of investment, especially given water quality allowances are harder to deliver when water is scarce. Need a review of where real-time data loggers are needed, and to act on this. Real-time data access required. Need delivery in partnership with agencies, with data sharing and access arrangements, roles, and clear responsibilities and resourcing.

Option Number	Option Name	Consensus from agency subject-matter experts	
Option 14	Implement state-wide groundwater quality monitoring program and management program	Average at Minor / Moderate improvement (slight trend).	Generally welcome but need further detail. Unlikely to have a big impact in the Border Rivers region. Stygofauna studies required as this is a knowledge gap. Models that link surface and groundwater systems are also needed.
Option 15	Modification and/or removal of existing priority flood work structures causing adverse impacts	Minor / Moderate improvement	This should only apply to existing licensed flood works and not works that have existing rehabilitation orders or are unlicensed.
Option 16	Providing incentives to landholders to conserve and rehabilitate riparian, wetland, and floodplain vegetation	Minor / Moderate improvement	Benefits will accrue over time. Strategic prioritisation of sites against ecological criteria to create ecological outcomes should be the basis of the decision making and prioritisation framework. Support delivery via agency partnership.
Option 17	Riparian habitat restoration and re-establishing threatened species	Minor / Moderate improvement	Has the potential to produce major improvements to the river (trophic inputs, shading, filtering of fine sediment and pollutants) on a large scale, but if applied at small scales then benefits will be negligible.
Option 18	Investigate land use change impacts on water resources	Minor / Moderate improvement	Needs to be combined as a package with options 11, 12 and 13. Suggest scope needs to include assessment of growth, and shifts to different types of agriculture (e.g., if there is a shift to permanent plantings this will have impacts on AWD and licensing).

Option Number	Option Name	Consensus from agency subject-matter experts	
Option 19	Revise water sharing plan provisions for planned environmental water	Minor / Moderate improvement	This should result in increased flexibility for use and the capability to deliver in extreme events such as blackwater events and droughts.
Option 20	Improve benefits of planned environmental water	Average at Minor / Moderate improvement (slight trend)	Should support refuge pools and riparian function under increasing drought conditions, and not just calculate minimum environmental flow needs. Need clarification of how this will be linked to policy such as resumption of flow rules and channel-sharing arrangements.
Option 21	Active management to protect water for the environment in unregulated rivers	Minor / Moderate improvement	There is very little registered entitlement in the Border Rivers
Option 22	Improve understanding of water use in unregulated water sources	Minor / Moderate improvement	Modelling the groundwater take effects on unregulated streams and aquifers is needed. Extraction could dry out residual pools and waterholes and is linked to options 16 & 17. Improves capacity to make decisions about rules for unregulated WSP.
Option 23	Improve connectivity with downstream systems	Major / Extreme improvement	This is essential as it is currently very difficult to recommend end-of-system flows (EOSF) to ensure connectivity with lower sections of the Barwon-Darling because this depends on inflows from other major tributaries plus and the river channel being wet. Rules to meet EOSF will need to include modelling so that Border River's make a fair contribution to aid downstream very low flows, base flows and freshes.

Option Number	Option Name	Consensus from agency subject-matter experts	
Option 24	Protecting ecosystems that depend on groundwater resources	Major / Extreme improvement	GDEs are still poorly understood and appreciated and so the proposed projects have the potential to better manage GDEs. GDEs may be under serious risk from falling groundwater levels because of severe drought & climate change. Need to consider stygofauna as part of this.
Option 25	Review of water markets in the Border Rivers region	Slight trend towards Major/ Extreme impact.	Would potentially have a major impact on environmental outcomes. Consultation with environmental water holders and environmental agencies required.
Option 26	Reuse, recycle and stormwater projects	No/little change	Could take pressure off river ecosystem during droughts, but also need to account for loss of return flows through modelling.
Option 27	Water efficiency projects (towns and industries)	Slight trend towards minor improvement.	Could take pressure off river ecosystem during droughts, but unlikely to have a large effect. Savings unlikely to be significant for the environment if uptake is ad hoc, voluntary, and small scale.
Option 28	Review urban water restrictions policy	Slight trend towards minor improvement.	May have minor positive outcomes for RWS environmental objective (if for example savings relieve pressure on PEW in early stages of drought). Needs to align with policy review s49A and 49B, s60 WMA, development of Extreme Events Policy, definition of Critical Needs and links to operational rules. May have value for Town Water Supply for the same water source.

Option Number	Option Name	Consensus from agency subject-matter experts	
Option 29	New drought operational rules	Major / Extreme impact	If the new rules entail restricting flows to long sections of river when there is a real need to provide occasional flows to sustain refuge pools there will be severe impacts on threatened species and ecological communities. Need to maintain enough flow to sustain drought refugia and maintain ecological and geomorphic function through progressive drought stages.
Option 30	Review of regulated river water accounting and allocation process	Slight trend towards Minor/ moderate improvement.	Impact uncertain, but potentially very significant as General Security (GS) is allocated every 2 years, High Security (HS) is annual. It could reduce the reliability of held and planned environmental water (HEW and PEW). Could mean more water being diverted to upper catchment, reducing flows to lowlands.
Option 31	Investigation of licence conversions	Major / Extreme impact	Could mean more water is being diverted to the upper catchment, reducing flows to lowlands. Need to ensure that it does not reduce PEW and HEW availability. Potentially very significant impacts as GS is allocated every two years, HS is annual.

Option Number	Option Name	Consensus from agency subject-matter experts	
Option 32	Improved data collection	Minor / Moderate improvement	Good to improve planning, coordination and funding of water quality and ecological monitoring and evaluation across the State. If strategic, led by a single agency and improves the information used in key decision-making frameworks may produce environmental benefits. Needs to incorporate funding, governance, ensure suitable platforms for storing data, and real-time data access. Overlaps with Option 13.
Option 33	Training and information sharing program	No/little change	No commentary
Option 34	Investigation to maintain amenity for regional towns during drought	Slight trend for No/little change.	Unclear what the details of this option would be but should consider options such as reducing water demand and reuse of wastewater.
Option 35	Sustainable access to groundwater	Minor / Moderate improvement	Should provide greater protection of groundwater dependent ecosystems. Recommend developing additional modelling capacity to link surface and groundwater models. Management would need to focus on recovery of aquifers already overallocated.
Option 36	Improved clarity in managing groundwater resources sustainably	Minor / Moderate improvement	Overlap with Option 35 and 37. Suggest these options are precursors to other groundwater related proposals.

Option Number	Option Name	Consensus from agency subject-matter experts	
Option 37	Improved understanding of groundwater processes	Minor / Moderate improvement	Recommend Options 36 and 37 are combined as a package and treated as precursors to proposals related to further development of groundwater resources. Recommend additional modelling capability is developed to support improved understanding and that capability includes development of linked surface and groundwater models.
Option 38	Extending the Cap and Pipe the Bores Program	Slight trend towards minor improvement.	No commentary
Option 39	Maintaining the Great Artesian Basin for the future	Slight trend towards minor improvement.	Given that Basic Landholder Right bores are the more abundant type of bores then reasonable use guidelines pose a risk, because they are subjective and so interpretations vary. Greater benefits may be gained by development of volumetric based thresholds supported by metering and monitoring of bores. Alignment between the Great Artesian Basin Strategic Management Plan and NSW Groundwater Action Plan is needed. There will be likely be more future pressure on groundwater resources, so these issues need to be managed.
Option 40	Support reforms to simplify and strengthen cross-border groundwater management	Slight trend towards Minor /moderate improvement.	More information is required. For example, how would the current Queensland and NSW arrangements be reconciled, including a different approach to rolling averages?

Option Number	Option Name	Consensus from agency subject-matter experts	
Option 41	Improve knowledge of fractured rock groundwater sources in the upper catchment	Slight tends towards Minor/ moderate impact.	Potential to impact on upland streams that are fed from springs and other groundwater features. Could have a large impact on the threatened southern purple spotted gudgeon and other important species that depend on these upland systems.
Option 42	Culturally appropriate water knowledge program	No/little change	No commentary
Option 43	Water-dependent cultural practices and site identification project	No/little change	No commentary
Option 44	Secure flows for water-dependent cultural sites	Minor / Moderate improvement	This should increase opportunities to protect the Boobera Lagoon ecosystem, but clarification of 'secure' is required (continual or seasonal?). Potential for minor improvements if delivery of water to site supports ecological co-benefits (e.g., drought refuges during prolonged dry spells). Further detail needed (e.g., on planned timing & volume of flows).
Option 45	Shared benefit project (environment and cultural outcomes)	Minor / Moderate improvement	Has potential and requires coordination with environmental water holders / agencies. Potential minor/moderate improvement if water is made available for cultural outcomes in addition to environmental water allowances.
Option 46	Establish a regional Aboriginal Water Advisory Committee	Slight trend towards minor improvement.	No commentary

Option Number	Option Name	Consensus from agency subject-matter experts	
Option 47	Water allocations for Aboriginal communities	Slight trend towards No/little change.	Need to develop with consideration of current legislation, including the Fisheries Management Act 1994.
Option 48	Aboriginal cultural water access licence review	Slight trend towards No/little change.	There are existing cultural water provisions. Improving Aboriginal access rights to water, allocations and management of that water requires active Aboriginal water management in each valley to support meaningful outcomes.
Option 49	Co-management investigation of Travelling Stock Reserves	Slight trend towards Minor/moderate improvement.	Proposed environmental outcomes for river /wetland management are unclear.
Option 50	Regional Cultural Water Officer Employment Program	Slight trend towards No/little change.	Suggest this could see minor improvement but would be dependent on how well aligned with other activities it is. Recommend careful design with targeted on-ground works being supported and complemented by environmental watering.
Option 51	River Ranger Program	Slight trend towards Minor/moderate improvement	No commentary
New opt 52	Water security for discrete communities	All agencies stating that there is insufficient information.	Would need to investigate the interaction of option with existing water sharing arrangements to determine environmental implications from new practices (both direct and indirect)
New opt 53	New option: New and improved farming practices	All agencies stating that there is insufficient information.	Would need to investigate the interaction of option with existing water sharing arrangements to determine environmental implications from new practices (both direct and indirect)

Option Number	Option Name	Consensus from agency subject-matter experts	
New opt 54	New option: Water use efficiency for non-town-based industries	All agencies stating that there is insufficient information.	Would need to investigate the interaction of option with existing water sharing arrangements to determine environmental implications from new practices (both direct and indirect)