
Appendix G

Hydrology assessment

Billabong Creek Regulators Hydrology Assessment

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NSW Department of Climate Change, Energy, the Environment
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Billabong Creek EIS



Billabong Creek Regulators Hydrology Assessment

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Executive Summary

Introduction

NSW Department of Climate Change, Energy, the Environment and Water (NSW DCCEEW) is proposing to replace two existing weirs along Billabong Creek with new regulators (the proposal). The two existing weirs to be replaced are Hartwood Weir and Wanganella Weir. The proposal is located within the Yanco Creek System which forms a part of the Murray-Darling Basin in south-west New South Wales (NSW). The proposal is one part of the broader Yanco Creek Modernisation Project (YCMP) which aims to allow water to be delivered more efficiently within the Yanco Creek system, minimising water losses. The YCMP in turn is part of the Sustainable Diversion Limit Adjustment Mechanism (SDLAM) acceleration program designed to achieve similar or improved environmental outcomes for rivers, wetlands and wildlife using less water.

The new regulators, referred to as Hartwood regulator and Wanganella regulator throughout this report, would be fully automated and remotely operated, are intended to allow for the regulation of flows in the lower sections of Billabong and Forest Creeks, providing river operators with greater operational flexibility to deliver the right amount of water to the right place at the right time. This increased operational flexibility is intended to increase the river operators' ability to deliver water orders including orders for environmental water. In addition, this increased level of flow control is intended to result in the reduction of unplanned end of system flows in Billabong Creek at Darlot, because it is intended that the regulators will hold back this unplanned water to meet consumptive (irrigation, stock and town water supply) and environmental water requirements.

Overall, it is intended that the new regulators will facilitate smarter use of water within the Yanco Creek system by enabling the reduction of unplanned surpluses and shortfalls. As a result, this means that the current levels of service for environmental and water supply demands could be maintained or improved. The new regulators would also feature fishways to support fish movement past the new structures.

This hydrology assessment has been prepared to support the Environmental Impact Statement and in particular to address the Secretary's Environmental Assessment Requirements (SEARs) pertaining to hydrological impacts.

Background

The Yanco Creek System links two of Australia's largest rivers - the Murrumbidgee and Murray - through over 800 km of interconnected waterways, including Yanco Creek, Colombo Creek, Billabong Creek, and Forest Creek. Prior to European settlement, Yanco Creek was a high-level gaining creek (i.e. receives groundwater). Under current conditions, flows within the Yanco Creek System are highly variable at all locations and there is an absence of near no-flow years, resulting in a more consistently flowing system than under pre-development conditions.

The hydrology of the Yanco Creek System, including the proposal study area, is highly altered from pre-development, with a loss or considerable alteration of key hydrological flow components and processes. As such the Yanco Creek System is characterised as being highly flow modified, which is consistent with previous historical analysis of the hydrology. Flow within the Yanco system is regulated at key locations to manage water delivery. Weirs regulate the share of water between Colombo Creek and Yanco Creek (Tarabah Weir) and between Forest Creek and Billabong Creek (Hartwood Weir and Forest Creek Regulator). In addition, there are over 30 private licenced fixed crest weirs that were constructed to provide a local store of water. As a result of regulation, flows through the Yanco Creek System are maintained at artificially high levels during high demand periods and as such the total annual flow volume is much higher than pre-development.

The current hydrology of Mid Billabong Creek from Jerilderie to downstream of Hartwood Weir (where Lower Yanco Creek joins Billabong Creek) and Lower Billabong Creek and intersecting streams from downstream of

Hartwood Weir to Moulamein (inclusive of Wanganella and Darlot) varies widely depending on rainfall, inflows, evaporation and demands including irrigation, industry, communities and the environment.

Methods

Hydrological modelling

An eWater Source model was developed by NSW DCCEEW for the Murrumbidgee River downstream of Burrinjuck and Blowering Dams to Balranald Weir. This Source model is the best available estimate of how this complex system interacts and behaves under a range of different scenarios. The Base Murrumbidgee Source Model has been calibrated based on available data and can be run so that different scenarios can be analysed over a long climatic period (i.e. 1895 to 2020).

The modelled Base Case scenario is comparable to current hydrological conditions and is representative of existing weirs and other structures, flow constraints, environmental baseflow provisions, environmental flow provisions and irrigation escape flows current conditions.

The modelled Change Case scenario is representative of the predicted changes to hydrological conditions with operation of the regulators (i.e. the proposal) and other broader system changes specified in the Yanco Creek System Operations Plan (NSW DCCEEW 2023b). The Change Case scenario model includes the Hartwood and Wanganella regulators (and applicable operating principles, targets and water ordering rules) as well as other operational changes as detailed in the Yanco Creek System Operations Plan (including new no order flow limits for the irrigation escapes and new environmental baseflow provisions).

The modelled Cumulative Change Case scenario is consistent with the Change Case scenario model, but with the inclusion of applicable components of the Forest Creek Return Flows Project.

Environmental Water Requirement (EWR) assessment

The Environmental Water Requirement assessment code (EWR Tool) is a computer code in Python that assesses the occurrence of flow conditions that meet or partially meet the Long-Term Water Plan (LTWP) EWRs in observed or modelled flow time series. It was originally developed in Python by the Murray–Darling Basin Authority (MDBA) and further refined with input from the NSW DCCEEW's Biodiversity, Conservation and Science Group, who were responsible for the development of the LTWPs and their EWRs for New South Wales. Version 0.0.5 of the EWR Tool was used to compare EWR achievement between the Base Case, Change Case and Cumulative Change Case scenarios.

The EWR Tool has been specifically developed to reflect detailed analysis used in the development of EWRs for NSW LTWPs. However, slight variations have been made to improve the assessment where appropriate. Although this may cause some misalignment of assessment methods, sensitivity testing indicates that this is minor. In addition, there have been several levels of quality assurance, and as such there is a high degree of confidence in the EWRs adopted to inform this hydrological impact assessment of the new regulators.

River Flow Objectives assessment

The River Flow Objectives for Controlled rivers with altered flows (regulated Creeks) are applicable to Billabong Creek below the Colombo Creek confluence (NSW Water Quality and River Flow Objectives: Water Quality Objectives - Murray River (NSW)). An assessment of the river flow impacts of the proposal during operation, to the extent of proposal influence up and down stream, has been undertaken under the Change and Cumulative Case scenarios in comparison to the Base Case scenario.

Key findings

Modelled current hydrological conditions (Base Case scenario)

Under modelled Base Case scenario, the total annual flows throughout the Yanco Creek System are highly variable, primarily associated with unregulated flows through Yanco Offtake and the unregulated upper Billabong Creek catchment passing through the system.

The modelled mean annual water balance results show that under the Base Case scenario flows within the Yanco Creek System are distributed between connected waterways, with some gains and losses in flow between these waterways attributed to consumptive extractions, irrigation escape inflows and evaporation losses. Mean monthly flows display a typical temperate seasonal pattern, with generally higher flows during winter-spring and lower flows during summer-autumn periods, which is generally consistent with pre-developed natural conditions. High variability in averaged daily flow volumes is particularly evident from December to April which is likely in response to modelled irrigation, consumptive and environmental demands during periods of lower flow.

The flow size analysis indicates overbank flows (small and large) occur infrequently under current conditions and that cease-to-flow and very low flows (in Yanco and Colombo Creeks) no longer occur. The relative proportion of large and small freshes and baseflow is not considered to be substantially dissimilar between any of the reaches within the system. Overall, flows downstream of Hartwood Weir are lower than at other locations within mid and lower Billabong Creek, as a result of diversion of flows to Forest Creek through the Forest Creek Offtake. Correspondingly, baseflow occurs across a greater proportion (majority of flows) of modelled flows downstream of Hartwood Weir. In contrast, small freshes occur across a greater proportion of the flow regime at Wanganella and Darlot due to additional flow contribution from Lower Yanco Creek which occurs upstream of Wanganella.

Proposal construction impact assessment

During construction of the Hartwood and Wanganella regulators respectively, the associated existing weirs will remain in place for the majority of the construction timeframe, only being demolished once the new regulator is fully installed and will therefore continue to have a similar influence on hydrology during the construction period compared to current conditions. In addition, partial cofferdamming of Billabong Creek within the construction timeframes for each respective regulator construction site will allow for passing flows to meet irrigation and consumptive demands and environmental water provisions.

Therefore, it is considered unlikely that construction of the proposal would have a material adverse effect on the hydrology of Billabong Creek, either upstream or downstream. If there were to be any potential changes in the hydrology of Billabong Creek, either upstream or downstream, it is considered they would be short-term (i.e. within the construction timeframes of the proposal) and would not adversely affect irrigation and consumptive demands and environmental water provisions.

Given the above findings, it is also considered unlikely that construction of the proposal would adversely impact the relevant River Flow Objectives for Controlled rivers with altered flows (regulated Creeks) applicable to the proposal study area (mid and lower Billabong Creek) during the proposal construction period.

Modelled operational impacts with the proposal (Change Case scenario)

The Change Case scenario results indicate minor alterations in mean annual flows within the Yanco Creek System. The typical temperate seasonal pattern of flows is maintained, with minimal impact on mean monthly flow volumes throughout the Yanco Creek System, including the proposal study area (Billabong Creek from Jerilderie to Darlot). The Change Case scenario results indicate the proposal does not substantially impact annual or daily flow volume variability and there are minimal impacts on daily flow sizes. Overall, the hydrological analysis suggests that while operation of the proposal will have some localised (within reach)

effects on hydrology (i.e. water balance, seasonality, flow variability, and flow sizes) the impacts are generally minor and consistent with those expected as a result of implementing the proposal and broader system changes, and do not substantially alter the overall hydrological characteristics of Billabong Creek within the proposal study area or the broader Yanco Billabong System.

The findings of the EWR analysis suggest that there are generally either no change or improvements in achieving EWRs with operation of the proposal (i.e. the Change Case scenario). There is predicted to be improvements in the frequency of achieving baseflows, Native Fish Nesting Support, small freshes and large fresh EWRs throughout the Yanco Creek System, including the proposal study area. Very minor modelled reductions in some very low flow and very high flow EWRs can be attributed to the limitations of the Source model. Therefore it is concluded that operation of the proposal will result in an overall improvement in the frequency of achieving EWRs for a number of EWR categories to support key ecological values of the system.

Compared to existing conditions, the water surface level in the Hartwood Regulator weir pool is predicted to be marginally higher (median 22 mm higher) in the irrigation season and median 3 mm lower in the non-irrigation season. Operation of the Hartwood Regulator to achieve the proposed weir pool target levels will result in surface water levels within the weir pool of the regulator being higher than the median (50th%ile) water surface level of the existing Hartwood weir less frequently (-3.5%). Under the full supply level (FSL) and Maximum Operating Flow scenario, there is an approximate 51,590 m² or 7.7% increase in overall inundation extent compared to existing conditions, but no significant change in upstream longitudinal inundation and a minor increase in downstream weir pool extent due to the proposed regulator being located approximately 70 m downstream of the existing structure.

For the Wanganella Regulator, compared to existing conditions, the water surface level in the Wanganella Regulator weir pool is predicted to be median 65 mm higher in the irrigation season and median 43 mm lower in the non-irrigation season. Operation of the Wanganella Regulator to achieve the proposed weir pool target levels will result in surface water levels within the weir pool of the regulator being higher than the median (50th%ile) water surface level of the existing Wanganella weir +33.5% more frequently. Under the full supply level (FSL) and Maximum Operating Flow scenario, there is an approximate 110,350 m² or 30% increase in overall inundation extent compared to existing conditions, but no significant change in upstream longitudinal inundation and a minor increase in downstream weir pool extent due to the proposed regulator being located approximately 55 m downstream of the existing structure.

Effective General Security Allocations are predicted to increase marginally under the Change Case scenario, compared to Base Case, for opening allocation and summer planning decision dates. A very minor decrease is predicted for end of the year, but this is likely an artifact of the limitations of the Source model. As such, little to no reduction in water availability to meet Water Access Licenses is predicted under the Change Case scenario with operation of the proposal.

Modelled cumulative impacts with the proposal (Cumulative Change Case scenario)

When comparing the Cumulative Change scenario results to the Change Case scenario results, there are only minor differences in the hydrology (i.e. water balance, seasonality, flow variability, and flow sizes) and EWR frequency analyses, except for Forest Creek at Warriston Weir. The reductions for Forest Creek at Warriston Weir can be directly attributed to the Forest Creek Return Flows Project. In addition, the Cumulative Change scenario model indicates no reductions to average Murrumbidgee General Security water availability (General Security Allocations plus carryover) across the water year. Therefore, no reduction in water availability to meet Water Access Licenses is predicted under the Cumulative Change Case scenario. As such, the proposal is not anticipated to negatively impact these key hydrological aspects of the Yanco Creek System, including the proposal study area, when taking into consideration potential cumulative effects associated with the Forest Creek Return Flows Project.

Conclusions

Overall, the hydrological analysis suggests that the operation of the proposal will have some minor localised effects on hydrology (i.e. water balance, seasonality, flow variability, and flow sizes) which are consistent with the aims of the proposal and the broader system changes outlined in the Yanco Systems Operations Plan. As such, the overall hydrological characteristics of Billabong Creek within the proposal study area or the broader Yanco Billabong System will not substantially alter as a result of the proposal. Operation of the proposal will result in an overall improvement in the frequency of achieving EWRs for a number of EWR categories to support key ecological values of the system. The proposal is also not anticipated to negatively impact key hydrological aspects of the Yanco Creek System, including the proposal study area, when taking into consideration potential cumulative effects associated with the Forest Creek Return Flows Project.

Important note about this report

The 3Rivers Joint Venture (3Rivers), a joint venture between Jacobs Group (Australia) Pty Limited and GHD Pty Ltd has been engaged to provide certain Engineering and Approvals Services for the NSW Sustainable Diversion Limit Adjustment Mechanism (SDLAM) program in accordance with the Agreement between 3Rivers and the NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW) (the client).

The sole purpose of this report and the associated services performed by Jacobs is to review the potential environmental effects associated with the construction and operation of the Billabong Creek Regulators in accordance with the scope of services set out in the contract between 3Rivers and the Client. That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Client (if any) and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

This assessment has been prepared in the timeframe and on the basis of the project description prepared by the client and within the limits of the budget approved for the work.

This report has been prepared on behalf of, and for the exclusive use of, the Client, and is subject to, and issued in accordance with, the provisions of the contract between 3Rivers and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

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Glossary

Term	Description
Anabran	A section of a river or stream that diverts from the main channel of the watercourse and rejoins downstream.
Clearing area	This is the area required to construct the proposed infrastructure. Within this area it is assumed that all vegetation would be removed, including trees and ground cover vegetation. Borrow pits also include a clearing area. However this is a conservative assumption and contractors would be encouraged to avoid removal where they can (through proposed mitigation measures).
Commonwealth Environmental Water Holder	The Commonwealth Environmental Water Holder is a statutory position established under the <i>Water Act 2007</i> (Cth) responsible for managing the Commonwealth's environmental water holdings. These water holdings are used to protect or restore environmental assets of the Murray-Darling Basin.
Construction activity zone	The area surrounding and including the 'clearing area' that would be used for construction purposes e.g., laydown, site sheds, parking. It is assumed topsoil will need to be removed / cleared, with some re-grading to create level areas with grubbing and clearing of small shrubs/grasses. Trimming of trees may be required. Tree removal would not occur in portions of the CAZ outside of a clearing area.
Cumulative impacts	The combined impacts of the proposal on a matter with other relevant future projects
Disturbance area	The disturbance area includes all locations where the proposal directly impacts the land surface or water body. This includes clearing areas, construction activity zones, access tracks and power supply routes.
Efficiency measure	Provide more water for the environment by making water delivery systems for irrigation more efficient. This can include replacing or upgrading on-farm irrigation, or lining channels to reduce water losses within an irrigation network
Entitlement	The volume of water authorised to be taken and used by an irrigator or water authority; includes bulk entitlements, environmental entitlements, water rights, sales water and surface-water and groundwater licenses.
Environmental flow	Any river flow pattern provided with the intention of maintaining or improving river health.
Environmental Water Requirement	Describes a set of recommended flow characteristics (flow threshold or volume, duration, timing, frequency, maximum inter-event period) at a certain location (river gauge) to meet a particular set of environmental objectives in a particular river reach and its associated floodplain (referred to as a planning unit in NSW LTWPs). A number of EWRs are defined for each river gauge location covering a range of flow categories including, but not limited to, cease-to-flows, baseflows, small and large freshes and overbank flows.
Fish passage	The ability of fish or other aquatic species to move through an aquatic system.

Term	Description
Fishway	Structures placed on or around constructed barriers (such as dams or weirs) to give fish the opportunity to move past the barrier.
Pre-developed conditions	Conditions without any water regulating infrastructure or demands
The proposal	The construction and operation of the two regulators and supporting infrastructure.
The proposal site	The footprint that would be directly affected by construction and the location of operational infrastructure.
Regulator	A gated structure used to actively manage or control the amount of water that flows from one location to another.
Regulated	A water system in which water is stored or flow levels are controlled through the use of structures such as dams and weirs.
River Flow Objectives	The NSW River Flow Objectives are the agreed high-level goals for surface water flow management. They identify the key elements of the flow regime that protect river health and water quality for ecosystems and human uses. Although RFOs have effectively been superseded by Long Term Watering Plan flow objectives, they still provide some guidance to assess impacts of flow modification in relevant systems
Sustainable diversion limit adjustment mechanism	A mechanism under the Murray-Darling Basin Plan that allows the sustainable diversion limit to be adjusted under certain circumstances.
Study area	The area investigated for this assessment which includes the proposal site and surrounding area, with the potential to be directly or indirectly affected by the proposal.
Weir	A low barrier or dam that is built across a watercourse and is designed to store water, control or alter the flow of water in a creek

Abbreviations

Abbreviations	Definitions
AHD	Australian height datum
AWD	The volume of water licensed users can have, known as an allocation or available water determination (AWD), varies from year to year based on the licence category and size of their individual entitlement. This allocation is dependent on a range of factors including dam storage levels, river flows and catchment conditions.
CCD	Coleambally Catchment Drain Irrigation Escape
CEWO	Commonwealth Environment Water Office
CICL	Coleambally Irrigation Co-operative Limited
Cth DCCEEW	Commonwealth Department of Climate Change, Energy, the Environment and Water

Abbreviations	Definitions
DPE	NSW Department of Planning and Environment, now renamed as the Department of Planning, Housing and Infrastructure
DPHI	NSW Department of Planning, Housing and Infrastructure
DPIE	NSW Department of Planning, Industry and Environment (formerly known as NSW Department of Planning and Environment)
EIS	Environmental impact statement
EP&A Act	Environmental Planning and Assessment Act 1979 (NSW)
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999 (Cth)
EWR	Environmental Water Requirement
FM Act	Fisheries Management Act 1994 (NSW)
FSL	Full supply level
GL	Gigalitre
GS	General Security
HEW	Held Environmental Water
km²	Square kilometres
LEP	Local environmental plan
LGA	Local government area
MaxOF	Maximum Operating Flow
MaxOL	Maximum Operating Level
MinOL	Minimum Operating Level
MinOF	Minimum Operating Flow
ML	Megalitre
NSW DCCEEW	NSW Department of Climate Change, Energy, the Environment and Water. Formerly Water Infrastructure NSW.
PEW	Planned Environmental Water
SDL	Sustainable diversion limit
SDLAM	Sustainable diversion limit adjustment mechanism
SEARs	Secretary's environmental assessment requirements
SEPP	State environmental planning policy
YCMP	Yanco Creek Modernisation Project

1. Introduction

1.1 Overview

NSW Department of Climate Change, Energy, the Environment and Water (NSW DCCEEW) is proposing to replace two existing weirs along Billabong Creek with new regulators (the proposal). The two existing weirs to be replaced are Hartwood Weir and Wanganella Weir. These structures are situated on Billabong Creek within the Yanco Creek System in south-west NSW (refer Figure 1-1).

These weirs were built in the early 20th century and have been used to regulate flows through Billabong Creek, create weirs pools for irrigation and, in the case of Wanganella Weir, provide town water supply. The weirs are currently in states of declining condition and functionality and are barriers to the movement of fish through the creek. Their condition limits their ability to regulate flows through the Yanco Creek System and leads to inefficiencies in how water is delivered to the environment and irrigators.

The new regulators, referred to as Hartwood regulator and Wanganella regulator throughout this report, which would be fully automated and remotely operated, will allow regulation of flows in the lower sections of Billabong and Forest Creeks, providing river operators with greater operational flexibility to deliver the right amount of water to the right place at the right time. This increased operational flexibility is intended to increase the ability to deliver water orders including orders for environmental water. The regulation of flows in the lower sections of Billabong Creek will also result in a reduction in unplanned end of system flows in Billabong Creek at Darlot. Overall, it is intended that the new regulators will facilitate smarter use of the available water within the Yanco Creek system whilst maintaining or improving current levels of service for environmental and water supply demands.

The new regulators would feature fishways to support fish movement past the new structures. The operational plan and manuals for these new regulators would also take into account the regulation requirements at each regulator, as well as constraints such as limits to rates of rise and fall to accommodate fish breeding requirements.

The proposal is subject to environmental and planning approvals in accordance with the *NSW Environmental Planning and Assessment Act 1979* (EP&A Act) and the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The proposal is State significant infrastructure (SSI), and the Minister for Planning and Public Spaces is the approval authority. An environmental impact statement (EIS) is required to accompany the application for approval of the proposal.

1.2 Purpose and scope of this report

This report has been prepared by 3Rivers (a joint venture between Jacobs Group (Australia) and GHD) as part of the EIS for the proposal. The EIS has been prepared to accompany the application for approval of the proposal and addresses the Secretary's Environmental Assessment Requirements (the SEARs), issued on 17 October 2024.

The purpose of this report is to assess potential hydrology issues from the construction and operation of the proposal, and where required, identify feasible and reasonable mitigation and management measures. This report:

- Describes the current hydrological condition of key waterway reaches within the Yanco Creek System where relevant to the assessment of the proposal.
- Assesses the potential hydrological impacts of construction of the proposal.
- Describes the modelled potential hydrological impacts (adverse and beneficial) for key waterway reaches within the Yanco Creek System associated with the operation of the proposal.

- Describes the modelled potential hydrological impacts (adverse and beneficial) for key waterway reaches within the Yanco Creek System associated with cumulative impacts of the proposal and the Forest Creek Return Flows Project.
- Assesses the potential impacts (adverse and beneficial) of the proposal with regard to relevant Environmental Water Requirements (EWRs) specified in the Long-Term Watering Plan for the Murrumbidgee.

1.3 Structure of this report

The report is structured as follows:

- Section 1 – provides an introduction to the proposal and the assessment.
- Section 2 – describes the methodology for the assessment.
- Section 3 – describes current hydrological conditions of the Yanco Creek System
- Section 4 – assesses the impacts of the construction and operation of the proposal on the hydrological conditions of the Yanco Creek System
- Section 5 – water surface levels and weir pool extents assessment
- Section 6 – provides mitigation measures for any impacts identified.
- Section 7 – summarises the key findings and conclusions of this assessment of the proposal in relation to impacts on the hydrological conditions of the Yanco Creek System

1.4 Summary of the proposal

1.4.1 Location

The proposal is located on Billabong Creek, which is part of the Yanco Creek System in south-west New South Wales (NSW). The Yanco Creek System forms a part of the Murray-Darling Basin. An overview of the location of the proposal is shown in Figure 1-1. The proposal is located within the local government area (LGA) of Edward River.

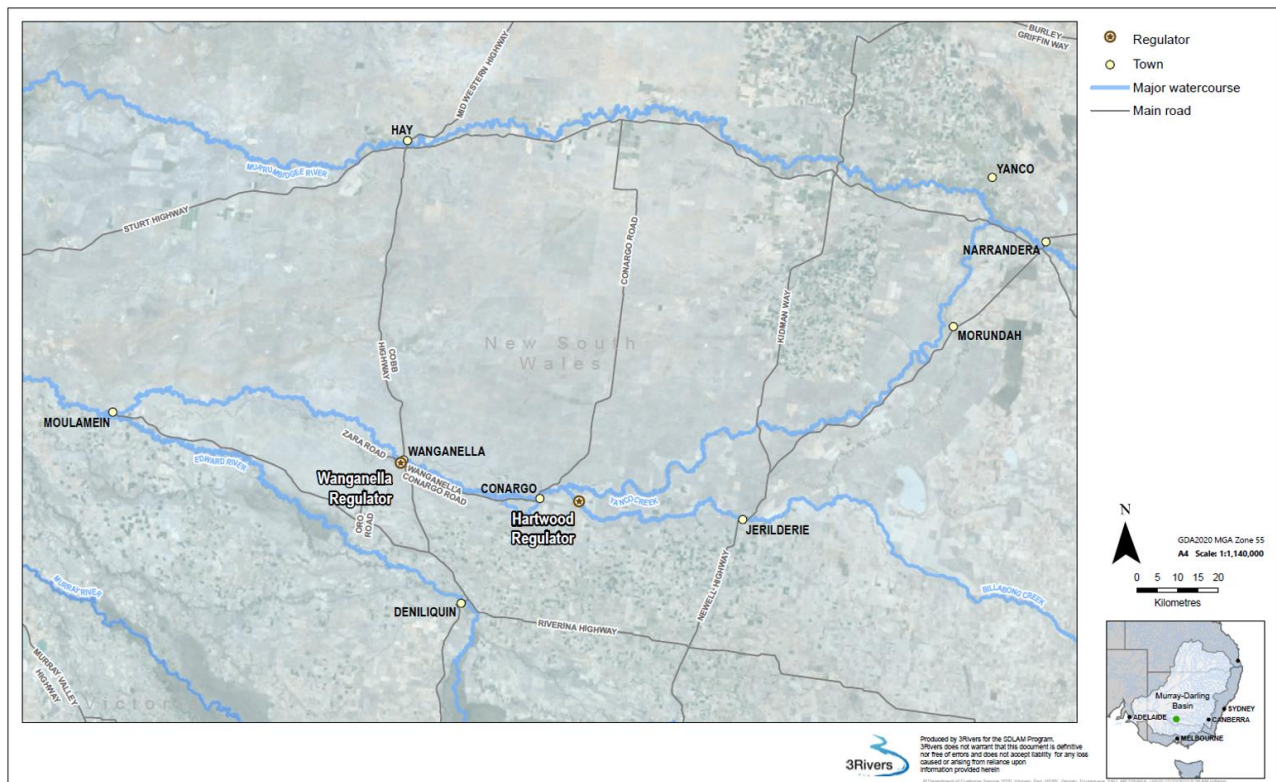


Figure 1-1 Location of the proposal.

1.4.2 Existing weirs

The existing Hartwood and Wanganella weirs are currently in states of declining condition and functionality and are barriers to the movement of fish through the creek. Their condition limits their ability to regulate flows through the Yanco Creek system and leads to inefficiencies in how water is delivered to the environment and irrigators.

Detailed description of the existing weirs within scope of the proposal are provided below. The proposal involves replacing the existing Hartwood and Wanganella weirs with new regulating structures, including fishways.

1.4.2.1 Hartwood weir

Hartwood Weir was privately built from 1915-1916 (Heritage NSW 2019). The structure is now owned and operated by WaterNSW. Hartwood Weir now largely operates as a fixed crest weir with a concrete apron and abutments. The weir contains manual drop boards that would have been used historically to regulate flows past the weir and are now only removed in high flows. The existing top of boards (crest) level is recorded at 95.28m AHD with a sill level of 94.69m AHD. The extent of the weir pool at full supply level, upstream of the structure, is around 16.5 kilometres.

Hartwood Weir is located downstream of the Billabong Creek and Forest Creek junction and can share the regulated flows between the two creeks by creating a weir pool to divert water to Forest Creek (Alluvium, 2013). The weir provides the head to divert regulated flow to Forest Creek (Cooling and Gippel 2018). When flow in Billabong Creek at Hartwood Weir exceeds 1200 ML/day, except if this is part of a managed environmental flow event, Forest Creek Offtake Regulator gates send unregulated flows to Forest Creek. Otherwise, i.e. when flow in Billabong Creek at Hartwood Weir is below 1200 ML/day, flows into Forest Creek are controlled by the Forest Creek Offtake Regulator to meet orders.



Figure 1-2 Hartwood Weir

1.4.2.2 Wanganella weir

Wanganella Weir was built in 1927. The existing structure is owned and maintained by Edward River Council. The weir was constructed for the Wanganella town water supply and still provides a weir-pool for town water supply. The structure contains 11 drop board bays and appears to have previously had provision for drop

boards to be installed to vary the height of the structure. However, the drop boards are no longer in place as they were removed in the 1980s, and the structure now operates as a fixed crest weir with a concrete apron and abutments. It is approximately 2 m high by 30 m across the length of the crest. The existing sill and previous crest height are recorded as 80.75 m AHD and 81.50 m AHD respectively. The extent of the weir pool at full supply level upstream of the structure is around 13 kilometres.



Figure 1-3 Wanganella Weir

1.4.3 Key features of the proposal

As discussed in Section 1.1, the proposal involves replacing two existing weirs along Billabong Creek with new regulators including fishways.

The new regulators, referred to as Hartwood regulator and Wanganella regulator throughout this report, which would be fully automated and remotely operated, are intended to allow for the regulation of flows in the lower sections of Billabong and Forest Creeks, providing river operators with greater operational flexibility to deliver the right amount of water to the right place at the right time. This increased operational flexibility is intended to increase the river operators' ability to deliver water orders including orders for environmental water.

In addition, this increased level of flow control is intended to result in the reduction of unplanned end of system flows in Billabong Creek at Darlot, because it is intended that the regulators will hold back this unplanned water to meet consumptive (irrigation, stock and town water supply) and environmental water requirements. As a result, it is intended that there is a reduction to the risk of additional adverse local socioeconomic outcomes resulting from additional water market purchases required to meet legislative water recovery targets of the Murray-Darling Basin Plan 2012.

Overall, it is intended that the new regulators will facilitate smarter use of water within the Yanco Creek system by enabling the reduction of unplanned surpluses and shortfalls. As a result, this means that the current levels of service for environmental and water supply demands could be maintained or improved.

The new regulators would also feature fishways to support fish movement past the new structures and improve fish passage outcomes compared to current conditions. The operational plan and manuals for these new regulators would take into account the regulation requirements at each regulator, as well as constraints such as limits to rates of rise and fall to accommodate fish breeding requirements.

The primary objectives of the Hartwood Regulator are to increase operational flexibility by providing re-regulation capacity of flows in Billabong Creek, and to maintain a pool height to allow the delivery of regulated flow requirements (including managed environmental flows) to Forest Creek at Offtake (41010309) as well as supply to irrigation demands.

The primary objectives of the Wanganella Regulator are to increase operational flexibility by providing re-regulation capacity of flows in Billabong Creek and creating a pumping pool for Wanganella's town water supply and nearby stock, irrigation and domestic uses.

The core structure of the new Hartwood and Wanganella regulators is similar and would include:

- concrete piers with maintenance bulkhead slots.
- automated lay flat gates across the crest of the structure to assist with flow management and downstream fish passage.
- a low turbulence 'keyhole' type vertical slot fishway with allowances for variable headwater to provide upstream fish passage.
- automated sidewinder gates within the vertical slot fishway to allow for variable headwater conditions.
- fixed concrete crests on the opposite side of the gates to the vertical slot fishway.
- concrete apron downstream of the structure.
- concrete wingwalls upstream and downstream of the structure.
- access from a trafficable deck for maintenance (Hartwood Regulator only).
- pedestrian walkway access part way across Wanganella Regulator structure to facilitate housing of gate actuators and for maintenance.
- walkway grating over gates to facilitate operations and maintenance.
- crushed rock maintenance pads, access and turnaround areas adjacent to the structure.
- rip rap and rock beaching upstream and downstream of structure for erosion protection.
- control house.
- sheet pile cut-off walls beneath the structure.
- fencing of the structures to prevent public access.
- SCADA control system.

An indicative layout of a regulator is shown in Figure 1-4. This example is of a five-gate regulator with a fish passage and trafficable deck for maintenance vehicles.



Figure 1-4 Indicative layout of a regulator.

The proposal would also involve the following elements:

- Power supply to the regulators would be provided by a mix of underground and overhead electricity cables connecting the structures to the grid.
- Access to the regulators would require permanent tracks for maintenance and some additional tracks to support construction only.
- As part of the access track upgrades at Hartwood Weir, a new culvert would be installed within an existing irrigation channel to provide a crossing point for vehicles.
- The existing Forest Creek block bank, associated with the Hartwood Regulator, would be replaced with a similar earthen structure to the existing. This would include two concrete sills to define the upstream and downstream top of bank and armoured with rock beaching and crushed rock for erosion protection.
- A flood bypass channel would be constructed to reduce potential upstream flooding impacts from the Wanganella Regulator. The channel would enable flood waters to drain between the billabongs in the Wanganella Reserve during flood events. It would be 85 metres long, around 40.0 metre wide and 1.7 metre deep and located north of the Wanganella Tip. Once completed, the channel sides and base would be naturalised and vegetated with appropriate local native species.
- An existing borrow pit on lot 56 / DP756322 near Hartwood Weir would be extended to provide material for the construction of Hartwood Regulator and Forest Creek block bank. Additional material may be used from a borrow pit near Wanganella Swamp for construction of Wanganella Regulator. Use of the Wanganella Swamp borrow pit is being assessed as part of a different proposal and will be subject to a separate approval process.

The location of the existing weirs, proposed infrastructure, and the indicative proposal footprints are shown on Figure 1-5 and Figure 1-6.

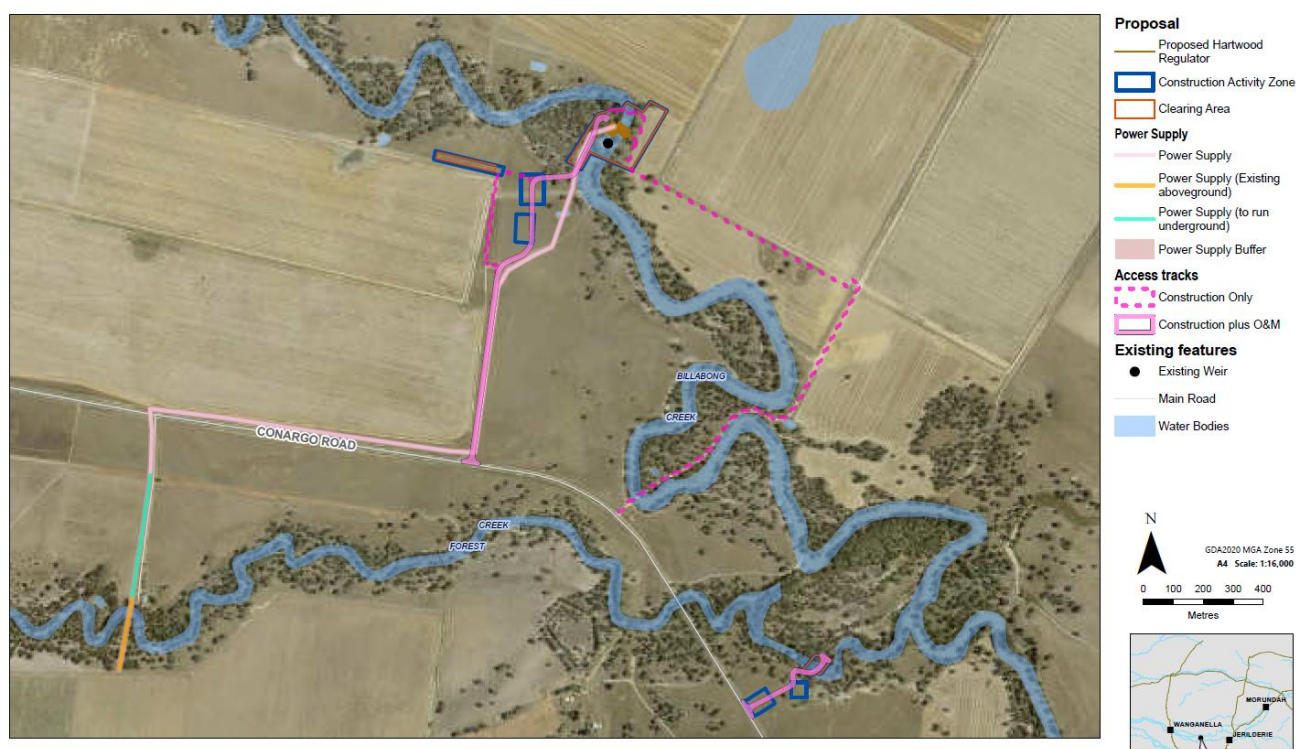


Figure 1-5 Location of Hartwood Regulator and proposed works

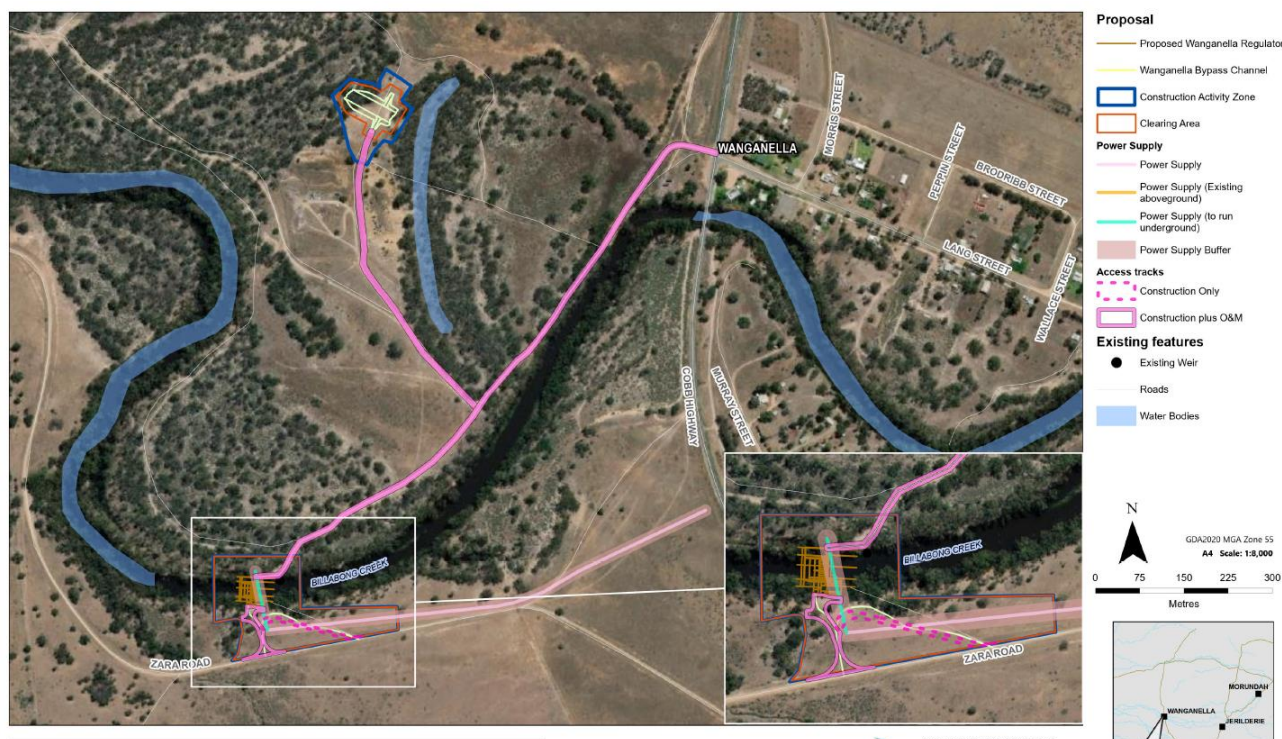


Figure 1-6 Location of Wanganella Regulator and proposed works.

1.4.4 Proposed regulator design

1.4.4.1 Hartwood Regulator

The proposed Hartwood Regulator will be located approximately 70 m downstream of the existing structure and has been designed to include the following elements to control the passing flow and level of the weir pool:

- A fishway section to allow fish passage on the western bank that will pass a constant flow of 20 ML/day.
- A gated section of weir that can be controlled to pass operational and/or environmental flows, whilst maintaining a weir pool level – this section consists of five (5) by 2.02 m wide lay flat gates with a sill level of 92.7 m AHD.
- A fixed crest section of weir that will block off the remainder of the channel to maintain the weir pool – this section consists of a rectangular shape broad crested weir with a crest level of 95.84 m AHD and a width of 20.5 m.

The proposed structure will also include the following works around Hartwood Regulator:

- A maintenance gantry over the fishway and gated/fixed crest portions of the proposed weir.
- A stilling basin downstream of the gates and weir.
- A transition back to natural channel to facilitate fish passage, which also has a trafficable deck over it to allow for maintenance of the structure.
- An access track from trafficable deck connecting back up to Conargo Road.

1.4.4.2 Wanganella Regulator

The proposed Wanganella Regulator will be located approximately 55 m downstream of the existing structure and has now been designed to include the following elements to control the passing flow and level of the weir pool:

- A fishway section to allow fish passage on the western bank that will pass a constant flow of 20 ML/day.
- A gated section of weir that can be controlled to pass operational and/or environmental flows, whilst maintaining a weir pool level – this section consists of four (4) by 2.02 m wide lay flat gates.
- A fixed crest section of weir that will block off the remainder of the channel to maintain the weir pool – this section consists of a rectangular shape broad crested weir with a crest level of 82.20 m AHD and a width of 20.5 m.

The proposed structure will also include the following works around Wanganella Weir:

- A maintenance gantry over the fishway and gated/fixed crest portions of the proposed weir.
- Basin at upstream and downstream of the regulator.
- A transition back to natural downstream channel to facilitate fish passage, which also has a trafficable deck over it to allow for maintenance of the structure.

1.4.5 Proposed regulator operation

The proposal would be operated in accordance with the operating requirements established with the new asset owner (WaterNSW) and developed in consultation with key stakeholders. The proposed operational principles for the regulators are detailed in the Yanco Creek System Operations Plan (NSW DCCEEW 2023b). An outline of the proposed operational principles set out in the operations plan is provided in Section 1.4.5.1.

The overarching operational principle for these regulators is to control flows in Billabong Creek to enable the delivery of the right amount of environmental and consumptive water to the right place at the right time. The overarching operational principle for the associated fishways is to improve the passage of fish through the system compared to current conditions.

1.4.5.1 General operating principles of the regulators

1.4.5.1.1 Hartwood Regulator

The proposed general operating principles of Hartwood Regulator are as follows:

- Primarily used to maintain a weir pool height sufficiently high enough to deliver normal regulated flow requirements (including managed environmental flows) at Forest Creek at Offtake (41010309).
- Used to create a pumping pool for six irrigation pumps within the influence of the weir pool and to provide re-regulation capacity of flows in the Billabong Creek. Some stock and/or domestic pumps also extract water from within the influence of the weir pool.
- Regulation gates to be fully open during moderate to large unregulated flow events at every possible opportunity to enable unrestricted fish passage opportunities.
- Equitable sharing of adverse outcomes across water access licence holders during unexpected supply shortfalls.
- Optimisation of regulator pool operations to minimise the risk of adverse environmental outcomes.
- Distribution of flows downstream of the regulator to be proportioned across each of the regulation gates to maximise the effectiveness of the fishway.

1.4.5.1.2 Wanganella Regulator

The proposed general operating principles of Wanganella Regulator are as follows:

- Primarily used to create a pumping pool for Wanganella's town water supply, one irrigation pump and to provide re-regulation capacity of flows in the Billabong Creek.
- Some stock and/or domestic pumps also extract water from within the influence of the weir pool.

- Another irrigation pump benefits from the weir pool when operated within upper parts of the yellow zone.
- Regulation gates to be fully open during moderate to large uncontrolled flow events at every possible opportunity to enable unrestricted fish passage opportunities.
- Equitable sharing of adverse outcomes across water access licence holders during unexpected supply shortfalls
- Optimisation of weir pool operations to minimise the risk of adverse environmental outcomes.
- Distribution of flows downstream of the regulator to be proportioned across each of the regulation gates to maximise the effectiveness of the fishway.

1.4.5.2 Proposed operating levels of the regulators

Figure 1-7 and Figure 1-8 show the proposed operating levels for different operating zones of the existing and proposed Hartwood and Wanganella Regulators. Full supply level is the maximum operating level, the top of green zone corresponds to the modelled median flow level for the existing weirs, and the bottom of green zone is the Minimum Operating Level and corresponds to the typical top of drop board level at the existing weir.

1.4.5.2.1 Hartwood Regulator

The Hartwood Regulator will be commonly operated within the green zone. Different target levels for operation within the green zone will apply to ensure that there is always water available for downstream requirements, with a higher target level identified for the irrigation season when greater demand is likely.

Operations of the regulator within the yellow zone would occur when catchment rainfall provides stream flows that could be captured by the regulator. This would reduce the quantity of regulated water required by the Yanco Creek system and allow more responsive delivery of irrigation and environmental water from the regulator.

The operations plan proposes that the yellow zone should be primarily used during the irrigation season and is for the capture of the end of an unregulated flow event allowing the rise and peak of the flow event to continue downstream, capturing a portion of the water in the recession of the peak flow. The water stored in the yellow zone would be held until used and this would depend on water demands downstream. In the event of a second unregulated event in the upstream catchment, the operations plan proposes to temporarily draw down the storage to the green zone and refilling the yellow zone on the recession of the second event.

The operations plan defines maximum rates of rise and fall of regulated water stored by the regulator. These are designed to limit impacts to bank stability and any nesting of native fish. The maximum rate of fall is 100 millimetres per day and the maximum rate of rise is 300 millimetres per day.

1.4.5.2.2 Wanganella Regulator

The Wanganella Regulator will be commonly operated within the green zone. Different target levels for operation within the green zone will apply to ensure that there is always water available for downstream requirements, with a higher target level identified for the irrigation season when greater demand is likely. Operations of the regulator within the yellow zone would occur when catchment rainfall provides stream flows that could be captured by the regulator. This would reduce the quantity of regulated water required by the Yanco Creek system and allow more responsive delivery of irrigation and environmental water from the regulator.

The operations plan proposes that the yellow zone should be primarily used during the irrigation season and is for the capture of the end of an unregulated flow event allowing the rise and peak of the flow event to continue downstream, capturing a portion of the water in the recession of the peak flow. The water stored in the yellow zone would be held until used and this would depend on water demands downstream. In the event

of a second unregulated event in the upstream catchment, the operations plan proposes to temporarily draw down the storage to the green zone and refilling the yellow zone on the recession of the second event. The operations plan defines maximum rates of rise and fall of regulated water stored by the regulator. These are designed to limit impacts to bank stability and any nesting of native fish. The maximum rate of fall is 100 millimetres per day and the maximum rate of rise is 300 millimetres per day.

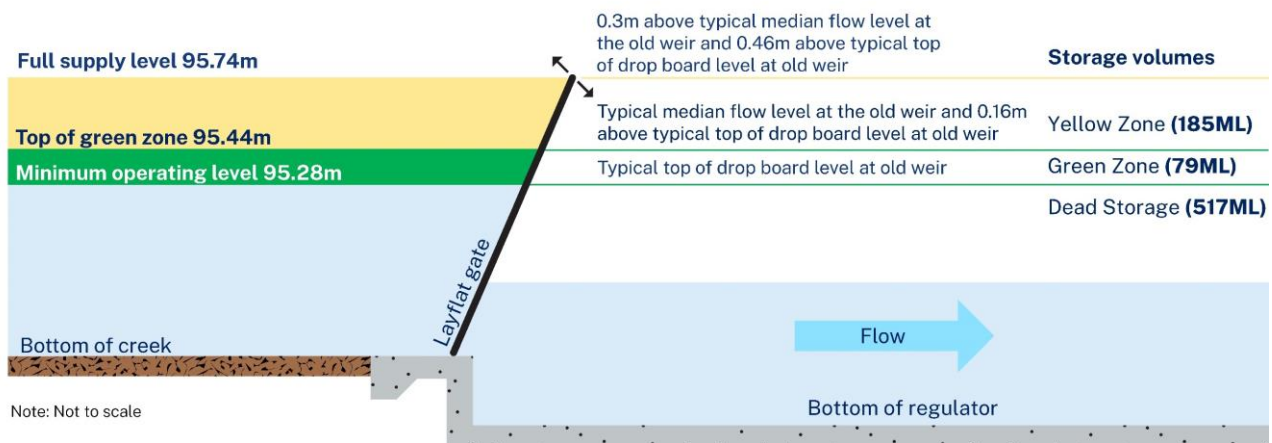


Figure 1-7 Hartwood Regulator operating zones.

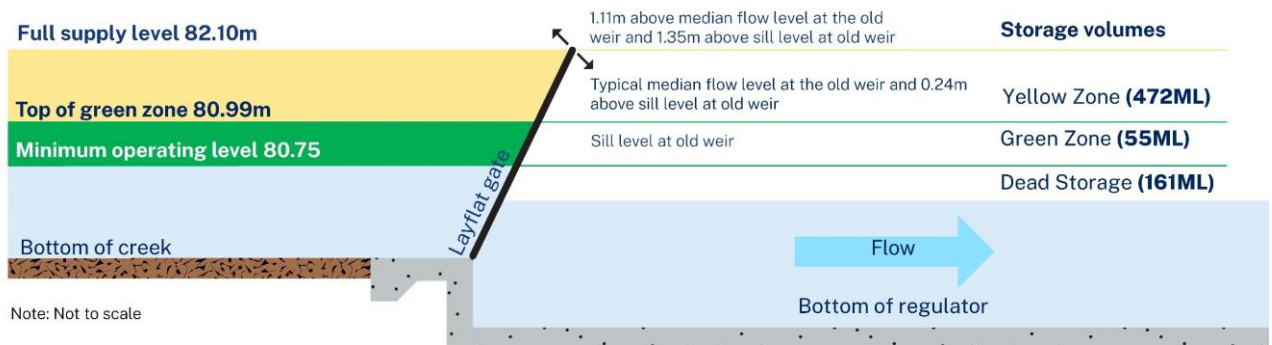


Figure 1-8 Wanganella Regulator operating zones.

1.4.5.3 Unregulated flow operations

The operations plan defines how Hartwood and Wanganella Regulators are operated following rainfall events resulting in higher than planned flows that cannot be controlled by river operators with available water regulation infrastructure. The unregulated flow operational principles are described below.

Hartwood Weir

- Water resource availability will be optimised consistent with the yellow zone operations detailed above.
- When flows downstream of Hartwood Regulator exceed normal regulated river flow requirements Hartwood Regulator will initially be placed in upstream control at any level within the green zone.
- When flows in the Billabong Creek @ downstream Hartwood Regulator (410168) are equal to or more than 1,200ML/day, the gates at Forest Creek Offtake are to be fully opened (i.e. lifted clear of the water).
 - During this period, Hartwood Regulator will be placed on upstream control at 95.44m (top of the green zone) until such time as downstream water levels increase to 95.44m.

- When water levels downstream of Hartwood Regulator increase to 95.44m the regulator gates will be fully opened until downstream water levels fall again to 95.44m.
- When water levels downstream of Hartwood Regulator fall below 95.44m, Hartwood Regulator will be placed in upstream control at 95.44m until flows are about to recede to normal regulated operating conditions.
- When flows in the Billabong Creek @ downstream Hartwood Regulator (410168) fall below 1,200ML/day, the gates at Forest Creek Offtake will be placed back in the water to meet regulated water delivery requirements and Hartwood Regulator will be operated in upstream control at any level within the green zone.
 - Delay filling Hartwood Regulator to full supply level until near the end of an unregulated or unplanned flow event without compromising total water resource availability.
 - Return to normal regulated flow conditions including adoption of regulator pool target levels.
- Regulator pool full supply levels do not apply when regulation gates are fully open during high flow events.

It should be noted that the 1,200ML/day flow trigger downstream of Hartwood Regulator is consistent with plans established following the implementation of a previous Water for Rivers water savings project within the Forest Creek System downstream of Warriston Weir. It should also be noted that there are flexibility provisions in the operations plan where this 1,200ML/day flow trigger downstream of Hartwood Regulator does not apply subject to advice from environmental water managers.

Wanganella Weir

- Water resource availability will be optimised consistent with yellow zone operations detailed above.
- When flows downstream of Wanganella Regulator exceed normal regulated river flow requirements, Wanganella Regulator will initially be placed in upstream control at any level within the green zone.
- When water levels downstream of Wanganella Regulator increase to 80.82m, the regulator gates will be fully opened until downstream water levels fall again to 80.82m.
- When water levels downstream of Wanganella Regulator fall below 80.82m, Wanganella Regulator will be placed in upstream control at 80.82m until flows are about to recede to normal regulated operating conditions.
- Delay filling Wanganella Regulator to full supply level until near the end of an unregulated or unplanned flow event without compromising total resource availability.
- Return to normal regulated flow conditions including adoption of regulator pool target levels.
- Regulator pool full supply levels do not apply when regulation gates are fully open during high flow events.

1.4.5.4 Comparison of key physical and operational parameters of the existing and proposed Hartwood and Wanganella Regulators

Table 1-1 summarises the key physical and operational parameters of the proposed Hartwood and Wanganella Regulators and compares these to those of the existing weir structures.

Table 1-1 Key physical and operational parameters of the existing and proposed Hartwood and Wanganella Regulators.

Parameter	Hartwood		Wanganella	
	Proposed Hartwood Regulator	Existing Hartwood weir	Proposed Wanganella Regulator	Existing Wanganella weir
Crest RL (m AHD)	95.84	95.28 (top of boards crest) 94.69 (sill)	82.2	81.50 (top of boards crest) 80.75 (sill)
Width of Gates (m)	2.02	1.8 m (drop board bays)	2.02	
Number of Gates	5	12 drop board bays	4	11 drop board bays
Width of Crest (m)	20.5	approximately 40m	23.3	
Full supply level (RL)	95.74	95.44 ¹	82.1	80.99 ²
Top of Green Zone (m)	95.44	NA	80.99	NA
Bottom of Green Zone (m)	95.28	NA	80.75	NA
Minimum Operating Level (m)	95.28	NA	80.75	NA
Operating Range (m) (Full supply level - Minimum Operating Level)	0.46	NA	1.35	NA
Weir Pool targets (1-Nov to 30-Apr) (m)	95.44	NA	80.99	NA
Weir Pool targets (1-May to 31-Oct) (m)	95.32	NA	80.82	NA
Maximum daily rate of fall (m)	0.1	NA	0.1	NA
Maximum daily rate of rise (m)	0.3		0.3	

¹. Typical median flow level for existing Hartwood weir and 0.16m above typical top of drop board level (see Figure 1-7)

². Typical median flow level for existing Wanganella weir and 0.24m above sill level (see Figure 1-8).

1.4.5.5 Water Access licenses

The following summary of water access licence information (Table 1-2) is taken from the Yanco Creek System Operations Plan (NSW DCCEEW 2023b). The operations plan includes general operating principles for Hartwood Regulator and Wanganella Regulator for the "equitable sharing of adverse outcomes across water access licence holders during unexpected supply shortfalls (i.e. when WaterNSW cannot deliver water order requests)."

Table 1-2 Yanco Creek System water access licence summary, based on conditions on 29 May 2022

Licence type	Number of licences	Volume (ML)
Domestic and Stock	158	4,530
Local Water Utility	5	8,336
General Security	165	103,776
High Security	17	2,801
Supplementary	78	27,627
Total	423	152,222

1.4.6 Proposed regulator construction timing

Construction of the proposal is anticipated to start in 2025 and be completed by 2026. The construction period is anticipated to be around 18 months. Construction would pause during periods of high flow.

1.5 Secretary's environmental assessment requirements

This hydrology assessment has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) pertaining to hydrological impacts. Table 1-3 outlines the SEAR requirements relevant to this assessment and summarises the key findings from this assessment relevant to each of the SEAR requirements. The assessment also considers the requirements raised by the NSW DCCEW and the Department of Primary Industries (Fisheries).

Table 1-3 SEARs requirements relevant to this hydrology assessment

SEAR requirements	Where this is addressed in this report	Summary of key findings
3. Include a thorough description of the existing environmental conditions and hydrological regime to the extent of proposal influence up and down stream, including:		
a) Comprehensive mapping of baseline conditions of rivers, streams, wetlands, and groundwater potentially impacted by the proposal, inclusive of existing weirs, regulators, block banks, water allocations and operating conditions.	Descriptions of the baseline hydrological conditions within key reaches of the Yanco Creek System relevant to the proposal, including existing weirs, water allocations and operating conditions are described in Section 3.1 - Current catchment conditions, Section 3.1.4 - Existing weirs and Section 3.1.5 - Current hydrological conditions.	Under current conditions, flows within the Yanco Creek System are highly variable and there is an absence of no-flow years. The hydrology of the Yanco Creek System, including the proposal study area, is highly altered from pre-development (i.e. loss or considerable alteration of key hydrological flow components and processes). As such the Yanco Creek System is characterised as being highly flow modified, which is consistent with previous historical analysis of the hydrology. Flow within the Yanco system is regulated at key locations to manage water delivery. Weirs regulate the share of water between Colombo Creek and Yanco Creek (Tarabah Weir) and between Forest Creek and Billabong Creek (Hartwood Weir and Forest Creek Regulator). In addition, there are over 30 private licenced fixed crest weirs that were constructed to provide a local store of water. As a result of regulation, flows through the Yanco Creek System are maintained at artificially high levels during high demand periods and as such the total annual flow volume is much higher than pre-development. The current hydrology of Mid Billabong Creek - from Jerilderie to downstream of Hartwood Weir (to where Lower Yanco Creek joins

SEAR requirements	Where this is addressed in this report	Summary of key findings
		Billabong Creek) - and Lower Billabong Creek and intersecting streams - from downstream of Hartwood Weir to Moulamein (inclusive of Wanganella and Darlot) – is highly altered from pre-development and vary widely depending on rainfall, inflows, evaporation and demand - including irrigation, industry, communities, the environment.
b) Existing river running heights under current operating conditions and water allocations, including the extent and height of existing weir pools.	Descriptions of the existing river running heights under current operating conditions and water allocations, including the extent and height of existing weir pools are provided in Section 5.1- Water surface levels and Section 5.1.4 - Weir pool extents.	River running heights (i.e. water surface levels) under existing crest and sill levels at Wanganella Weir for the Minimum (25 ML/day for Hartwood and 30 ML/day for Wanganella) and Maximum (500 ML/day for Hartwood and 400 ML/day for Wanganella) Operating Flow scenarios were determined for the Hartwood and Wanganella weir pools. As expected, water surface levels under regulated flow conditions do not exceed their respective existing full supply levels. River running heights over a 22-year time period were also determined for Hartwood and Wanganella weir pools using a mixture of operational results and flood modelling predictions. Over a 22-year time period, the mean monthly water surface levels at Hartwood and Wanganella weir pools rarely exceed their respective existing median (50th%ile) water surface level over a 22-year time period, except during periods of high unregulated flows. Weir pool extents under existing conditions and supply levels at Maximum Operating Flow were determined for Hartwood and Wanganella weir pools, to understand the potential upper limit to the degree of change at Hartwood and Wanganella weir pools. The modelled weir pool extent for Hartwood is from Hartwood Weir to Old Woodshed Dam (16.3 km in length, 671,404 m² in area), and for Wanganella is from Wanganella Weir to 4 Mile Dam (16.46 km in length, 364,531 m² in area).

SEAR requirements	Where this is addressed in this report	Summary of key findings
4. Include a thorough assessment of the hydrological impacts of the proposal in comparison with existing hydrological conditions, to the extent of proposal influence up and down stream, including:		
a) A detailed and consolidated catchment scale water balance and projected alterations in water supply and demand management.	Assessments of the potential impacts of the proposal on the catchment scale water balance are described under operation of the proposal in Section 4.2.1 (Change Case scenario) and Section 4.3.1 (Cumulative Change Case scenario) in comparison to the modelled current conditions described in Section 3.2.1 (Base Case scenario) of this report. Assessments of potential alterations in water supply and demand management are described for operation of the proposal in Section 4.2.6 and 4.2.1.1 respectively.	Based on the modelled Change Case scenario, with operation of the new Hartwood and Wanganella regulators and broader system changes, it concluded that there are only minor changes to the modelled mean annual water balance of the Yanco Creek System, and these changes represent a low degree of hydrological alteration. The same findings apply to the Cumulative Change Case scenario, with the exception of Piccaninny Creek, which is a direct result of the Forest Creek Return Flows project. The minor changes are considered the product of the following differences from the Base Case scenario: ▪ New flow provisions - environmental baseflow, native fish environmental flow and additional environmental. ▪ The ability of the new regulators to regulate flows within Billabong Creek itself to meet environmental and water supply demands ▪ New limits to when water can be ordered from Finley Escape, Coleambally Catchment Drain (CCD) and Drainage Channel 800 (DC800) Irrigation Escapes ▪ New operational principle to divert unplanned flows down Piccaninny Creek to assist in preventing unplanned flows in Forest Creek downstream of Warriston Weir during normal regulated periods.
b) Comprehensive modelling of proposed river running heights, including the extent and height of each weir pool created by the project under proposed operating conditions.	Descriptions of the modelled river running heights with operation of the regulators for the proposal, including the extent and height of existing weir pools are provided in Section	River running heights under operation of the proposal at the proposed Minimum Operating Level and Maximum Operating Level for the Minimum and Maximum Operating Flow scenarios were determined for the Hartwood and Wanganella weir pools using hydraulic modelling.

SEAR requirements	Where this is addressed in this report	Summary of key findings
	5.1- Water surface levels and Section 5.1.4 - Weir pool extents.	River running heights over a 22-year time period (2000-2022) were determined for the Hartwood and Wanganella weir pools by translating daily modelled flows from the Source modelling into water levels using rating curves, which were derived from a mixture of hydraulic calculations and flood modelling results under operation of the proposal. As expected, water levels were modelled to be in line with the proposed operational parameters, and changes in water levels compared to existing conditions are consistent with those expected with operation of the regulators for the proposal. Mean monthly water levels at Hartwood and Wanganella weir pools are within the proposed green operating zones the majority of the time, except during periods of high unregulated flows. In addition, there is minor change in monthly water levels between existing and proposed conditions, with the minor change being attributed to the change in operating levels at Hartwood and Wanganella. Weir pool extents under operation of the proposal at Maximum Operating Flow and the proposed full supply level were determined for Hartwood and Wanganella weir pools, to understand the potential upper limit to the degree of change at Hartwood and Wanganella weir pools. For Hartwood weir pool, there is a small increase in inundation extent area (approximately 51,590 m² or 7.7%), with a small increase in lateral inundation and a small increase in longitudinal inundation (73 m or 0.4%) towards the downstream end of the Hartwood weir pool as a result of the new regulator structure being located approximately 70m downstream of the existing Hartwood weir. For Wanganella weir pool, there is a moderate increase in weir pool extent area (approximately +110,350 m² or +30%), with a moderate increase in lateral inundation but no increase in longitudinal inundation.

SEAR requirements	Where this is addressed in this report	Summary of key findings
		The focus of the assessment of river running heights and weir pool extents was on Hartwood and Wanganella weir pools, and other sites were not assessed. This is because hydraulic modelling has comprehensively demonstrated that under operation of the proposal, the fundamental change in water levels across the Yanco Creek System occurs at the Hartwood and Wanganella weir pools (3Rivers, 2024a and 2024b).
c) Description of all works/activities that may intercept, extract, use, divert or receive surface water and/or groundwater. This includes the description of any development, activities or structures that will intercept, interfere with or remove surface water or groundwater, both temporary and permanent, ensuring achievement with regional Water Sharing Plans and Water Resource Plans, and with sustainable diversion limits of the Murray-Darling Basin Plan.	Descriptions of works/activities during construction and operation of the proposal relevant to surface water are described in Sections 1.4.4 and Section 1.4.5 respectively.	The proposal involves replacing two existing weirs along Billabong Creek with new regulators including fishways. The primary objectives of the Hartwood Regulator are to increase operational flexibility by providing re-regulation capacity of flows in Billabong Creek, and to maintain a pool height to allow the delivery of regulated flow requirements (including managed environmental flows) to Forest Creek at Offtake as well as supply to irrigation demands. The primary objectives of the Wanganella Regulator are to increase operational flexibility by providing re-regulation capacity of flows in Billabong Creek and creating a pumping pool for Wanganella’s town water supply and nearby stock, irrigation and domestic uses. The core structure of the new Hartwood and Wanganella regulators is similar and would include: ▪ concrete piers with maintenance bulkhead slots ▪ automated lay flat gates across the crest of the structure to assist with flow management and downstream fish passage. ▪ a low turbulence ‘keyhole’ type vertical slot fishway with allowances for variable headwater to provide upstream fish passage. ▪ automated sidewinder gates within the vertical slot fishway to allow for variable headwater conditions.

SEAR requirements	Where this is addressed in this report	Summary of key findings
		- fixed concrete crests on the opposite side of the gates to the vertical slot fishway - concrete apron downstream of the structure - concrete wingwalls upstream and downstream of the structure
d) Assessment of impacts on surface and ground water sources (both quality and quantity), related infrastructure, adjacent licensed water users, basic landholder rights, watercourses, riparian land, groundwater dependent ecosystems, and ground water levels; including measures proposed to reduce and mitigate these impacts.	Assessment of the potential impacts of the proposal on surface water quantity for licensed water users has been undertaken in relation to Environmental Watering Requirements (Section 4.2.5 (Change Case scenario) and 4.3.5 (Cumulative Change Case scenario), Water Extractions (Section 4.2.1 (Change Case scenario) and Section 4.3.1 (Cumulative Change Case scenario) and Effective General Security Allocations (Section 4.2.6 (Change Case scenario) and Section 4.3.6 (Cumulative Change Case scenario) in comparison to existing conditions.	There are generally either no change or improvements in achieving EWRs across the Yanco Creek system under operation of the proposal and when considering cumulative impacts with the Forest Creek Return Flows project. There is predicted to be some improvements in the frequency of achieving baseflows, Native Fish Nesting Support, small freshes and large fresh EWRs throughout the Yanco Creek System, including the proposal study area. Very minor modelled reductions in some very low flow and very high flow EWRs can be attributed to the limitations of the Source model. Effective General Security Allocations are predicted to increase marginally with operation of the proposal, for opening allocation and summer planning decision dates. A very minor decrease is predicted for end of the year. There are predicted to be no decreases to Effective General Security Allocations for end of the year under operation of the proposal when considering cumulative impacts with the Forest Creek Return Flows project.
l) An assessment of the impact of the project on water savings under the Sustainable Diversion Limit Adjustment Mechanism (SDLAM) framework, and in consideration of the Murray-Darling Basin Plan including environmental flow requirements and environmental watering.	Assessment of the potential impacts of the proposal on EWR attainment has been undertaken in Sections 4.2.5 (Change Case scenario) and 4.3.5 (Cumulative Change Case scenario) in comparison to the modelled current conditions described in Section 3.2.5 (Base Case scenario) of this report.	SDLAM projects are designed to deliver better environmental outcomes without the need for additional water recovery, through infrastructure, changing rules to deliver water to high value environmental sites and changing the way rivers are managed. The Yanco Creek Modernisation Project (YCMP) is part of the SDLAM acceleration program which will deliver up to 45GL of the outstanding amount needed to reach the 605GL target required by the Basin Plan each year. (NSW DCCEW 2024).

SEAR requirements	Where this is addressed in this report	Summary of key findings
		The MDBA (2020) identified that supply and constraint projects are complex projects that together make a substantial contribution to the overall sustainable diversion limit adjustment. These projects include the modernising of water delivery infrastructure in Yanco Creek to improve the operation of Yanco Creek and its environmental outcomes. One such project is this proposal. The MDBA made an estimate of the volumetric contribution of projects to the SDLAM offset, using two methods to develop an estimated range of potential supply contributions for supply projects. It is estimated that a water saving of 16GL per year will be achieved when the Yanco Creek Modernisation Project is combined with the Computer Aided River Management (CARM) project. There are generally either no change or improvements in achieving EWRs across the Yanco Creek system under operation of the proposal when considering cumulative impacts with the Forest Creek Return Flows project. There is predicted to be some improvements in the frequency of achieving baseflows, Native Fish Nesting Support, small freshes and large fresh EWRs throughout the Yanco Creek System, including the proposal study area. Very minor modelled reductions in some very low flow and very high flow EWRs can be attributed to the limitations of the Source model.
m) Changes to environmental water availability, both regulated/licensed and unregulated/rules-based sources of such water, specifically: assessment of impacts to the volume, reliability and effectiveness of Planned Environmental Water in the catchment downstream of the proposed works.	Assessment of the potential impacts of the proposal on EWR attainment has been undertaken in Sections 4.2.5 (Change Case scenario) and 4.3.5 (Cumulative Change Case scenario) in comparison to the modelled current conditions described in Section 3.2.5 (Base Case scenario) of this report.	The assessment is based on any potential impacts of the proposal to change the EWRs documented in the MLTWP across the entire Yanco Creek System. The key findings are: - There are generally either no change or improvements in achieving EWRs under operation of the proposal and when considering cumulative impacts with the Forest Creek Return Flows project - There is predicted to be some improvements in the frequency of achieving baseflows, Native Fish Nesting Support, small freshes

SEAR requirements	Where this is addressed in this report	Summary of key findings
assessment of impact to volume, reliability, effectiveness or deliverability of Held Environmental Water assets in the catchment downstream of the works. any water substitution effects of the removal of surplus or tributary flows from the catchment that may then require held or discretionary planned environmental water to make up the shortfall		and large fresh EWRs throughout the Yanco Creek System, including the proposal study area. Very minor modelled reductions in some very low flow and very high flow EWRs can be attributed to the limitations of the Source model. The above findings illustrate that the proposal is not expected to negatively impact attainment of the EWRs, and in some cases, an improvement in the attainment of EWRs is anticipated when modelled within the context of broader system changes as documented in the operations plan. As such, no compensatory water would be required from Held Environmental Water (HEW) or Planned Environmental Water (PEW). The improvement in attainment of some EWRs because of the new environmental flow provisions, resulting in an increase in PEW, as well as the proposal itself. The proposal would offer improved regulation of water, including environmental water, to the environmental assets downstream on Billabong Creek and, with improved water management at Harwood Regulator, to Forest Creek. For example, the proposal is intended to offer more responsive and more efficient water delivery into Wanganella Swamp to maintain water levels during bird breeding events rather than the longer delivery time for water coming from the Murrumbidgee River. Associated with the proposal is the commencement of new environmental flow provisions in the Yanco Creek system. The maintenance of flows in the creek system would mean that the volume of a targeted environmental water is not reduced during delivery by a drier creek system.
5. Include a thorough assessment of the water quality impacts of the project during construction and operation, to the extent of project influence up and down stream, including:		

SEAR requirements	Where this is addressed in this report	Summary of key findings
A. The ambient NSW Water Quality and River Flow Objectives (NSW WQO) and environmental values for the river, including the indicators and associated trigger values or criteria for the identified environmental values.	Assessment of the potential impacts of the proposal on River Flow Objectives for Controlled rivers with altered flows (regulated Creeks) during operation has been undertaken in Sections 4.3.7 and for construction in Section 4.1.5 of this report	Construction of the proposal is not expected to result in adverse impacts on River Flow Objectives. The construction methods, components and phasing allow for passing flows and the existing weirs (i.e. Hartwood and Wanganella weirs) will remain in place for majority of the construction timeframe to retain the water and not allow the creek to become unregulated. No potential adverse impacts, and some minor improvements, to River Flow Objectives are predicted with operation of the regulators for the proposal and broader system changes. No adverse effects and some improvements are expected to low flows (i.e. unnatural prolonged drying), the proportion of moderate flows ('freshes') and high flows, no material change in the overall annual flow variability within the Yanco Creek System with operation of the proposal and mostly no change or some minor improvements in the frequency in the expected frequency of over bank wetland connection or floodplain connection flows. No adverse impacts to naturally temporary waterways, groundwater dependent surface flows and ecosystems or the occurrence of high-quality flowing habitat or water quality is expected within the proposal study area and the broader Yanco Creek System. An improvement in the rates of change in water levels is expected with implementation of operational limits for 'Pool Maximum Daily Rate of Rise' for Hartwood and Wanganella regulators and 'Native fish environmental flow provisions' for maximum rate of fall at Yanco Offtake and Billabong Creek at Darlot. Additionally, the design of the Hartwood and Wanganella regulators includes fishways that will allow an increase in river extent with unimpeded fish passage.
6. The EIS must also include:		

SEAR requirements	Where this is addressed in this report	Summary of key findings
c) A detailed assessment of refinements or improvements for all water users, including the environment, expected to result from the proposal.	Assessment of the potential impacts of the proposal on all water users has been undertaken in relation to Environmental Watering Requirements (Section 4.2.5 (Change Case scenario) and 4.3.5 (Cumulative Change Case scenario), Water Extractions (Section 4.2.1 (Change Case scenario) and Section 4.3.1 (Cumulative Change Case scenario) and Effective General Security Allocations (Section 4.2.6 (Change Case scenario) and Section 4.3.6 (Cumulative Change Case scenario) in comparison to existing conditions.	There are generally either no change or improvements in achieving EWRs across the Yanco Creek system under operation of the proposal and when considering cumulative impacts with the Forest Creek Return Flows project. There is predicted to be some improvements in the frequency of achieving baseflows, Native Fish Nesting Support, small freshes and large fresh EWRs throughout the Yanco Creek System, including the proposal study area. Very minor modelled reductions in some very low flow and very high flow EWRs can be attributed to the limitations of the Source model. Effective General Security Allocations are predicted to increase marginally with operation of the proposal, for opening allocation and summer planning decision dates. A very minor decrease is predicted for end of the year, but this is likely an artifact of the limitations of the Source model. There are predicted to be no decreases to Effective General Security Allocations for end of the year under operation of the proposal when considering cumulative impacts with the Forest Creek Return Flows project.
f) Details of any environmental flow regimes which will be impacted by the implementation of the proposal.	Assessment of the potential impacts of the proposal on environmental water requirements are described under operation of the proposal in Section 4.2.5 (Change Case scenario) and Section 4.3.5 (Cumulative Change Case scenario) in comparison to the modelled current conditions described in Section 3.2.5 (Base Case scenario) of this report.	The findings of the EWR analysis suggest that there are generally either no change or improvements in achieving EWRs with operation of the proposal under the Change Case scenario). There is predicted to be improvements in the frequency of achieving baseflows, Native Fish Nesting Support, small freshes and large fresh EWRs throughout the Yanco Creek System, including the proposal study area. Very minor modelled reductions in some very low flow and very high flow EWRs can be attributed to the limitations of the Source model. Therefore it is concluded that operation of the proposal will result in an overall improvement in the frequency of achieving EWRs for a number of EWR categories to support key ecological values of the system.



SEAR requirements	Where this is addressed in this report	Summary of key findings
		Under the Cumulative Change scenario, the EWR results are generally consistent with those predicted for the Change Case scenario. There are some minor differences in the frequency of attaining various EWRs under the Cumulative Change scenario compared to the Change Case scenario, but compared to the Base Case scenario, there are still predicted to be improvements in the frequency of achieving baseflow and improvements in the frequency of achieving Native Fish Nesting Support and small freshes EWRs throughout the Yanco Creek System, including the proposal study area. Again, very minor modelled reductions in some very low flow and very high flow EWRs can be attributed to the limitations of the Source model. Therefore it is concluded that operation of the proposal alongside the Forest Creek Return Flows project will result in an overall improvement in the frequency of achieving EWRs for a number of EWR categories to support key ecological values of the system.

1.6 Assumptions

The key assumptions relevant to this hydrological assessment of the proposal are documented throughout the document where relevant, including:

- The operations plan details how the Yanco Creek System will be operated into the future for river operators, local communities and other stakeholders once several infrastructure and other investments are made as part of the Yanco Creek Modernisation Project, which includes the proposal.
- The Source modelling, upon which this assessment is primarily based, has been undertaken according to the general operating principles, regulator pool target levels, normal regulated flow operational limits and unregulated flow operations for regulators and use of irrigation escapes as specified in the Yanco Creek System Operations Plan (NSW DCCEW 2023b).
- The Yanco Creek System Operations Plan acknowledges that operating the Yanco Creek System is complex and requires considerable flexibility. It involves balancing potentially competing objectives, considering a wide range of variables and numerous possible courses of action. Accordingly, the Yanco Creek System Operations Plan does not strictly prescribe what must be done but allows for exercising judgement with an adaptive management approach.

2. Assessment approach and methodology

2.1 Legislative and policy context to the assessment

This section summarises the legislation, guidelines and/or policies driving the approach to the hydrology assessment.

The SEARs requirements relevant to hydrology and where these have been addressed in this report, are discussed in Section 1.5.

2.1.1 Commonwealth legislation

2.1.1.1 Water Act

The Water Act 2007 (Commonwealth Water Act) provides the legislative framework for ensuring that the Murray-Darling Basin – Australia's largest water resource – is managed in the national interest. The Commonwealth Water Act aims to:

- Improve water security for all uses of water resources in the Basin;
- Promote the use and management of the Basin's water resources in a way that optimises economic, social and environmental outcomes;
- Ensure the return to environmentally sustainable levels of extraction for water resources that are overallocated or overused;
- Protect, restore and provide for the environment of the Basin;
- Maximise the economic returns to the Australian community from the use and management of the Basin's water resources;
- Implement relevant international agreements to address threats to the Basin's water resources;
- Ensure that the management of the Basin's water resources takes into account the broader management of natural resources in the Basin;
- Achieve efficient and cost-effective water management and administrative practices in relation to the Basin's water resources; and
- To provide for the collection, collation, analysis and dissemination of information about:
 - Australia's water resource
 - The use and management of water in Australia.

Components of the Commonwealth Water Act of relevance to this assessment include:

- The Murray Darling Basin Authority (MDBA), which is the regulatory body responsible for overseeing water resource planning in the Murray-Darling Basin as a whole; and
- The Basin Plan which is a strategic plan for the integrated and sustainable management of water resources in the Murray-Darling Basin (discussed below).

2.1.1.2 The Basin Plan

The Basin Plan (MDBA, 2012) is the overarching, strategic plan for the integrated and sustainable management of water resources in the Murray-Darling Basin.

The Basin Plan provides a coordinated approach to managing Basin water resources across Queensland, NSW, ACT, Victoria and South Australia. In NSW, the plan came into effect following the signing of Inter-governmental and National Partnership Agreements in 2014. As lead agency, NSW DCCEEW (Water) is working across government with the Biodiversity and Conservation Division and Department of Primary Industries

(Fisheries) and other agencies to implement the plan. There are several sub-plans of the Basin Plan which are relevant to this proposal and have been considered for this assessment. These are described below.

2.1.2 NSW State Legislation, strategies, policies and guidelines

2.1.2.1 Water Management Act 2000 (and Water Act 1912)

The *Water Management Act 2000* (WM Act) is the primary legislation for the management of water in NSW. The WM Act contains provisions for the licensing of water access and use. Groundwater quality protection is also achieved through consideration of both the objects and principles of the WM Act.

In general, the WM Act governs the issue of Water Access Licences (WALs) and approvals for those water sources (rivers, lakes, estuaries and groundwater) in NSW, where Water Sharing Plans (WSPs) have commenced. WSPs have commenced within the study area and are shown in Table 2-1.

Table 2-1 Surface water and Groundwater Water Sharing Plans and sources in the study area.

Water type	Water Sharing Plan	Water Source of Management Area
Surface water	Water Sharing Plan for the Murrumbidgee Unregulated River Water Sources 2012	Lower Billabong Anabranh Water Source
	Water Sharing Plan for the Murrumbidgee Regulated River Water Sources 2020	Murrumbidgee Regulated River Water Source
Groundwater	Murray Alluvial Groundwater Sources 2020	Lower Murray Shallow Groundwater Source
	Murrumbidgee Alluvial Groundwater Sources 2020	Lower Murrumbidgee Shallow Groundwater Source

Section 91 of the WM Act requires an 'activity approval' to carry out a 'controlled activity' in, on or under waterfront land or to carry out an aquifer interference activity. An activity approval (including a controlled activity approval) under section 91 of the WM Act is likely to be required prior to commencement of construction activities.

Further, typically if an activity leads to a take from a groundwater or surface water source covered by a Water Sharing Plan, then an approval and/or licence is required. In general, the WM Act requires:

- A water use approval to use the water;
- A water management works approval, particularly a water supply work approval to construct and use a specified water supply work at a specified location; and,
- A WAL to take water.

2.1.2.2 Fisheries Management Act 1994

The *Fisheries Management Act 1994* (FM Act) provides for the conservation, protection and management of fisheries, aquatic systems and habitats in NSW. The FM Act is administered by NSW Fisheries as part of Department of Primary Industries (DPI) and establishes mechanisms for:

- The listing of threatened species, populations and ecological communities or key threatening processes (KTPs);
- The declaration of critical habitat;

- Issuing permits for certain works on 'water land';
- Requiring the provision of fishways in the construction of weirs; and
- Consideration and assessment of threatened species impacts in the development assessment process.

Sections of the FM Act which are applicable to this assessment are discussed below:

Fish Passage

Section 218(5) provides that a public authority that proposes to construct, alter or modify a weir on a waterway (or to approve of any such construction, alteration or modification) must notify the Minister of the project, and must, if the Minister so requests, include as part of the works a suitable fishway or fish bypass.

Section 219 prohibits the blocking of fish passage without a permit.

Key threatening processes (KTPs)

Part 7A of the FM Act states that a threatening process is eligible to be listed as a "key threatening process" (KTP) if, in the opinion of the Fisheries Scientific Committee:

- "it adversely affects threatened species or ecological communities", or
- "it could cause species or ecological communities that are not threatened to become threatened".
- Schedule 6 of the FM Act outlines the KTPs related to aquatic species and ecological communities. Of the KTPs listed, the proposal is expected to involve the following:
 - Installation and operation of instream structure and other mechanisms that alter natural flow regimes of rivers and streams;
 - Degradation of native riparian vegetation along NSW watercourses; and
 - Removal of large woody debris from NSW rivers and streams.

Alteration to the natural flow regimes of rivers is recognised as a major contributing factor to the loss of biological diversity and ecological function in aquatic ecosystems and is considered a Key Threatening Process (The Installation and Operation of Instream Structures that alter Natural Flow Regimes of Rivers and Streams).

2.1.2.3 NSW Water Quality and River Flow Objectives

The NSW Water Quality and River Flow Objectives (DCCEEW, 2006) are the environmental values and long-term goals for NSW surface waters. The NSW Water Quality and River Flow Objectives are in two parts, the NSW water quality objectives (WQO) and NSW river flow objectives (RFO), which are distinct because they relate to different environmental attributes of a waterway that are important for long term functionality. Proposal impacts to NSW river flow objectives nominated for waterways within the surface water study area have been described and addressed in this report. NSW water quality objectives have been described and addressed in the Billabong Creek Regulators Surface Water Quality and Aquatic Ecology Assessment. From herein, this report will only refer to the NSW river flow objectives.

The NSW RFOs are the agreed high-level goals for surface water flow management which have been developed by the NSW Government (DCCEEW, 2006). They identify the elements of the flow regime that protect river health and water quality for ecosystem and human uses. Each objective aims to improve river health by recognising the importance of natural river flow patterns. A set of objectives has been developed for the Murray River catchment which, under the RFO framework, includes the Yanco Creek system and the proposal site. Billabong Creek has been classified as a controlled river with altered flows (regulated Creeks) and therefore has the following river flow objectives:

- Protect natural low flows.
- Protect important rises in water levels.
- Maintain wetland and floodplain inundation.

- Mimic natural drying in temporary waterways
- Maintain natural flow variability.
- Maintain natural rates of change in water levels.
- Manage groundwater for ecosystems.
- Minimise effect of weirs and other structures.

2.1.2.4 Policy and Guidelines for Fish Habitat Conservation and Management 2013

The *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013) is the guideline applicable to all planning and development proposals and various activities that affect freshwater ecosystems in NSW. The aims of this guideline are to maintain and enhance fish habitat for the benefit of native fish species, including threatened species in freshwater environments. First published in 1999, the 2013 updated document assists developers, their consultants, and government and non-government organisations to ensure their actions comply with legislation, as well as policies and guidelines that relate to fish habitat conservation and management. It is also intended to inform land use and natural resource management planning, development planning and assessment processes, and to improve awareness and understanding of the importance of fish habitats and how impacts can be mitigated, managed and offset. The guidelines outlined in this document are taken into account when NSW Fisheries assesses proposals for developments and other activities that affect fish habitats. The document contains:

- Background information on aquatic habitats and fisheries resources in NSW;
- An outline of the legislative requirements relevant to planning and development which may affect fisheries or aquatic habitat in NSW;
- General policies and classification schemes for the protection and management of fish habitats and an outline of the information that NSW Fisheries requires to be included in development proposals that affect habitat;
- Specific policies and guidelines aimed at maintaining and enhancing the free passage of fish through instream structures and barriers;
- Specific policies and guidelines for foreshore works and waterfront developments; and
- Specific policies and guidelines for the management of other activities that affect watercourses.

2.1.2.5 NSW Weirs Policy 1997

The NSW Weirs Policy provides a framework for the review of weirs across the state and establishes the goals and principles for the ongoing approval and management of weirs, including making formal allocations to the environment based on the best scientific information available (DPI, 1991). The goal of the NSW Weirs Policy is to halt and, where possible, reduce and remediate the environmental impacts of weirs. The goal is to be supported by the adoption of the following management principles:

1. The construction of new weirs, or enlargement of existing weirs, shall be discouraged.
2. Weirs that are no longer providing significant benefits to the owner or user shall be removed, taking into consideration the environmental impact of removal.
3. Where retained, owners shall be encouraged to undertake structural changes to weirs to reduce their environmental impact on the environment. For example
 - a. reducing the crest level and pool storage volume to the minimum necessary to satisfy the purposes for which the weir is required;

- b. modification of the weir to reduce its impact. For example, installing a larger outlet to permit the release of environmental flows or water level variation, or installing a dropboard or gated opening to allow free flow when the weir is not needed; and
 - c. constructing a fishway or modifying an existing fishway to reduce the weir's impact on fish passage.
4. Where retained, owners of weirs with regulatory works shall prepare and adhere to operational plans to reduce the environmental impact of those weirs. For example:
- a. achieving water level variations;
 - b. setting minimum rates of change for discharge and storage draw-down to mimic natural changes of water level within and downstream of the weir;
 - c. raising gates fully during any portion of the year when a weir is not needed, such as in the non-irrigation season or during significant unregulated flows; and
 - d. raising gates at times critical to maintenance of river health, wetlands, fish etc.
5. Where retained, gates, offtake structures and fishways on all weirs shall be maintained in good working order.
- a. Wetlands and riparian vegetation adjacent to weirs should be protected from permanent inundation.
 - b. Areas of environmental degradation caused by the impacts of weirs upstream and downstream of weir pools, should where possible be rehabilitated.
 - c. A respect for the environmental impact of weirs should be encouraged in all agencies and individuals who own, manage or derive benefits from weirs.

The NSW Weirs Policy has three components, the first relates to the approval to build a new, or expand an existing weir, the second is a review of all existing weirs (Weir Review Program) and the third is to address the provision of fishways.

The 'Weir Review Program' component was first implemented following the then NSW Fisheries and Department of Land and Water Conservation initial weir review program in 1999. This review evaluated the impact of licenced dams and weirs on fish passage for the purpose of identifying sites for remediation. Both the Hartwood Weir and Wanganella Town Weir were identified in this initial review (NSW DPI 2006). Hartwood Weir was identified for remediation as it acts as a barrier to fish passage during most flow conditions as the weir does not drown out and the area is recognised as key habitats for important fish species including threatened fish species and endangered ecological communities. Wanganella Town Weir was identified for remediation as it acts as a barrier to fish during low flow conditions (although does drown out several times a year). Similarly to Hartwood, it is recognised as key habitats for important fish species and the site is crucial for fish recruitment and migration (NSW DPI, 2006).

The NSW Weirs Policy requires that a proposal to build a new weir or enlarge an existing weir should not be approved unless it can be demonstrated that the primary component of the proposal is necessary to maintaining the essential social and economic needs of the affected community. In determining the need for a new or expanded weir, the following general principles apply:

- Provision for fish passage cannot be used as a sole justification to approve a proposal to enlarge an existing weir.
- An increase in town water supply for the purposes of meeting projected population demand cannot be used as a justification to approve a proposal to build a new, or expand an existing weir, if environmentally friendlier alternatives to meeting that demand exist, which are also economically feasible.
- Provision for future industrial expansion (such as, but not limited to, tourism) cannot be used as a justification to build a new or expand an existing weir.

- Subject to the usual EIA process, a proposal for the construction of new, or expansion of an existing weir, that will result in a net environmental benefit may be approved

The existing Hartwood and Wanganella weirs are currently in states of declining condition, which limits their ability to regulate flows through the Yanco Creek system and leads to inefficiencies in how water is delivered to the environment and irrigators. As discussed in Section 1.4.3, the new regulators are intended to facilitate smarter use of water within the Yanco Creek system by enabling the reduction of unplanned surpluses and shortfalls. As a result, it is intended that there is a reduction to the risk of additional adverse local socioeconomic outcomes resulting from additional water market purchases required to meet legislative water recovery targets of the Murray-Darling Basin Plan 2012. Therefore, it is necessary to seek approval for the proposal to maintain the essential social and economic needs of the affected community. In addition to this, it is anticipated that there will be a net environmental benefit under operation of the proposal, as a result of modelled increases in attainment of certain environmental watering requirements. This is discussed in further detail in Sections 4.2.5 and 4.3.5.

In response to principle 2, the hydrological and resulting environmental impacts of replacing the existing Hartwood and Wanganella weirs with new regulators is discussed in Section 4. In response to principle 3, to reduce the environmental impact of the new regulators, the proposal includes the provision of automated lay flat gates to allow for movement of fish downstream and provide for a low turbulence 'keyhole' type vertical slot fishway with allowances for variable headwater to provide upstream fish passage. In response to principle 4, the owners of the new regulators will adhere to the Yanco Systems Operations Plans and manuals for these new regulators, which will take into account the regulation requirements at each regulator as well as constraints such as limits to rates of rise and fall to accommodate fish breeding requirements. In response to principle 6, weir pool extents have been assessed to ensure that wetlands and riparian vegetation adjacent to weirs are protected from permanent inundation (refer to Section 5).

2.1.2.6 Murrumbidgee Long Term Water Plan - Part A: Murrumbidgee catchment and Part B: Murrumbidgee planning units

The Murrumbidgee Long-Term Water Plan (LTWP) is one of nine plans developed by NSW DCCEEW to cover the NSW portion of the Murray-Darling Basin. The Murrumbidgee LTWP is in two parts – Part A, which presents a catchment-scale description of the flow regimes required to maintain or improve environmental outcomes in the Murrumbidgee (DPIE, 2020a); and Part B, which describes the flow regimes required to maintain or improve environmental outcomes in the Murrumbidgee at a planning unit scale (DPIE, 2020b).

To address variation along the Murrumbidgee River, the Murrumbidgee Long-Term Water Plan divides the river into 14 planning units, which correspond to the 14 management zones in the WSP. The proposal spans across a number of planning units, with the proposed Hartwood Regulator located within the relevant planning units (PU) of Colombo and Billabong Creeks (PU11) and the proposed Wanganella Regulator located within the Lower Billabong and Intersecting Streams (PU13).

2.1.2.7 Murrumbidgee Surface Water Resource Plan (2020)

The proposal falls within the Murrumbidgee Surface Water Resource Plan: SW9 Water Resource Plan Area which comprises water between the banks of the Murrumbidgee River, from Burrinjuck Dam and Blowering Dam downstream to the confluence of the River Murray. It also includes the Lowbidgee and Yanco Creek, Colombo Creek, and lower sections of Billabong Creek. The WRP includes the regulated river systems, unregulated rivers flowing into the regulated river systems, unregulated gaining creeks flowing out of the regulated river system onto the plains, and water captured through farm dams.

2.1.2.8 Water Sharing Plan for the Murrumbidgee Regulated River Water Source (2020)

The Water Sharing Plan for the Murrumbidgee Regulated River Water Source (the Plan) supports sustainable water resources management within the Murrumbidgee region. The Plan outlines objectives for the long-term viability of water resources for the protection and enhancement of the environmental health of the Murrumbidgee River and its ecosystems. It establishes water allocation rules for water entitlements among various users, including environmental flows, irrigation, industry and urban supply, including water use restrictions, adjusting allocation rules and water-saving practices.

2.1.2.9 Draft Murrumbidgee Regional Water Strategy (2022)

The Draft Murrumbidgee Regional Water Strategy is one of the regional water strategies being developed by the then Department of Planning and Environment in partnership with water service providers, local councils, Aboriginal communities and other stakeholders across NSW. This strategy guides how the NSW Government address water-related challenges to support the Murrumbidgee region.

The proposal would support the delivery of four of the objectives, namely to:

- deliver and manage water for local communities – improve water security, water quality and flood management for regional towns and communities
- enable economic prosperity – improve water access reliability for regional industries
- recognise and protect First Nation's water rights, interests and access to water - Including Aboriginal heritage assets
- protect and enhance the environment.

2.1.2.10 Draft Murray Regional Water Strategy (2022)

The proposal would support the delivery of a number of options and commitments outlined in the strategy, including:

- insufficiently integrated land and water planning and management—to better integrate water resource management
- current water sharing arrangements based on 125 years of data—to consider the adequacies of existing water sharing and management arrangements in the region under a more variable and changing climate
- degradation of riverine and floodplain ecosystems—to address the risk to the environment, the ecology and groundwater dependent ecosystems and improve the health of the region's rivers and groundwater sources
- limits to water availability in times of a changing climate—to better understand water use behaviour, and to develop strategies and information to build greater resilience.

2.2 Methods

2.2.1 Study area

For the purposes of the assessment the proposal footprint, study area and area of investigation have been defined as follows:

Proposal footprint

The area that would be directly disturbed by construction and the location of operational infrastructure. The disturbance area would include clearing areas, construction activity zones, access tracks and power supply corridors. The proposal footprint is shown in Figure 1-5 and Figure 1-6.

Study area

The footprint of the proposal and the surrounding area with the potential to be directly affected by the proposal. As such, the study area for this hydrological impact assessment is considered to be from Billabong Creek at Jerilderie, just upstream of where the new regulators are located, to Billabong Creek at Darlot, which is where the most downstream gauge of the Yanco Creek System is located. The study area footprint is shown in Figure 2-1.

However, because of the potential indirect effects of the proposal on the broader Yanco Creek System as well as the inclusion of broader operational changes as per the Yanco Creek System Operations Plan (NSW DCCEEW 2023b), this hydrological impact assessment requires that the area of investigation be broadened beyond the study area to encompass the entire Yanco Creek System. This is discussed below.

Area of investigation

The area of investigation covered by this hydrological impact assessment is the entire Yanco Creek System starting from Yanco Creek at Yanco Offtake and finishing at Billabong Creek at Darlot (see Figure 2-3). This encompasses a broader area than that which is anticipated to be directly impacted by the new regulators (i.e. the study area), because the impacts of the new regulators have been assessed within the context of broader operational changes as per the Yanco Creek System Operations Plan (NSW DCCEEW 2023b) that influence river sections further upstream of the study area. This approach allows the cumulative hydrological impacts of the proposal infrastructure and operational rules to be assessed.

The Planning Units defined in the Murrumbidgee Long Term Water Plan Part A: Murrumbidgee catchment (NSW DPIE 2020) within the Yanco Creek System have been adopted for the hydrological assessment. The planning unit boundaries typically align with water source boundaries in the Murrumbidgee Water Resource Plan (NSW Government 2018). The following Planning Units are present within the area of investigation:

- **PU10: Upper Yanco Creek** - The Upper Yanco Creek PU is situated within the Murrumbidgee Western Water Source. Flows into the Yanco Creek System go through the Yanco offtake cutting. Flows are controlled by altering the height of Yanco Weir on the Murrumbidgee River downstream of the cutting.
- **PU11: Colombo & Billabong Creeks** - The Colombo & Billabong Creeks PU is situated within the Murrumbidgee Western Water Source and Lower Billabong Anabranh Water Source. It begins where Colombo Creek bifurcates from Yanco Creek near Morundah. The division of flows between Colombo Creek and Lower Yanco Creek is controlled by Tarabah Weir. Colombo Creek flows into Billabong Creek upstream of Jerilderie. Upstream of this junction, Billabong Creek is unregulated. The PU ends where Lower Yanco Creek joins Billabong Creek.
- **PU12: Lower Yanco Creek to Lower Billabong Creek** - The Lower Yanco Creek to Lower Billabong Creek PU is situated within the Murrumbidgee Western Water Source. It begins where Colombo Creek bifurcates from Yanco Creek near Morundah. The division of flows between Colombo Creek and Lower Yanco Creek is controlled by Tarabah Weir. The PU ends where Lower Yanco Creek joins Billabong Creek.

- **PU13: Lower Billabong and Intersecting Streams** - The Lower Billabong and Intersecting Streams PU is situated within the Lower Billabong Anabranh Water Source. It includes Forest Creek and Piccaninny Creek.



Figure 2-1 Study area for the hydrology assessment.

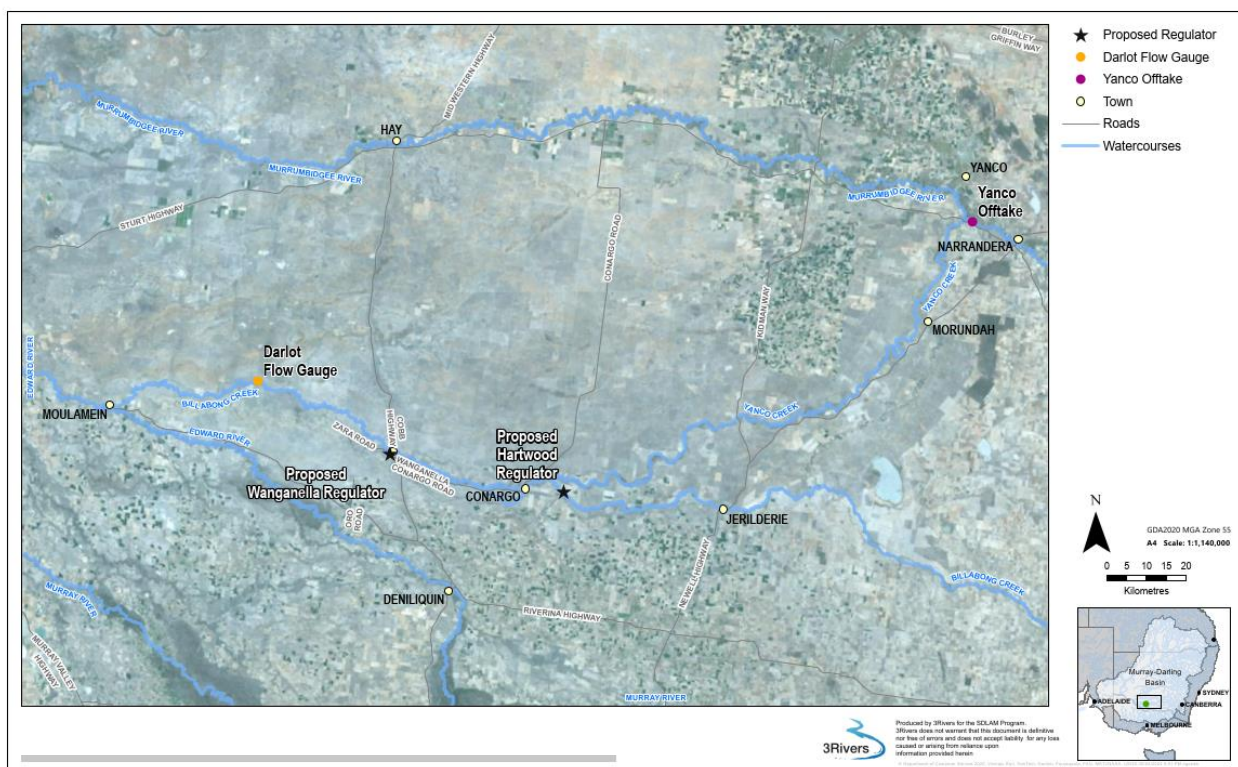
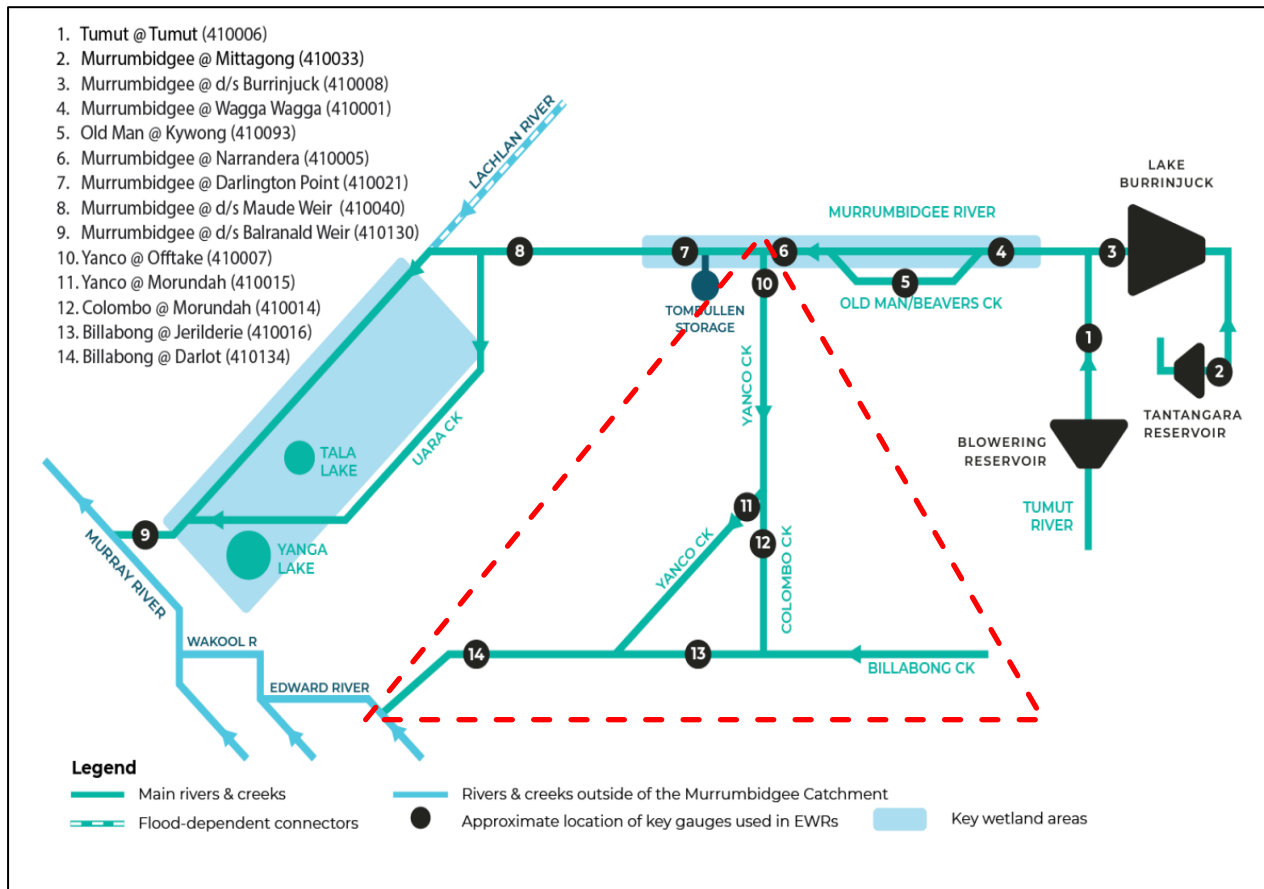


Figure 2-2 Area of Investigation for the hydrology assessment.



Modified from Murrumbidgee Long Term Water Plan Part A: Murrumbidgee catchment (NSW DPIE 2020)

Figure 2-3 Schematic diagram of the main watercourses, Planning Units and streamflow gauges in the Murrumbidgee catchment, with the area of investigation (Yanco Creek System) highlighted in red.

2.2.2 Construction impact assessment method

The construction impacts of the proposal on hydrology, to the extent of the proposal's influence up and down stream, have been assessed qualitatively based on available information for the construction methods and components and phasing of works associated with the proposal. The following qualitative assessments were undertaken to assess the construction impacts of the proposal:

- Impact on hydrology of Billabong Creek
- Impact on achievement of the relevant NSW River Flow Objectives across the area of investigation

2.2.3 Operational impact assessment method

The following quantitative and qualitative assessments were undertaken to assess the operational impacts of the proposal:

- Change in key flow regime characteristics across the area of investigation, using Source modelling
- Change in EWR achievement across the area of investigation, using Source modelling and the EWR tool
- Change in water extractions (irrigation + town water supply) across the area of investigation, using Source modelling
- Change in effective general security allocations across the area of investigation, using Source modelling

- Impact on achievement of the relevant NSW River Flow Objectives across the area of investigation

The framework adopted to assess the degree of change in flow regime characteristics under operation of the proposal when compared to the modelled current conditions is described in Table 2-2. Source modelling has been undertaken to assess key flow regime characteristics, and this is described in further detail in Section 2.2.4.

The same framework has been adopted to assess the degree of change in EWR achievement under operation of the proposal when compared to the modelled current conditions. An EWR assessment has been undertaken using the Source modelling results and the EWR Tool and this is described in further detail in Section 2.2.5.

This framework (Table 2-2) has been adapted from the framework determined by DPIE-Water in their Murrumbidgee Water Resource Plan Risk Assessment (DPIE-Water 2019). In the Murrumbidgee Long Term Water Plan (NSW DPIE 2020b), it was adopted to assess the degree of change in flow regime characteristics when comparing current conditions to near natural conditions (with no dams or water extractions). Thus, it is deemed to be an appropriate framework for this assessment on the operational impacts of the proposal.

It should be noted that we are unable to comment on the significance/insignificance of changes in key flow regime characteristics when compared to modelled current conditions without undertaking statistical analysis, which has been deemed to be out of scope of this hydrological impact assessment.

Table 2-2 Hydrologic alteration and EWR achievement categories adopted for the operational impact assessment.

Modified from Murrumbidgee Water Resource Plan Risk Assessment (DPIE-Water 2019)

Rating	Description for hydrologic alteration categories	Description for EWR achievement categories	Colour coding
Low (L)	Less than 20% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions	100-80% achievement of required frequency as per the EWRs	Low
Medium (M)	20-50% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions	80-50% achievement of required frequency as per the EWRs	Medium
High (H)	More than 50% difference (+/-) from Base Case scenario conditions	< 50% achievement of required frequency as per the EWRs	High
N/A	No risk outcome available	No risk outcome available	N/A

In addition to an assessment of key flow regime characteristics and achievement of environmental water requirements, an assessment of the proposal's impacts on water extractions (irrigation + town water supply) and effective general security allocations (on opening allocation (1-July), summer planning decision dates (15-September and 1-October) and end the Year (30-June) has been undertaken using the Source modelling results. General security licences are the last to receive allocations and are therefore the least secure licence

category. As such, by assessing this licence category, we are able to conservatively assess the impact of the proposal on water allocations (i.e. available water determinations - AWD).

An assessment of the proposal's impacts with respect to the relevant NSW River Flow Objectives has also been undertaken to comprehensively assess the operational impacts of the proposal. These objectives are further discussed in Section 2.2.6.

2.2.4 Source modelling

The sections below summarise the key elements, assumptions and limitations of NSW DCCEEW's modelling scenario builds and runs. For further details on the method, please refer to the "Technical Memo: eWater Source Modelling to support the EIS for re-regulation weirs" developed by NSW DCCEEW and dated 11th December 2023 as well as the Draft Yanco SDLAM Hydrological Model Build Report developed by NSW Department of Primary Industries and Environment and dated 2021.

An eWater Source model was developed by NSW DCCEEW for the Murrumbidgee Regulated River System. eWater Source is a hydrological modelling tool that is designed to support integrated water resources planning, policy and management. The choice of eWater Source was dictated by the need to integrate with the larger Murrumbidgee River system model being developed by the DPE-Water modelling team, and eWater Source's unique framework for representing water sharing arrangements in the Basin.

Based on discussions with the project team, the current version the Murrumbidgee Source Model (subversion revision 300) was deemed to be appropriate to assess the impacts of the proposal over the long-term climatic period. The SOURCE model has yet to be externally reviewed in its entirety. However, the flow calibration of the Yanco-Colombo-Billabong (YCB) System has been independently reviewed and deemed fit for purpose for the Yanco Modernisation Project.

The Murrumbidgee Source Model simulates the following processes:

- diversions for irrigation and town water supply
- environmental water demands
- flow routing (i.e. the lag and attenuation of flows as they move through the river system)
- rainfall-runoff processes
- net evaporation from water surfaces
- volumetric losses
- weir and irrigation escape operations
- resource allocation.

The Murrumbidgee Source Model has been calibrated to historical data as per Table 2-3. NSW DCCEEW then used this Base model to build the Base Case, Change and Cumulative Change scenario models. The results from these models were then provided to 3Rivers for interpretation. Model outputs include daily time series from the long-term model run (1/07/1895 – 30/06/2020) at flow gauging sites and other points of interest in the Yanco Creek system.

Table 2-3 Description of calibration method for different components of the Murrumbidgee Source Model

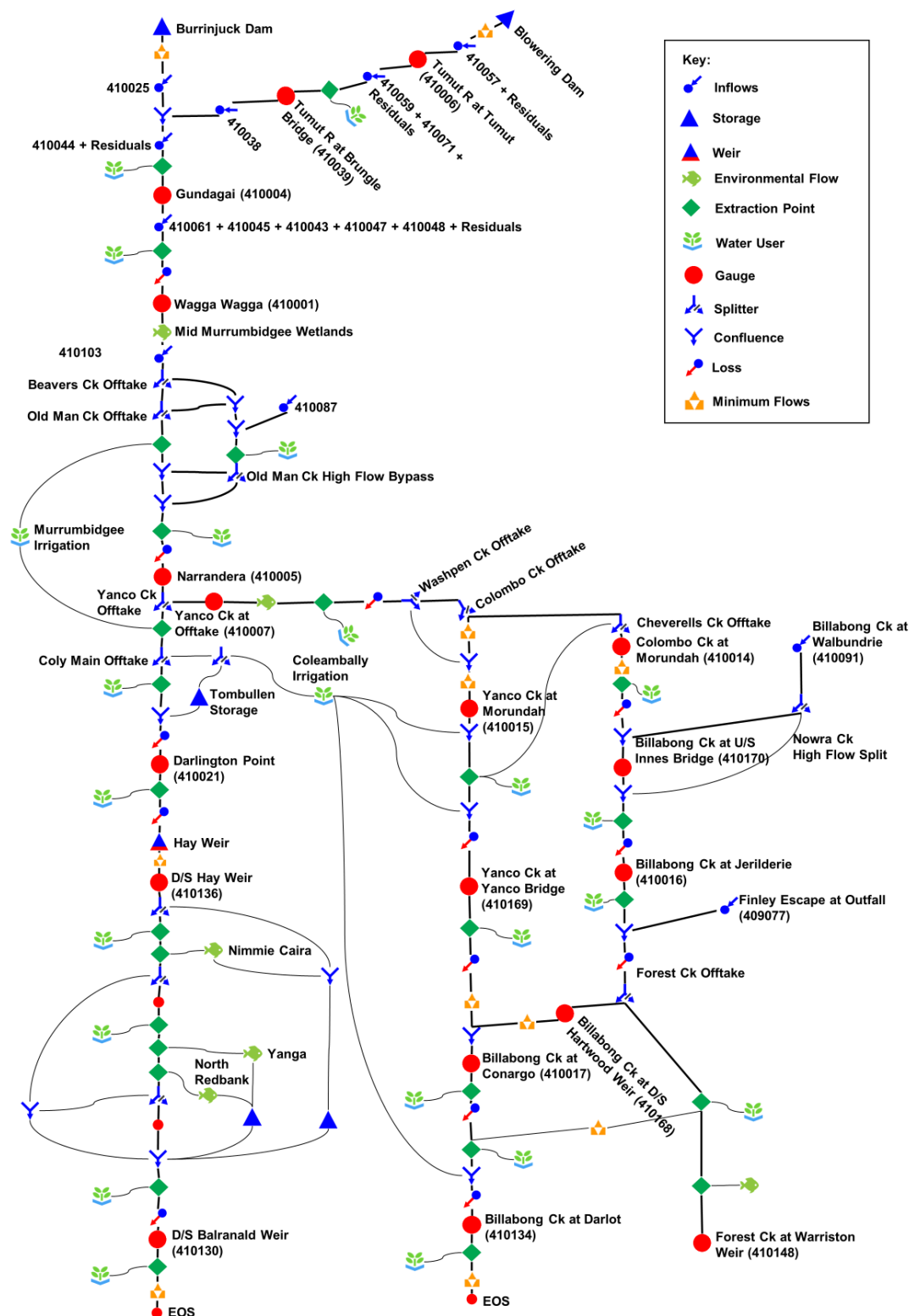
Model Calibration Component	Subcomponents	Description of calibration
Flow Calibration (Whole Murrumbidgee)	- Headwater calibrations - Reach calibrations - Observed Diversions	- Full flow model calibrated from 1982 – 2018 - Flow calibration in the YCB System from 1995-2018
Demand Calibration – Town water Supply	9 Urban Water supplies represented. 3 in the YCB System	Calibrated from the 2004/2005 water year to 2017/2018 water year, when there is better quality demand data
Demand Calibration – Irrigation	- Murrumbidgee Irrigation Area (MIA) Coleambally Irrigation Area (CIA) Main River irrigators lumped to reach scale - Yanco-Colombo-Billabong irrigators lumped to reach scale	- Calibrated from the 2004/2005 water year to 2017/2018 water year, when there is better quality demand data - Shorter periods used in some reaches where there was a clear change in behaviour post millennium drought.
Demand Calibration – Environmental Watering	- Mid River Wetlands and other Main Murrumbidgee demands - Yanco environmental demands (Cod Flows, Wanganella Swamp) - Lowbidgee Environmental Demands	Calibrated with 22,000 ML/day constraint at Wagga Wagga.
Water Management rules (and river operations)	- Water Accounting (entitlement distribution as of 30th June 2018) - Resource Assessment - Water Trading - Supplementary water access - Planned environmental water (e.g. min flow requirements, translucent and transparent releases) - Water orders and river operations (maximum constraints) - Interactions with other models (Snowy and Murray)	- Nominal calibration period of 2004/2005 to 2017/2018 - Consideration for Water for Rivers by adjusting inflows to Bowering Dam.

2.2.4.1 Source model scenarios

2.2.4.1.1 Base Case scenario

The Base Case scenario is representative of current conditions and operations. This includes existing weir structures, including the existing Hartwood and Wanganella weirs, flow constraints, environmental baseflow provisions, environmental flow provisions and irrigation escape flows under current conditions. It should be noted that there is no explicit representation of the current operation of the existing Hartwood or Wanganella weirs in the Base Case scenario model as they do not significantly re-regulate flow. This is consistent with the model development process adopted for the Murrumbidgee Source Model.

Figure 2-4 provides an overview of the key components of the Base Case scenario Source model, including the location of key storages, inflows, flow gauging stations, diversions, and environmental demands. Table 2-4 summarises the key inputs for the Base Case scenario Source model and compares these to the key inputs of the other model scenarios.



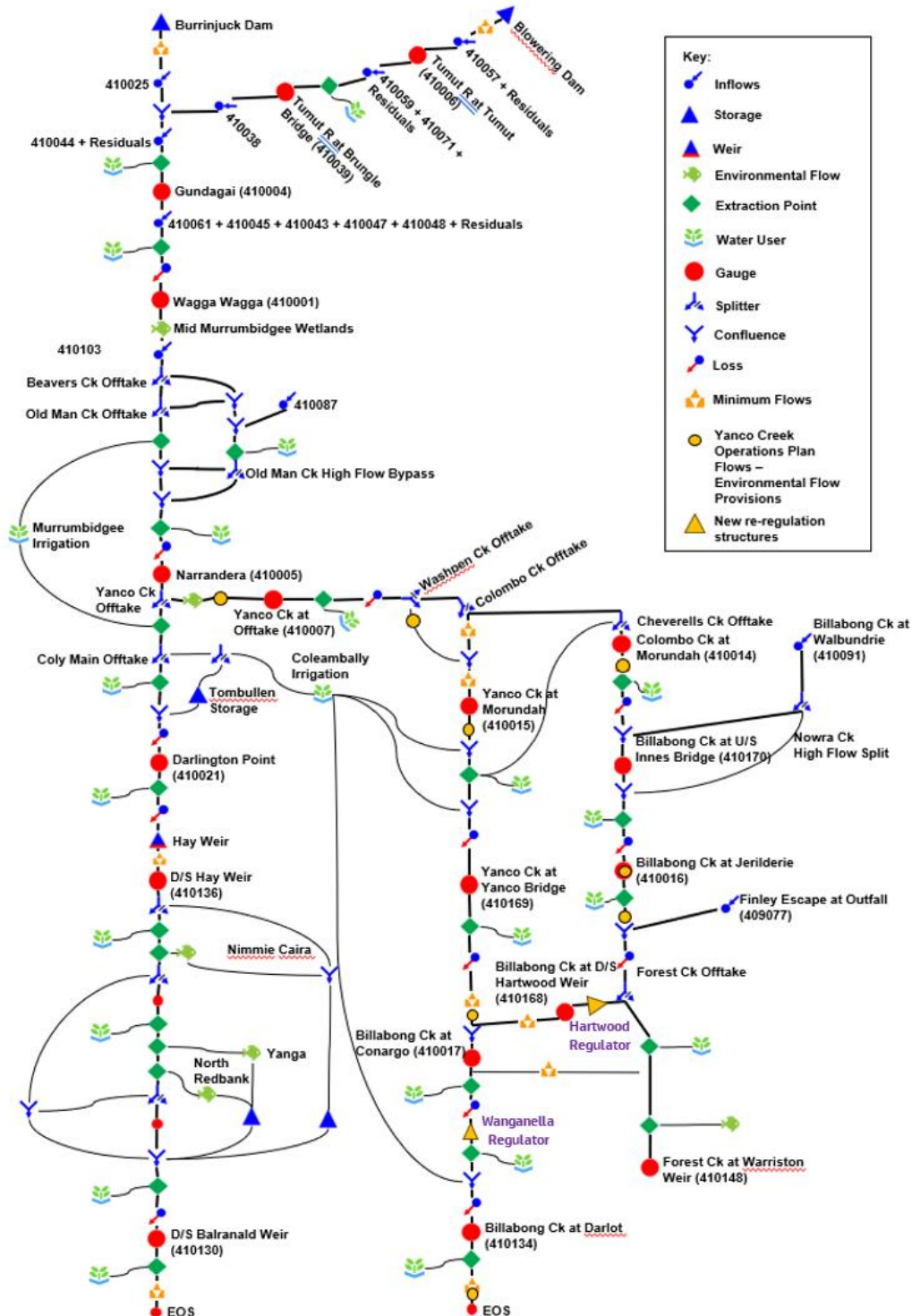
Source: Yanco Modernisation – Murrumbidgee Source Model Runs. eWater Source Modelling Technical Memo (NSW DCCEW 2023a).

Figure 2-4 Schematic of the Base Case scenario Source model

2.2.4.1.2 Change scenario

The Change Case scenario represents the potential impacts of the components of the SDLAM project that are subject to the EIS process, specifically, the replacement of the Hartwood and Wanganella weirs along Billabong Creek with new regulators, within the context of implementation of the broader operational changes documented in the Yanco Creek System Operations Plan (NSW DCCEEW 2023b). The reason why both the new regulators and the broader operational changes documented in the Yanco Creek System Operations Plan have been modelled is because it is intended that these changes will be implemented at the same time. Thus, DCCEEW have deemed it to be appropriate for the Change Case scenario to include both the new regulators and the broader operational changes.

Figure 2-5 provides a graphical overview of the key components of the Change Case scenario Source model, with the introduction of the new operating principles and limits for using irrigation escapes, new environmental baseflow provisions and the replacement of the Hartwood and Wanganella weirs along Billabong Creek with new regulators. Table 2-4 summarises the key inputs for the Change Case scenario Source model, including the proposed operational changes documented in the Yanco Creek System Operations Plan, and compares these to the key inputs of the other model scenarios. The Change Case scenario is consistent with the Yanco Creek System Operations Plan unless otherwise stated in Table 2-4. This includes new operating principles and limits for using irrigation escapes within the Coleambally Irrigation Co-operative Limited (CICL) and Murray Irrigation Limited (MIL) irrigation districts to deliver water more adaptively, flexibly and efficiently into the mid sections of the Yanco and Billabong Creeks. This also includes new environmental baseflow provisions for a number of sites which apply during periods when Murrumbidgee general security allocations (officially known as Available Water Determinations) are equal to or greater than 15%.



Source: Source: Yanco Modernisation – Murrumbidgee Source Model Runs. eWater Source Modelling Technical Memo (NSW DCCEW 2023a).

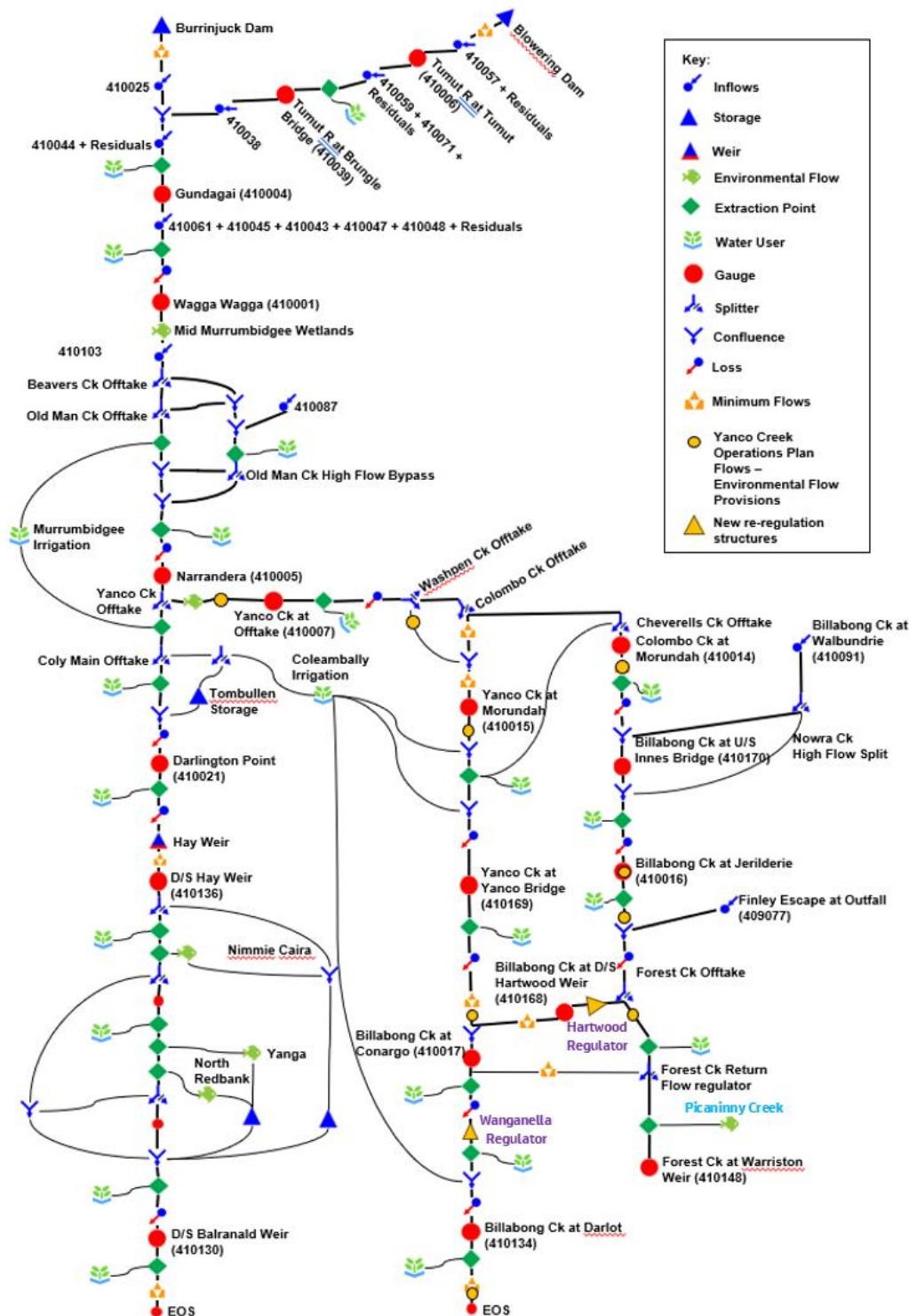
Figure 2-5 Schematic of the Change Case scenario Source model, with the new replacement regulators labelled in purple text.

2.2.4.1.3 Cumulative Change scenario

The Cumulative Change scenario represents the potential impacts of all aspects of the Yanco Modernisation Project that can be incorporated in the Murrumbidgee Source Model. In addition to the replacement of the Hartwood and Wanganella weirs along Billabong Creek with new regulators and implementation of the Yanco Creek System Operations Plan (i.e. the Change Case scenario), the Forest Creek Return Flows Project was incorporated into the Cumulative Change scenario Source model. This includes the 10 ML/day Forest Creek Offtake baseflow when general security allocations are equal to or greater than 15%.

The Forest Creek Return Flows Project involves replacing a block bank and pipe culvert structure in the connecting channel between Forest Creek and Piccaninny Creek, known as Piccaninny Offtake, with a new regulator, referred to as the Forest Creek Return Regulator, in order to allow excess Forest Creek flows (derived from the Forest Creek offtake at Hartwood Weir) to be diverted back to Billabong Creek via the Piccaninny offtake channel and Piccaninny Creek. The offtake channel receives flows from the Warriston Weir pool when it is full enough that water at the upstream end of the pool is directed down the channel. Currently, unplanned flows often overtop Warriston Weir due to mismatches between supply and demand in the regulated reaches of Forest Creek and continue downstream. The Forest Creek Return Flows Project would reduce unplanned flows over Warriston Weir during normal regulated periods. The block bank in the channel has an ungated DN600 pipe culvert that allows some flows coming down Forest Creek to enter Piccaninny Creek and flow back to Billabong Creek under base flow conditions. However, most of the flows coming down Forest Creek carry on to Warriston Weir that is located around 570 m downstream of the connection channel. In addition, this would allow river operators to deliver environmental water more effectively past Warriston Weir without losses of environmental water to Piccaninny Creek. Further detail regarding the general operating principles of Forest Creek Return Regulator can be found in the Yanco Creek System Operations Plan (NSW DCCEEW 2023b).

Figure 2-6 provides a graphical overview of the key components of the Cumulative Change Case scenario Source model, including the proposed Forest Creek Return Flow regulator. Table 2-4 summarises the key inputs for the Cumulative Change scenario Source model, including the proposed operational changes documented in the Yanco Creek System Operations Plan, and compares these to the key inputs of the other model scenarios. The Cumulative Change Case scenario is consistent with the Yanco Creek System Operations Plan unless otherwise stated in Table 2-4.



Source: Source: Yanco Modernisation – Murrumbidgee Source Model Runs. eWater Source Modelling Technical Memo (NSW DCCEW 2023a).

Figure 2-6 Schematic of Cumulative Change Case scenario Source model, with the new replacement regulators labelled in purple text.

2.2.4.2 Summary of scenario model inputs

Table 2-4 summarises and compares the key inputs for the Base Case, Change Case and Cumulative Change Case scenario Source models.

Table 2-4 Summary of key modelling inputs for the Base Case, Change and Cumulative Change scenario Source models.

Model Component	Base Case scenario	Change scenario	Cumulative Change scenario
Flow Constraints	22,000 ML/day at Murrumbidgee @ Wagga Wagga (in line with current operational limits) 1,400 ML/day at Yanco Creek @ offtake 600 ML/day at Colombo Creek @ Morundah	No change from Base Case	
Minimum Flow Targets from the Water Sharing Plan	Darlot End of System Flow Requirement of 50 ML/day plus downstream orders Balranald End of System Flow Requirement Blowering Minimum Flow Requirement Burrinjuck Minimum Flow Requirement	Darlot End of System Flow Requirement has been adjusted to include an environmental baseflow provisions of 200 ML/day at Darlot between the 1st to the 15th of March ¹ , with a maximum rate of fall of 9% to better align with the EWR for fish nesting in the long-term watering plan. Other sites are unchanged.	
Minimum Flow Targets (Current Operations)	Yanco Creek @ Downstream Tarabah Weir (41000213) of 25 ML/day Yanco Creek @ Morundah of 50 ML/day Colombo Creek @ Morundah of 65 ML/day Yanco Creek @ Wiraki of 75 ML/day from 16 th August to 15 th May, and 70 ML/day from 16 th May to 15 th August Billabong Creek @ Downstream Hartwood Weir (410168) of 25 ML/day Piccaninny Creek @ Wanganella Conargo Road of 1 ML/day	No change from Base Case, except for: Yanco Creek @ Morundah = 100 ML/day when General Security allocations exceed 15% Colombo Creek @ Morundah = 100 ML/day when General Security allocations exceed 15%	

Model Component	Base Case scenario	Change scenario	Cumulative Change scenario
Environmental Flow Provisions (New Sites)	None	New environmental baseflow provisions for the following sites which apply during periods when Murrumbidgee general security allocations (officially known as Available Water Determinations) are equal to or greater than 15% - Yanco Creek @ Yanco Offtake (410007) – 250 ML/day, with a maximum rate of fall of 9% between the 14th September and 16th November to better align with the EWR for fish nesting in the long-term watering plan. - Back Creek @ downstream Spillers Regulator – 10 ML/day - Yanco Creek @ Moonyanco – 50 ML/day - Colombo Creek (410014) and Yanco Creek (410015) @ Morundah – 100 ML/day - Billabong Creek @ Jerilderie (410016) – 70 ML/day - Billabong Creek @ Old Coree – 50 ML/day	As per Change scenario, with the addition of a new environmental baseflow provisions for: Forest Creek @ Offtake (41010309) – 10 ML/day when AWDs are greater than 15%
Billabong Yanco flow split	80:20 ratio of order up the Billabong and Yanco at the “Confluence Yanco Creek and Billabong Creek” node. This is consistent with the	As per Base Case scenario	

Model Component	Base Case scenario	Change scenario	Cumulative Change scenario
	representation in the Yanco SDLAM Hydrological Model Build Report: Draft.		
Murray Irrigation Limited (MIL) Finley Irrigation Escape (a.k.a. Billabong Escape)	Time series replaced with an ability to send orders into the Murray. This is consistent with the representation in the Yanco SDLAM Hydrological Model Build Report: Draft.	Updated to reflect the Yanco Creek System Operations Plan as per below. - Orders limited to 250 ML/day. - No orders until flows are forecast to be more than or equal to the following (adjusted for creek flow travel time): - Yanco Creek @ Offtake (410007) – 250 ML/day (assumed twelve-day creek flow travel time from Yanco Creek @ Offtake (410007) to Finley Escape) - Colombo Creek @ Morundah (410014) – 100 ML/day (assumed ten-day creek flow travel time from Colombo Creek @ Morundah (410014) to Finley Escape) - Billabong Creek @ Jerilderie (410016) – 70 ML/day (assumed one day creek flow travel time from Billabong Creek @ Jerilderie (410016) to Finley Escape) Unregulated flow operations were not modelled	
Coleambally Irrigation Co-operative Limited (CICL) Coleambally Catchment Drain Irrigation Escape (CCD)	Ordering between 15 Aug and 15 May. Zero otherwise. Orders limited to 300 ML/day	Updated to reflect the Yanco Creek System Operations Plan as per below. - As per Base Case scenario, with the additional operational limit of no orders until flows are forecast to be more than or equal to the following (adjusted for creek flow travel time): - Yanco Creek @ Offtake (410007) – 250 ML/day (Assumed three-day creek flow travel time from Yanco Creek @ Offtake (410007) to Coleambally Catchment Drain.) Unregulated flow operations were not modelled	
Coleambally Irrigation Co-operative Limited	Ordering between 15 Aug and 15 May. Zero otherwise. Orders limited to 100 ML/day	Updated to reflect the Yanco Creek System Operations Plan as per below.	

Model Component	Base Case scenario	Change scenario	Cumulative Change scenario
(CICL) Drainage Channel 800 (DC800) Irrigation Escape	because it is uncommon for larger water orders to be accepted by CICL	- As per Base Case scenario, with the additional operational limit of no orders until flows are forecast to be more than or equal to the following (adjusted for creek flow travel time): - Yanco Creek @ Offtake (410007) – 250 ML/day (Assumed eight-day creek flow travel time from Yanco Creek @ Offtake (410007) to DC800) - Yanco Creek @ Morundah (410015) – 130 ML/day (Assumed six-day creek flow travel time from Yanco Creek @ Morundah (410015) to DC800) Unregulated flow operations were not modelled	
Billabong Creek regulators	Not included	Included, with Hartwood Regulator and Wanganella Regulator modelled as per operations discussed in Section 2.2.4.1.2.	
Forest Creek offtake	When flow in Billabong Creek at Hartwood Weir exceeds 1200 ML/day, except if this is part of a managed environmental flow event², Forest Creek Offtake Regulator gates send unregulated flows to Forest Creek. Otherwise, i.e. when flow in Billabong Creek at Hartwood Weir is below 1200 ML/day, flows into Forest Creek are controlled by the Forest Creek Offtake Regulator to meet orders. No environmental flow provision for Forest Creek @ Offtake	As per Base Case scenario	As per Base Case scenario, except new environmental flow provision for Forest Creek @ Offtake of 10 ML/day when AWDs are greater than 15%
Forest Creek return flows via Piccaninny Creek	Environmental flow provision for Piccaninny Creek @ Wanganella Conargo Road of 1 ML/day	As per Base Case scenario	Surplus water is sent down Piccaninny Creek to prevent unplanned flows in Forest Creek downstream of Warriston Weir during normal regulated periods based on the following rules

Model Component	Base Case scenario	Change scenario	Cumulative Change scenario
			▪ Achieve 0 ML/day at Forest Creek downstream of Warriston Weir except during managed environmental flow events downstream of Warriston Weir ▪ Divert unplanned flows to Piccaninny Creek rather than permitting flow down Forest Creek up to Forest Creek return regulator's flow capacity of 50 ML/day ▪ Achieve environmental flow provision for Piccaninny Creek @ Wanganella Conargo Road of 1 ML/day
Demand models	Irrigation demand model and Town Water Supply models calibrated to data from 2004-2018 and an area factor applied to set the consumptive take to the current estimate of the Model Diversion Limit (1599.61GL, which is the previous Murrumbidgee SDLAM model's (Revision 300) diversion limit of 1634.20GL less 34.51GL of recovery to account for full bridging the gap target) over the basin planning period (1895-2009)	No change from Base Case scenario	
Environmental Demands	Current set up as at Murrumbidgee Model repository version 300.	No change from Base Case scenario	

Model Component	Base Case scenario	Change scenario	Cumulative Change scenario
Entitlement Distribution	As at 30 th of June 2018 + an additional 34.51GL of recovery to account for full bridging the gap target (known water recovery). Further details are provided to the right.	No change from Base Case scenario. The input set adjusts the entitlements in the underlying Murrumbidgee model for any post 2018 environmental water recovery. This involves moving 18,682 shares from MIA Conveyance Entitlement to the Environment, 3,982 shares of High Security Entitlement from the irrigators to the Environment and 24,311 shares of General Security Entitlement from Irrigators to the Environment. The reduction in High Security and General Security Entitlements has been spread across all irrigation nodes based on the proportion of entitlement at these nodes in the current conditions model.	

¹ Note that the Operations Plan allows this to be delivered during any consecutive 14-day period between 1 February and 31 March.

² Note that the Operations Plan includes additional flexibility provisions that extend beyond the limitations of the Source model.

2.2.4.3 Flow regime characteristics assessed

Using outputs from the Source modelling, the Yanco Creek System's flow regime characteristics under each of the three scenarios have been assessed to determine the impacts of the proposal as well as the cumulative impacts when considered with other proposed changes in the vicinity.

The metrics and analyses adopted to assess the flow regime characteristics are described in Table 2-5. More detailed metrics have been assessed to determine the impacts of the proposal on scoring against specific environmental water requirements. These are detailed in Section 2.2.5.

Table 2-5 Flow regime characteristics and the corresponding metrics and analyses adopted to assess hydrological impacts of the proposal.

Flow regime characteristic	Metrics adopted at key locations within area of investigation	How the results have been used
Flow volume	Change in mean annual water balance from Base Case scenario under the Change Case scenario and Cumulative Change scenario over the modelling time period of 1 July 1895 to 30 June 2022	To understand at an annual timestep where water goes in the Yanco Creek System under existing conditions, and how this changes under operation of the proposal
Seasonality of flow	Change in mean monthly flows from Base Case scenario under the Change Case scenario and Cumulative Change scenario over the modelling time period	To understand the seasonality of flows under existing conditions, and how this changes under operation of the proposal
Flow variability	Change in total annual flows and mean daily flows from Base Case scenario under the Change Case scenario and Cumulative Change scenario over the modelling time period	To understand how flow varies across years and days under existing conditions, and how this changes under operation of the proposal
Flow size	Change in mean daily flow duration percentiles from Base Case scenario under the Change Case scenario and Cumulative Change scenario over the modelling time period	To understand what portion of daily flows sit in different flow categories under existing conditions, and how this changes under operation of the proposal
River running height and extent	Change in water levels and extents between existing and proposed conditions under different regulator operational scenarios and over the long term	To understand water levels and extents upstream and downstream of the existing weirs under existing conditions, and how this changes under operation of the proposal

The key locations where these flow regime characteristics have been assessed are described in Table 2-6 with respect to the Planning Units of the Murrumbidgee Catchment they lie within, as defined in the Murrumbidgee Long Term Water Plan. Subsequent discussion in Sections 3 and 4 on the characteristics of the modelled flow regime under the three scenarios will be centred around these Planning Units.

Table 2-6 The relevant Planning Unit for each key location where flow regime characteristics have been assessed.

Planning Unit	Key location assessed (and associated gauge number)
PU10: Upper Yanco Creek	410007 Yanco Offtake
PU12: Lower Yanco Creek to Lower Billabong Creek	410015 Yanco Creek at Morundah 410169 Yanco Creek at Yanco Bridge
PU11: Colombo & Billabong Creeks	410014 Colombo Creek at Morundah 410016 Billabong Creek at Jerilderie 410168 Billabong Creek at DS Hartwood Weir
PU13: Lower Billabong and Intersecting Streams	410148 Forest Creek at Warriston Weir 41010810 Billabong Creek at Wanganella 410134 Billabong Creek at Darlot

2.2.4.4 Assumptions and limitations

Table 2-7 summarises the key assumptions, the reasoning behind why these assumptions have been adopted, and the potential impact of these assumptions on the report findings from Source modelling, if any. Likewise, Table 2-8 summarises the key limitations, the reasoning behind why these limitations were accepted, and the potential impact of these limitations on the report findings from Source modelling, if any.

Table 2-7 Key assumptions, reasoning and potential impact on findings from Source modelling.

Model component	Assumption	Reasoning why these assumptions have been adopted	Potential impact on findings
Demand models	There is no change in the consumptive take over the basin planning period (1895-2009) between the three model scenarios	This allows us to compare model scenario results on the same basis.	None
Demand models	An area factor has been used to set the consumptive take to the current estimate of the Model Diversion Limit over the basin planning period	This allows us to align with the latest estimate of the Model Diversion Limit	None
Billabong Yanco flow split	An 80:20 ratio of order up the Billabong and Yanco at the "Confluence Yanco Creek and Billabong Creek" node has been adopted	This has been adopted based on observed data and information provided by the operators. This is described in further detail in the NSW Department of Primary Industries and Environment (2021) Yanco SDLAM Hydrological Model Build Report.	Anticipated to be insignificant as this assumption is a reasonable representation of observed data
Water Management rules (and river operations)	Relative differences between the scenario runs will not change because of any changes made to the interactions with the Snowy Scheme in the Murrumbidgee Source Model	The modelling for the EIS process was undertaken at the same time as further development of the Source Murrumbidgee Model. Revision 300 of the Murrumbidgee SDLAM model has been used for all scenarios to support the EIS.	None

Model component	Assumption	Reasoning why these assumptions have been adopted	Potential impact on findings
		As we are comparing model scenario results, it has been assumed that any changes made to the interactions with the Snowy Scheme in the Murrumbidgee Source Model will not change the relativity of the results between the three model scenarios	
Environmental demands	The modelling results discussed in this EIS do not account for any additional water that may need to be put aside in the resource assessment process to meet the environmental flow provisions outlined in the Yanco Creek System Operations Plan.	A scenario was modelled where an additional 15 GL of water was set aside for the environment under the Base Case. This had no adverse water reliability impacts to General Security Allocations, given how small this volume was compared to total system flow. Thus, it was deemed that the modelling results are not sensitive to any additional water that may need to be put aside in the resource assessment process to meet environmental flow provisions.	Assumed to be insignificant
Flow constraints at Murrumbidgee @ Wagga Wagga	A flow constraint of 22,000 ML/day at Murrumbidgee @ Wagga Wagga has been adopted for all scenarios in line with current operational limits.	Adopting the same flow constraint at Murrumbidgee @ Wagga Wagga for all scenarios is considered appropriate for the purposes of determining the impacts of the	None



Model component	Assumption	Reasoning why these assumptions have been adopted	Potential impact on findings
		proposal under the current flow constraint. It is out of scope to assess the impacts of higher flow options for the Murrumbidgee River, which are currently being considered as part of the Reconnecting River Country Program, on the impacts of the proposal. These higher flow constraints are only options at this point in time, and no decision has yet been made to change the current flow constraint.	

Table 2-8 Key limitations, reasoning and the potential impact on findings from Source modelling

Model component	Limitation	Reasoning why these limitations were accepted	Potential impact on findings
Catchment features	The following structures described in the Yanco Creek System Operations Plan are not included in the Source model: i. Mollys Lagoon ii. Wilson Anabranch iii. Wanganella Swamp	This infrastructure has not been modelled as it is not anticipated to have a significant impact key hydrological parameters at the gauges of interest within the area of investigation.	Anticipated to be insignificant
Entitlement Distribution	The modelling does not account for the additional entitlements created in the Murrumbidgee due to the SDLAM Program.	There will be entitlements created in the Murrumbidgee for SDLAM, but they have not yet been defined and therefore can't be modelled.	Anticipated to be insignificant as additional entitlements created are minor compared to existing entitlements.
Environmental Flow Provisions (New Sites)	It is not possible to represent the minimum flow requirements for Cheverells Creek @ Offtake of 10 ML/day when AWD (available water determinations) exceed 15% in the Change and Cumulative Change scenarios Source Models.	This is because insufficient information is available on the current flows into Cheverells Creek and the maximum and minimum operating curves for the new regulator.	As we are comparing model scenario results, it has been assumed that this limitation will not change the relativity of the results between the three model scenarios.
Farm dam representation	There is no farm dam representation in the Source model as Source struggles to represent small storages	Source is the best modelling platform available to inform this EIS	Anticipated to be insignificant

Model component	Limitation	Reasoning why these limitations were accepted	Potential impact on findings
Flow extremities	The Source model has potential limitations in accurately predicting flows outside of the regulated flow range (i.e. very low flows and very large flows).	The Source model is calibrated to perform well (i.e. high degree of confidence that modelled results are a good representation of reality) in the regulated flow range. However, it is not possible for a model to represent the entire flow spectrum perfectly. In addition, poor timing of extractions/losses, due to the limitations of the Source model in its ability to fully represent the complexity of the draft operations and its numerous operational rules, will have a disproportionate impact on very low flows.	It has been chosen to exclude the 0% and 100% percentiles from daily flows analyses. Given that flows outside the regulated flow range occur for an insignificant amount of time over the long assessment time period, it is anticipated this has an insignificant impact on the report findings.
Hartwood and Wanganella re-regulators	Source is able to represent small re-regulation storages, however Source still struggles to represent small storages where the storage volume is the same order of magnitude as the daily flow rate.	Source is the best modelling platform available to inform this EIS	Anticipated to be insignificant

Model component	Limitation	Reasoning why these limitations were accepted	Potential impact on findings
Irrigation escapes operational rules	The following aspects of the operations plan are not reflected in the Source model under the Change and Cumulative Change Case scenarios: The first 50ML/day of water orders to assist in meeting water orders downstream of Billabong Creek @ Puckawidgee (410017) will be met from Finley Escape prior to ordering any water from Coleambally Catchment Drain (CCD) and/or Drainage Channel 800 (DC800). No restriction applies to Coleambally Catchment Drain (CCD) and/or Drainage Channel 800 (DC800) water orders after Finley Escape orders are more than or equal to 50ML/day.	The current representation of the irrigation escape operational rules in the Source model is considered adequate for the purposes of this comparative assessment between the three scenarios.	Anticipated to be insignificant
Operation of Hartwood and Wanganella re-regulators	Underlying issues with the eWater Source modelling platform as a result of the model's long travel times make it difficult to improve how well the "water forecast to arrive" and water ordering modelling functions match with reality and on-ground operation decisions. As a result, the modelled operation of the Hartwood and Wanganella re-regulators is not necessarily aligned with its anticipated on-ground operation, especially outside the regulated flow range.	Source is the best modelling platform available to inform this EIS	Given that flows outside the regulated flow range occur for an insignificant amount of time over the long assessment time period, it is anticipated this has an insignificant impact on the report findings.

Model component	Limitation	Reasoning why these limitations were accepted	Potential impact on findings
Unregulated flow operations	Unregulated flow operations were not modelled in Source.	This cannot be captured within Source, as the operations plan has some flexibility on unregulated flow operations, and unregulated flow operations is based on the discussions with NSW DCCEEW and other stakeholders.	Anticipated to be insignificant given unregulated flows occur for an insignificant amount of time over the long assessment time period
Yanco Modernisation project options	The Cumulative Change scenario Source Model does not represent all the options being considered by the Yanco Modernisation project. The Source model does not include: a) SDLAM Option Part 1: Environmental water efficiency b) SDLAM Option Part 3: Wilson Anabranh c) SDLAM Option Part 5: Improved flow measurement d) SDLAM Option Part 7: Improved use of technology e) SDLAM Option Part 8: Improved riparian management	Source is unable to represent these options. In addition, they are expected to have a negligible impact on the results	Anticipated to be insignificant

2.2.5 Environmental Water Requirements assessment

As defined in the NSW long-term water plans (NSW DCCEEW 2024 Draft), an environmental water requirement (EWR) describes a set of recommended flow characteristics (flow threshold or volume, duration, timing, frequency, maximum inter-event period) at a certain location (river gauge) to meet a particular set of environmental objectives in a particular river reach and its associated floodplain (referred to as a Planning Unit in NSW LTWPs). A number of EWRs are defined for each river gauge location covering a range of flow categories including, but not limited to, cease-to-flows, baseflows, small and large freshes and overbank flows. These flow categories are described in further detail in the following section.

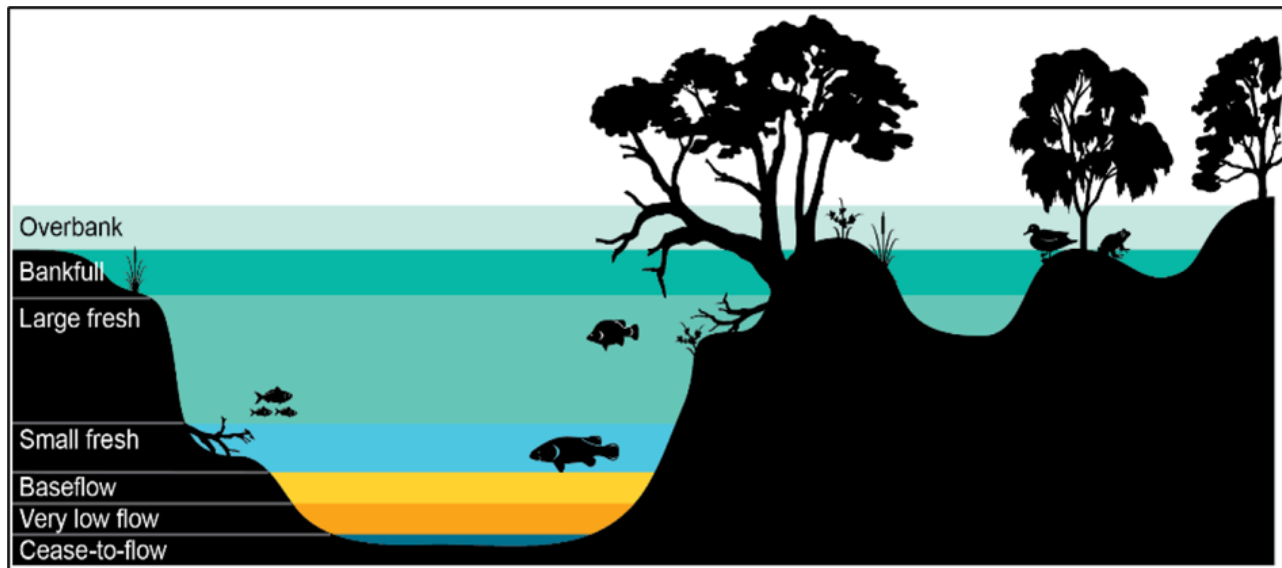
An EWR is the flow or inundation regime that a species, or community, needs to ensure its survival and persistence. It can also be the flow regime needed to meet the water requirements of a range of species in a defined geographic area. EWRs are based on knowledge of a species' biological and ecological needs, such as what it needs to feed, breed, disperse and migrate (DPIE 2020a). The environmental outcomes associated with each flow category are expected to begin occurring at the bottom end of the flow ranges. Greater and sometimes substantially increased outcomes are likely to occur (e.g. for wetland connecting large freshes and overbank flows) as flows increase in size (NSW DPIE 2020a).

2.2.5.1 Description of flow categories

A flow regime represents the sequence of flow events over time, and it is this sequence of different flow magnitudes that produce flooding and drying patterns (NSW DPIE 2020a). Flow regimes govern river channel and wetland formation, their configuration and connectivity with the floodplain. Flow regimes prompt key ecological processes such as nutrient cycling and energy flow, breeding and migration, and dispersal of plants and animals.

As described in the Murrumbidgee Long-term Watering Plan (NSW DPIE 2020a), the sequence of flows over time can be considered as a series of discrete events. These events can be placed into different flow categories (e.g. baseflows, freshes, bankfull, overbank and wetland flows) according to the magnitude of flow discharge or height within a watercourse, and the types of outcomes associated with the events (e.g. inundation of specific features such as channel benches, riparian zones or the floodplain).

Flow categories describe the height or level of a flow within a river channel or its extent across a floodplain (see Figure 2-7). The flow rates that define each flow category (baseflows, small freshes etc.) and associated EWRs will vary between catchments and river reaches. Descriptions of the role of each flow category are shown in Table 2-9. Table 2-10 presents the flow rate threshold estimates (ML/d) for flow categories for regulated planning units in the Yanco Creek system within the area of investigation for the proposal.



Source: Murrumbidgee Long Term Water Plan Part A: Murrumbidgee catchment (NSW DPIE 2020)

Figure 2-7 Conceptual diagram of different flow categories.

Table 2-9 Description of the role of each flow category

Source: Murrumbidgee Long Term Water Plan Part A: Murrumbidgee catchment (NSW DPIE 2020)

Flow category	Description
Floodplain connection flow/overbank (OB)	Floodplain connection flows provide broad scale lateral connectivity with floodplain and wetlands. They support nutrient, carbon and sediment cycling between the floodplain and channel, and promote large-scale productivity.
Bankfull flow (BK)	Inundates all in-channel habitats and connects many low-lying wetlands. They provide partial or full longitudinal connectivity and drown out of most small in-channel barriers (e.g. small weirs).
Large fresh (pulse) (LF)	Inundates benches, snags and inundation-tolerant vegetation higher in the channel. They support productivity and transfer of nutrients, carbon and sediment. They also provide fast-flowing habitat and may connect wetlands and anabranches with low commence-to-flow thresholds. The key benefit of these flows is to increase productivity and nutrient transport in the river channel and increase habitat area.
Wetland connection flow (Wetland-LF)	These (not shown in Figure 2-7) are larger 'large fresh' flows which provide significant connectivity to wetlands and anabranches, but which remain under bankfull level. In other catchments, connection to major wetlands systems would generally occur at and above bankfull level. The geomorphology of the Murrumbidgee system is such that many major billabong, anabranch and other off-channel wetland systems are connected below bankfull level. Hence the category of 'wetland connecting flow' is used in the Murrumbidgee. These connections happen through natural 'break outs' or low sills in the side of riverbanks. They can also happen via regulating structures (particularly in the Lowbidgee) or via pumping.
Small fresh (pulse) (SF)	Improves longitudinal connectivity. They inundate lower banks, bars, snags and in-channel vegetation, and can flush pools and stimulate productivity/food webs. They can provide a trigger for aquatic animal movement and breeding.
Baseflow (BF)	Provides connectivity between pools and riffles and along channels. They provide sufficient depth for fish movement along reaches.
Very low flow (VLF)	Minimum flow in a channel that prevents a cease to flow. They provide connectivity between some pools.
Cease-to-flow (CtF)	Partial or total drying of the channel. The stream contracts to a series of disconnected pools and there is no surface flow.

Table 2-10 Flow rate threshold estimates (ML/d) for different flow categories for the Planning Units within the area of investigation.

Modified from Murrumbidgee Long Term Water Plan Part A: Murrumbidgee catchment (NSW DPIE 2020)

Gauging site	Very low flows	Baseflow	Small Fresh	Large Fresh (LF1-3)	Large Fresh: wetland connection (W-LF4-8)	Small overbank (OB-S1&2)	Large Overbank (OB-L1)
Upper Yanco Creek (@ Offtake: 410007)	80-250	250-450	450-1,000	1,000-1,500	1,500*-2,500	2,500*-4,000	>4,000*
Colombo Creek (@ Morundah: 410014)	40-70	70-250	250-400	400-700	700-1000	1,000*-1,400	>1,400*
Middle Billabong Creek (@ Jerilderie: 410016)	50-70	70-250	250-400	400-700	700-1000	1,000*-1,400	>1,400*
Lower Yanco Creek (@ Morundah: 410015)	40-130	130-250	250-450	400-800	800-1,000	1,000*-2,000	>2,000*
Lower Billabong Creek (@ Darlot: 410134)	30-50	50-200	200-700	700-1,000	1,000-1,600	1,600*-3,000	>3,000*

* Denotes flows to this zone are not deliverable or delivery is severely limited, because of the need to avoid unacceptable impacts on third parties. Usually deliveries to these areas are only possible with pumping or where other infrastructure exists to divert water to off-channel wetlands. These flows generally only occur due to tributary rainfall events or dam spills. Under a 'constraints relaxed' scenario, the delivery of these flows and the ability to achieve the associated objectives of this Plan would be significantly enhanced for wetland connecting flow (W-LF4-8)

2.2.5.2 The EWR Tool

The sections below summarise the key elements, assumptions and limitations of NSW DCCEEW's EWR assessments. For further details on the method, please refer to the "NSW long-term water plans environmental water requirement assessment code description" developed by NSW DCCEEW and the MDBA and dated February 2024.

The EWR assessment code (EWR Tool) is a computer code in Python that assesses the occurrence of flow conditions that meet or partially meet the LTWP EWRs in observed or modelled flow time series. It was

originally developed in Python by the Murray–Darling Basin Authority (MDBA) and further refined with input from the NSW Department of Climate Change, Energy, the Environment and Water's Biodiversity, Conservation and Science Group, who were responsible for the development of the LTWPs and their EWRs for New South Wales. Version 0.0.5 of the EWR Tool was used to compare EWR achievement between the Base Case, Change and Cumulative Change scenarios.

The EWR Tool has been specifically developed to reflect detailed analysis used in the development of EWRs for NSW LTWPs. However, slight variations have been made to improve the assessment where appropriate. Although this may cause some misalignment of assessment methods, sensitivity testing indicates that this is minor. In addition, there have been several levels of quality assurance, and as such there is a high degree of confidence in the EWRs adopted to inform this hydrological impact assessment on the new regulators.

2.2.5.3 The EWR codes assessed

Table 2-11 describes the EWR codes which have been assessed using the EWR Tool to inform this hydrological impact assessment. These span across all flow categories critical to support ecological values of the Yanco Creek System as described in Table 2-9.

The definition of these EWR codes is based on how the EWRs have been defined in the LTWPs. An extract of the relevant EWR parameters (e.g. flow rates, timing, duration and frequency) used to inform this hydrological impact assessment, along with a description of what these EWR parameters mean, is presented in Appendix A: Description of EWR code parameters. Whilst the flow rates for each flow category are expressed as ranges in Table 2-10, flow rates for the EWRs presented in Appendix A: Description of EWR code parameters are expressed as minimum flow rates (i.e. the bottom end of the range) in most cases. This means that as long as the flow rate is larger than this minimum flow rate, the EWR has been satisfied. As such, an EWR may also be met by higher flows in larger flow categories.

Table 2-11 Descriptions of EWR codes assessed using the EWR Tool

Flow category	EWR code	Description
Cease-to-flow	CF1	Specifies the maximum number of CTF events in the river/creek. These tend to be zero duration CTF requirements (indicating CTF events should not occur in the river/creek) or CTF requirements informed by expert opinion.
Very low flow	VF1_a	Specifies the minimum required number of days per water year where the very low flow threshold is exceeded. This number of days should be met in at least 50% of years over the long term. This aligns with 'typical year' minimum durations for very low flows expressed in LTWPs.
	VF1_b	Specifies the minimum required number of days per water year where the very low flow threshold is exceeded. This number of days should be met in 100% of years over the long term. This aligns with 'dry year' minimum durations for very low flows expressed in LTWPs.
Baseflow	BF1_a	Specifies the minimum required number of days per water year where the baseflow threshold should be exceeded. BF1_a should occur in at least 50% of years. This aligns with 'typical year' minimum durations for baseflow 1 (BF1) flows expressed in LTWPs. There is mostly have no seasonal restriction (can occur any time during the year).
	BF1_b	Specifies the minimum required number of days per water year where baseflow threshold should be exceeded. BF1_b should occur in 100% of years to ensure the required minimum baseflow days are met in the dry and very dry years. This aligns with 'dry or very dry year' minimum durations for baseflows expressed in LTWPs. There is mostly have no seasonal restriction (can occur any time during the year).
Nesting Support	NestS1_mc	Specific timing window for Murray cod where unnaturally rapid changes in water levels should be avoided to avoid the stranding or abandonment of nests
	NestS1_tcmc	Specific timing window for trout cod and Murray cod where unnaturally rapid changes in water levels should be avoided to avoid the stranding or abandonment of nests
Small fresh	SF1_P	Small fresh 1 (SF1) applies to all LTWP areas. The addition of _P and _S occurs when SF1 has a 'preferred' seasonal timing (_P) or can occur any time that is considered 'satisfactory' (_S). For example, SF1_P and SF1_S are applied when the required timing of an SF1 EWR is 'Aug-May or any time'.
	SF1_S	

Flow category	EWR code	Description
	SF2	Small fresh 2 (SF2) applies to all LTWP areas. SF2 applies on its own (without SF2_P, SF2_S etc.) when there is only one timing specified in the EWR table in Part B of the LTWPs.
Large fresh	LF1_P	Large fresh 1 (LF1) applies to all LTWP areas. LF1 applies on its own (without _P and _S) when there is only one timing specified in the EWR table in Part B of the LTWPs. The addition of _P and _S occurs when LF1 has a 'preferred' seasonal timing (_P) or can occur any time that is considered 'satisfactory' (_S)
	LF1_S	
	LF2	Large fresh 2 (LF2) applies to all LTWP areas. LF2 applies on its own when there is only one timing specified in the EWR table in Part B of the LTWPs.
Large fresh (wetland connection)	W-LF4_P	Wetland connection flows in the Murrumbidgee are achieved through larger large fresh flows (i.e. larger magnitude than LF1 and LF2 flows). These flows connect the river to anabranches and wetlands but remain below bankfull level. These EWRs are referred to as 'wetland-connecting large fresh' flows. The EWR group W-LF4 has 2 timings specified in the EWR table in Part B of the LTWPs. The 'preferred' seasonal timing is assessed using W-LF4_P and the 'any time' timing as W-LF4_S
	W-LF4_S	
	W-LF5	Wetland connection flows in the Murrumbidgee are achieved through larger large fresh EWRs. These flows connect to anabranches and wetlands but remain below bankfull level. The EWR W-LF5 only has one timing applied, as in the EWR tables in Part B of the Murrumbidgee LTWP
	W-LF6_P	Wetland connection flows in the Murrumbidgee are achieved through larger large fresh EWRs. These flows connect to anabranches and wetlands but remain below bankfull level. The EWR W-LF6 has 2 timings specified in the EWR tables in Part B of the Murrumbidgee LTWP. The 'preferred' seasonal timing is assessed using W-LF6_P and the 'any time' timing as W-LF6_S
	W-LF6_S	

Flow category	EWR code	Description
	W-LF7	Wetland connection flows in the Murrumbidgee are achieved through larger large fresh EWRs. These flows connect to anabranches and wetlands but remain below bankfull level. The EWR W-LF7 only has one timing applied, as in the EWR tables in Part B of the Murrumbidgee LTWP
	W-LF8	Wetland connection flows in the Murrumbidgee are achieved through larger large fresh EWRs. These flows connect to anabranches and wetlands but remain below bankfull level. The EWR group W-LF8 only has one timing applied, as in the EWR tables in Part B of the Murrumbidgee LTWP
Small overbank	OB-S1	These EWR codes represent a range of overbank flow EWRs that provide broadscale lateral connectivity in the Murrumbidgee. They range from small (OB-S1) to large (OB-L1) overbank flows. OB-*** applies when there is only one timing applied. The addition of _P and _S occurs when OB-** has a 'preferred' seasonal timing (_P) or can occur any time that is satisfactory (_S)
	OB-S2	
	OB-S2_P	
	OB-S2_S	
Large overbank	OB-L1	
	OB-L1_P	
	OB-L1_S	

To capture the detail of the EWRs as described in the LTWP, there are multiple EWR codes for certain flow categories which can be attributed to:

- Different event parameters
 - Small fresh, large fresh, large fresh (wetland connection) and small overbank EWRs have different parameter requirements for different events.
- Typical vs dry year EWRs
 - Cease to flow, very low flow and baseflow EWRs will have different requirements (e.g. minimum durations) in typical vs dry years. This is because we want to retain this natural variability. As a result, the EWR code has been modified to have a '_a' appended for assessment against the typical year target (required at least 50% of years over the assessment period), and a '_b' appended for assessment against the dry year target (required 100% of years over the assessment period).
- Preferred vs sufficient timing windows
 - A common characteristic of EWRs is having an ideal/preferred timing window (typically constrained to a month range), and a sufficient timing window (not constrained – can occur any time). Where this has been identified, the EWR is split into two, with each clone having the same characteristics, with the exception of the timing window. The EWR code is modified in the process to have a '_P' appended for the ideal/preferred option, and a '_S' appended for the sufficient option. The same approach is adopted for EWRs that have ideal timing windows stipulated, with the exception of where if it is a natural event it can occur any time.

2.2.5.4 Calculating EWR scores

Table 2-12 provides details in regard to the definition and calculation methods for EWR scores under the Base Case, Change and Cumulative Change scenarios.

Table 2-12 Definitions and calculation methods for EWR frequency and adjusted frequency scores

Score	Definition	Calculation method
Frequency Score*	The number of successful years which satisfy the EWR requirement (aka event years) as a proportion of the target number of successful years over the entire assessment period. Partial achievement of the EWR requirement in a particular year is not captured in this metric. As a result, even if there were some successful events in a particular year, if the target number of successful events was not met in that year, achievement against that particular EWR would be zero for that particular year.	Frequency score (%) = Number of successful years / Target number of successful years * 100
Adjusted frequency score*	Accounts for partial achievement with the EWR for a particular year, and as a result, considers partially compliant years as a proportion of the target number of successful years over the entire assessment period.	Adjusted frequency score = Sum of (modelled frequency / target frequency for each year) / Target number of successful years * 100

* Note that for cease-to-flow (CTF) events, the modelled frequency and target frequency have been inverted to enable frequency scores to be calculated for CTF events (i.e. a target frequency of 0% CTF events instead uses 100%). Note also that a CTF adjusted frequency score of more than or equal to 99% (i.e. CTF events occur in less than or equal to 1% of years over the entire assessment period) has been recorded as 100% in the outputs of this assessment.

2.2.5.5 Assumptions and limitations

Table 2-13 summarises the key assumptions, the reasoning behind why these assumptions have been adopted, and the potential impact of these assumptions on the EWR success results, if any. Likewise, Table 2-8 summarises the key limitations, the reasoning behind why these limitations were accepted, and the potential impact of these limitations on the model results, if any.

Table 2-13 Key assumptions, reasoning and potential impact on EWR scores

Category	Assumption	Reasoning why these assumptions have been adopted	Potential impact on results
Defining EWRs	All values given are taken to be inclusive. For example: A minimum flow threshold of 400 ML/day is equal to or greater than 400 ML/day A minimum duration of 5 days is equal to or over than 5 days A timing window of July to September is inclusive of July and September	N/A	No impact

Table 2-14 Key limitations, reasoning and potential impact on EWR scores

Category	Limitations	Reasoning why these limitations have been accepted	Potential impact on results
Using Source modelling results	The Source modelling results have been used to calculate EWR scores under the three scenarios. Thus, the EWR assessment is subject to the same limitations as the Source modelling results. The EWR assessment is more uncertain for flow categories outside of the regulated flow range (i.e. very low flows and very large flows). In addition, the modelled operation of the Hartwood and Wanganella re-regulators is not necessarily aligned with its anticipated on-ground operation. As a result, the calculated EWR scores may not align exactly with what will be observed in reality when the proposal and broader operational changes are implemented.	The Source modelling results are the best available representation of the flow regime under the three scenarios	Anticipated to be insignificant

2.2.6 NSW River Flow Objectives

The River Flow Objectives (RFOs) for Controlled rivers with altered flows (regulated Creeks) presented in Table 2-15 are applicable to Billabong Creek below the Colombo Creek confluence (NSW Water Quality and River Flow Objectives: Water Quality Objectives - Murray River (NSW)). Although RFOs have effectively been superseded by Long Term Watering Plan flow objectives, they still provide some guidance to assess impacts of

flow modification in relevant systems. An assessment of the river flow impacts of the proposal during operation, to the extent of proposal influence up and down stream, has been undertaken in Section 4.2.7 for the Change Case scenario, and Section 4.3.6 for the Cumulative Change Case scenario.

Table 2-15 River Flow Objectives for Billabong Creek below the Colombo Creek confluence

River Flow Objectives	Description
Protect natural low flows	Protect natural low flows that would occur under pre-development conditions without any water regulating infrastructure or demands on the system
Protect important rises in water levels	Protect or restore a proportion of moderate flows ('freshes') and high flows
Maintain wetland and floodplain inundation	Maintain or restore the natural inundation patterns and distribution of floodwaters supporting natural wetland and floodplain ecosystems
Mimic natural drying in temporary waterways	Mimic the natural frequency, duration and seasonal nature of drying periods in naturally temporary waterways
Maintain natural flow variability	Maintain or mimic natural flow variability in all streams
Maintain natural rates of change in water levels	Maintain rates of rise and fall of river heights within natural bounds
Manage groundwater for ecosystems	Maintain groundwater within natural levels and variability, critical to surface flows and ecosystems
Minimise effects of weirs and other structures	Minimise the impact of instream structures

2.2.7 Water surface levels and weir pool extents analysis

The “Yanco Creek Modernisation: Hydraulic Modelling Technical Report – Hartwood Weir to Piccaninny Weir Study Area” and “Yanco Creek Modernisation: Hydraulic Modelling Technical Report – Piccaninny Weir to Wanganella Weir Study Area” reports comprehensively discuss the hydraulic modelling methods undertaken to assess the degree of change in water levels and extents under operation of the proposal for different operational scenarios compared to existing conditions.

A long-term water level assessment at the Hartwood and Wanganella weir pools was also undertaken to assess the degree of change in water levels over a 22-year time period under operation of the proposal compared to existing conditions. The aforementioned hydraulic modelling technical reports comprehensively demonstrated that the fundamental change in water levels across the Yanco Creek System are at the Hartwood and Wanganella weir pools. As such, it was deemed appropriate to focus the long-term water level assessment on these key locations which are anticipated to experience the most change.

The long-term water level assessment focuses purely on the impacts of the proposal on water levels at Hartwood and Wanganella. Broader system changes as detailed in the Yanco Systems Operations Plan were not incorporated into the long-term water level assessment as water levels at Hartwood and Wanganella are considered to be largely independent of these broader system changes, given their strict operating water level requirements.

Existing conditions were characterised using a mixture of operational results for flows less than 500 ML/day at Hartwood and 400 ML/day at Wanganella, and flood modelling predictions for flows greater than these values under the existing conditions. Proposed conditions were characterised by using two rating curves to translate daily modelled flows from the Source modelling into water levels. These rating curves were derived for the two different weir pool target periods specified in Table 1-1 from a mixture of hydraulic calculations and flood modelling results under operation of the proposal.

It should be noted that it is not appropriate to derive daily water levels from the Source modelling results to inform the long-term water level assessment because the Source model is not able to account for daily gate operations to maintain target water levels. As such, monthly average water levels derived from the Source modelling results were used to inform the long-term water level assessment. This was determined to be the best possible analysis available to give an indication of the degree of change in water levels over the long term under operation of the proposal compared to existing conditions. However, the accuracy of this monthly analysis is still quite limited due to the limitations in the approach adopted.

3. Current conditions

3.1 Current catchment conditions

3.1.1 The Murray-Darling Basin

The Murray-Darling Basin (the MDB) is located in the interior south-east of Australia and is the country's largest river system by area. The MDB holds great environmental, cultural, and economic significance, supporting 16 internationally significant wetlands, many endangered or threatened species, more than 40 Aboriginal First Nations, and an agricultural region that produces around one-third of the national food supply. From its headwaters along the Great Dividing Range, it drains predominantly in a south-west direction into the Great Australian Bight in South Australia. The MDB spans most of NSW, Victoria, and the Australian Capital Territory, and the lower third of Queensland and the south-eastern corner of South Australia.

The two longest rivers in the Murray-Darling Basin are the Murrumbidgee and the Murray Rivers. These rivers run roughly parallel to each other for much of their length, and before they reach their confluence, they are connected by the Yanco Creek System, a distributary that runs between them.

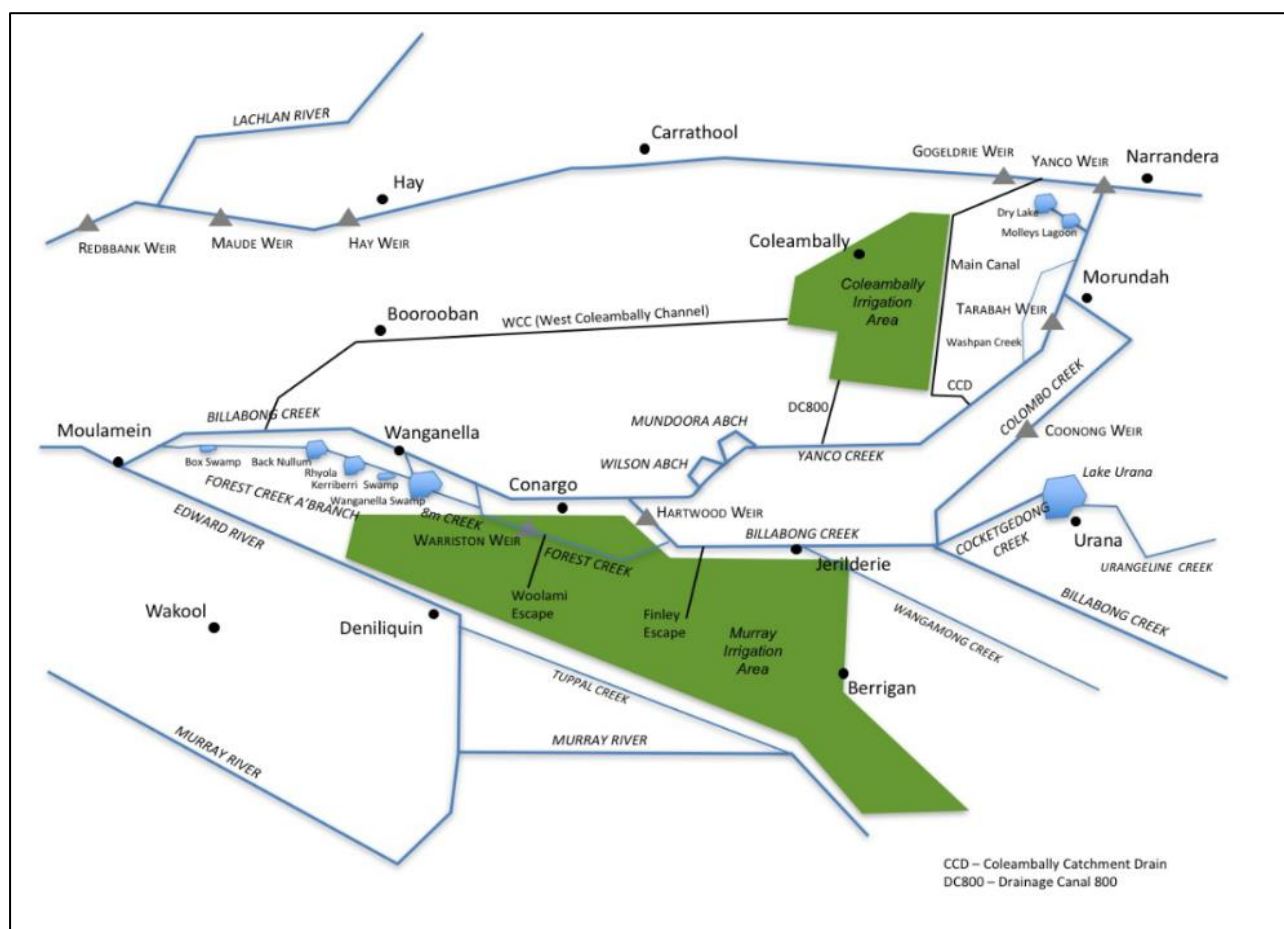
3.1.2 Yanco Creek System

The Yanco Creek System is an anabranch complex that broadly connects the Murrumbidgee River near Narrandera with the Edward River at Moulamein (Cooling and Gippel 2018). Along its path the Yanco Creek System passes from the traditional lands of the Wiradjuri people, and through Bangerang, Barapa-Barapa and Wemba-Wemba traditional country.

The Yanco Creek System is a complex, braided system of interconnecting Creeks and anabranches. The Yanco Creek System generally flows south-west from the Murrumbidgee River about 14 km downstream of Narrandera until it discharges into the Edward River (part of the Murray River basin) at Moulamein (Alluvium, 2013).

The Yanco Creek System is extensive, with almost 800 km of natural channels (creeks and streams) over a region that stretches 250 km from east to west (Cooling and Gippel 2018). The main branches of the system are Yanco, Colombo, Billabong, Forest and Piccaninny Creeks (Figure 3-1). Colombo Creek is an anabranch that diverges from the left bank of Yanco Creek just north of Morundah and continues in a south-westerly course that is broadly parallel to Yanco Creek (Cooling and Gippel 2018). There are also a number of diverse and significant floodplain wetlands, such as the Wanganella Swamp and Rhyolla Swamp along Eight Mile Creek and Forest Anabranch in lower Forest Creek.

The Yanco Creek System supports a number of environmental assets that are dependent on the hydrological behaviour of the creek system. These include a wide range of riparian and wetland vegetation communities and several large-bodied fish populations which are nationally threatened including Murray Cod and Trout Cod (NSW DPIE, 2019a). Fish movement in the Yanco Creek System is currently highly degraded and fragmented, with over 30 weirs in the system, only one of which has a fishway (Stuart, 2022).



Source: Cooling and Gippel 2018

Figure 3-1 Schematic of the Yanco Creek System

3.1.3 Billabong Creek

Billabong Creek is an unregulated tributary of the Yanco Creek System which drains a catchment of 791 km², the headwaters of which are in the western slopes of the Great Dividing Range near Holbrook (Cooling and Gippel, 2018). The upper portions of Billabong Creek are unregulated (Alluvium, 2013). Billabong Creek is joined by Colombo Creek west of Urana and continues to flow in a westerly direction toward Jerilderie, before converging with Yanco Creek upstream of Conargo. The watercourse continues as Billabong Creek and flows west to join the Edward River at Moulamein. Billabong Creek can be broadly divided into three reaches on the basis of hydrology, ecology and geomorphology (Alluvium, 2013; Cooling and Gippel, 2018). The proposal study area is located within the mid and lower sections of Billabong Creek.

The upper Billabong Creek is the unregulated portion of the creek extending from its headwaters near Holbrook to its confluence with Colombo Creek. This reach of Billabong Creek also receives inflows from Cocketgedong Creek. The upper Billabong Creek flows most of the time due to catchment rainfall.

The mid Billabong Creek extends from the Colombo Creek confluence to the Yanco Creek confluence. Flow in this reach is supplemented by water from Colombo Creek and becomes part of a regulated water source receiving water from the major dams on the Murrumbidgee River (Alluvium, 2013; Cooling and Gippel, 2018). The mid Billabong Creek has a broad channel with deep pools separated by shallower runs and benches at a variety of elevations in the channel. Mid Billabong Creek has several distributaries (also referred to as anabranches and paleochannels) that divert from the main channel and re-join it upstream of Moulamein.

There are a number of weirs in mid Billabong Creek below Jerilderie, including Hartwood Weir. Hartwood Weir raises the Billabong Creek level so that water enters Forest Creek via the Forest Creek offtake.

The Forest Creek anabranch complex includes Forest Creek, Eight Mile Creek, Box Creek, Estuary Creek, the Forest Creek Anabranch and Wanganella Swamp (Cooling and Gippel 2018). The perennial upper section of Forest Creek extends from its source at Hartwood Weir downstream to Warriston Weir. Forest Creek has been regulated to provide perennial regulated flow as far down as Warriston Weir. Downstream of the Warriston Weir Forest Creek only flows in response to occasional unregulated events and planned environmental flows. Breakout channels from Forest Creek can divert flow north to Billabong Creek at several locations including Piccaninny Creek, Back Creek, Flood Creek and Estuary Creek (Cooling and Gippel 2018).

The lower Billabong Creek is from below the Yanco Creek confluence to the Edward River confluence at Moulamein and is part of a regulated water source. There are numerous weirs along this stretch of Billabong creek including Boonoke Homestead Weir, Piccaninny Weir, Traceys Weir, Chinamans Weir, Four Mile Weir - Boonoke, Wanganella Homestead Weir, Wanganella Town Weir, Caroonboon Weir and Windouran Weir. The channel in the lower Billabong Creek is deep with steep one- to two-metre-high banks and has deep pools connected by shallow runs. Forest Creek is a notable anabranch of Billabong Creek. Forest Creek diverges from Billabong Creek upstream of the Yanco Creek confluence, near Hartwood Weir.

3.1.4 Existing weirs

The existing structures that regulate the Yanco Creek System comprise of weirs, inlet and outlet regulators, block banks and channels. Overall, the Yanco Creek System has been identified to contain thirty-six structures, many of which are in various states of degradation (Cooling and Gippel, 2018). The structures alter the distribution of water between the various creeks within the system and create weir pools that can be used to draw water. They also largely prevent the movement of fish along the system.

Over 30 private licenced fixed crest weirs or block banks are distributed throughout the Yanco Creek System, many of which were constructed to provide water for stock, domestic and irrigation use during low flow periods and continue to provide a water store for local extractors in the event of disrupted supply (Cooling and Gippel 2018). Many of these structures are in poor repair and require refurbishment or removal to improve flow throughout the system (SKM 2011).

Table 3-1 lists the existing structures on Billabong Creek that are located in the study area of the proposal (i.e. between Jerilderie and Darlot) - excluding Hartwood and Wanganella weirs (see Sections 1.4.2.1 and 1.4.2.2).

Table 3-1 Description of other existing weir structures within the Yanco Creek System

Structure	Location (Lat, Long)	Operation
Jerilderie Weir	Mid Billabong Creek	Provides some storage and therefore assists with the regulation of inflows from Billabong Creek catchment.
Algudgerie Weir	Billabong Creek (downstream of Jerilderie)	Rock rubble weir whose purpose is unknown
McCaughey Weir	Billabong Creek	Used to create a pumping pool for irrigation pumps
Forest Creek offtake	Mid Billabong Creek	Used to regulate the flows entering Forest Creek and Billabong Creek. Hartwood Weir raises the water level of Billabong Creek so that water enters Forest Creek via Forest Creek Offtake. Gates fully open and Forest Creek Offtake sends uncontrolled flows to Forest Creek when discharge in Billabong Creek downstream of Hartwood Weir exceeds 1,200 ML/d, unless it is the result of a managed environmental flow event or other necessary circumstances
Warriston Weir	Forest Creek	The delivery of regulated flow terminates at Warriston weir. Planned environmental water deliveries, excess water and flood flows pass Warriston Weir into the Forest Creek Anabranh.
Boonoke Homestead Weir	Mid Billabong Creek	Existing weir is privately owned and provides a weir-pool for stock and domestic / irrigation supply.
Piccaninny Weir	Lower Billabong Creek	Existing weir at Piccaninny is privately owned and provide a weir-pool for stock and domestic / irrigation supply.
Traceys Dam	Lower Billabong Creek	Existing weir is privately owned and provides a weir-pool for stock and domestic / irrigation supply.
Chinamans Dam	Lower Billabong Creek	Existing weir is privately owned and provides a weir-pool for stock and domestic / irrigation supply.
4 Mile Weir	Lower Billabong Creek	Existing weir is privately owned and provides a weir-pool for stock and domestic / irrigation supply.
Old Wanganella Homestead Weir	Lower Billabong Creek	Existing weir is dysfunctional. Original purpose may have been to increase water security for an old dysfunctional house next to the weir.

3.1.5 Current hydrological conditions

Prior to European settlement (pre-development) it is believed that the Murrumbidgee River only connected to the creek during flows of around 40,000 ML/day or greater (NSW DPI 2015). Pre-development flows into Yanco Creek occurred 1 in 2 years with a duration of less than 10% of the time (Alluvium 2013).

The Yanco Weir on the Murrumbidgee River was built in 1928 and upgraded in 1981 to control and increase flows into the Yanco Creek system (NSW DPI 2015). Yanco Weir allows flow into Yanco Creek to be controlled over a range of Murrumbidgee discharge from 1,500 ML/day to 15,000 ML/day downstream of Yanco Weir (Alluvium 2013). Murrumbidgee flows above 15,000 ML/day downstream of Yanco Weir exceed the capacity of the Yanco Regulator, on the Murrumbidgee River, and the share of flow between the Murrumbidgee and Yanco Creek (through the Yanco offtake) is uncontrolled (James McGuire OEH pers. comm. in Cooling and Gippel 2018). The hydraulics of the offtake directs approximately 10% of Murrumbidgee flow into Yanco Creek (Cooling and Gippel 2018). This has meant flows through the Yanco Creek System are maintained at artificially high levels during high demand periods.

WaterNSW manages the Yanco System to deliver around 110 GL annually to 423 water licensees and provide town water supply to Morundah, Urana, Oaklands, Jerilderie, Conargo and Wanganella (DPI Water 2017; NSW DPIE 2019a). Under typical conditions, the Water Sharing Plan for the Murrumbidgee Regulated River Water Source (NSW Government 2020) limits regulated flow in upper Yanco Creek to 1,400 ML/day (at offtake) to prevent excessive losses from overbank flows. A minimum daily flow of 50 ML/day plus downstream water orders at Darlot is provided to maintain connectivity with the Edward River and enable water order delivery, as per the Murrumbidgee Water Sharing Plan. Outfall drains (i.e. irrigation escapes) are used to supplement water supply and overcome capacity constraints - water may be provided from the Coleambally Irrigation Area to Yanco Creek and from the Murray Irrigation District to Billabong Creek and Forest Creek.

The total annual flow volume pre-development was much lower than under current conditions, which was more pronounced in the upper reaches (i.e. Yanco Creek and Colombo Creek) than in the lower reaches (Alluvium 2013). In addition, inter-annual variation in flows were generally more variable with average to high total annual flows frequently followed by near no-flow years. Before regulation, Colombo Creek was a high-level gaining creek that carried approximately 30% of the water passing down Yanco Creek. Tarabah Weir is operated to increase the proportion of flow passing down Colombo Creek to almost 50%. Combined with the greater inflows from the Murrumbidgee, flow is now seven times higher than pre-regulation in Colombo Creek (145 GL/year). Flow in Yanco Creek below the Tarabah Weir is now three times higher than pre-regulation (150 GL/year) (Alluvium 2013).

Flows in the Yanco Creek System vary widely depending on a range of factors, including rainfall, inflows, evaporation, and demand for water for human use. At any given time, water flowing through the system is directed for various uses, including irrigation, industry, communities, the environment. The exact mix of these flow components is determined by demand and water availability, amongst other factors. Flow within the Yanco system is regulated at key locations to manage water delivery. Weirs regulate the share of water between Colombo Creek and Yanco Creek (Tarabah Weir) and between Forest Creek and Billabong Creek (Hartwood Weir and Forest Creek Regulator). The delivery of regulated water in Forest Creek terminates at Warriston Weir (Cooling and Gippel 2018). In addition, there are over 30 private licenced fixed crest weirs that were constructed to provide a local store of water for stock and domestic use during low flow periods and continue to facilitate irrigation water supply (see Section 3.1.4).

Broadly, the current hydrology of the Yanco Creek System represents a high degree of hydrological alteration to flow categories (i.e. cease-to-flow, low flow and baseflow, freshes and high and infrequent flows), from that needed to meet the objectives and targets for priority environmental assets (water dependent ecosystems) and ecosystem functions identified in the Murrumbidgee Long Term Water Plan (NSW DPIE 2020b).

3.2 Modelled hydrological conditions - Base Case scenario

The following sections summarise the modelled hydrological regime as characterised using the Base Case scenario Source model results from 1 July 1895 to 30 June 2022.

For Yanco and Colombo Creeks, the modelled hydrological regime is representative of existing weir structures, flow constraints, environmental baseflow provisions, environmental flow provisions and irrigation escape flows applicable to these reaches.

For mid and lower Billabong Creek, which includes the proposal study area, the modelled hydrological regime is representative of the operation of the existing Hartwood and Wanganella weirs and other structures, flow constraints, minimum flow provisions, environmental flow provisions and irrigation escape flows applicable to these reaches.

3.2.1 Annual water balance

Figure 3-2 and Table 3-2 summarise the modelled mean annual water balance at key locations within the Yanco Creek System under the Base Case scenario.

The modelled mean annual water balance results show that under modelled Base Case scenario, flows that enter upper Yanco Creek through the Yanco Creek Offtake are distributed throughout waterways within the Yanco Creek System at key confluence and diffidence points. Flows are split relatively evenly at the Yanco Creek – Colombo Creek bifurcation between Yanco Creek at Morundah (135.1 GL/year) and Colombo Creek at Morundah (129.1 GL/year). Colombo Creek then joins Billabong Creek resulting in an increase in flows at Billabong Creek at Jerilderie (207.6 GL/year). Only a minor portion of flows are diverted to Forest Creek, with the majority of flows continuing to Billabong Creek downstream of Hartwood Weir (149.4 GL/year). Yanco Creek then joins Billabong Creek resulting in an increase in flows at Billabong Creek at Conargo (245.9 GL/year) which then flows onto Billabong Creek at Darlot (211.5 GL/year).

There are also several inflows into and extractions from the system, including consumptive extractions (66.9 GL/year), irrigation escape inflows (32 GL/year) and evaporation losses (23.2 GL/year). There is approximately 131.9 GL/year of miscellaneous lateral fluxes, which includes errors in gauging, seepage, overbank flows losses etc. which are not able to be explicitly modelled.

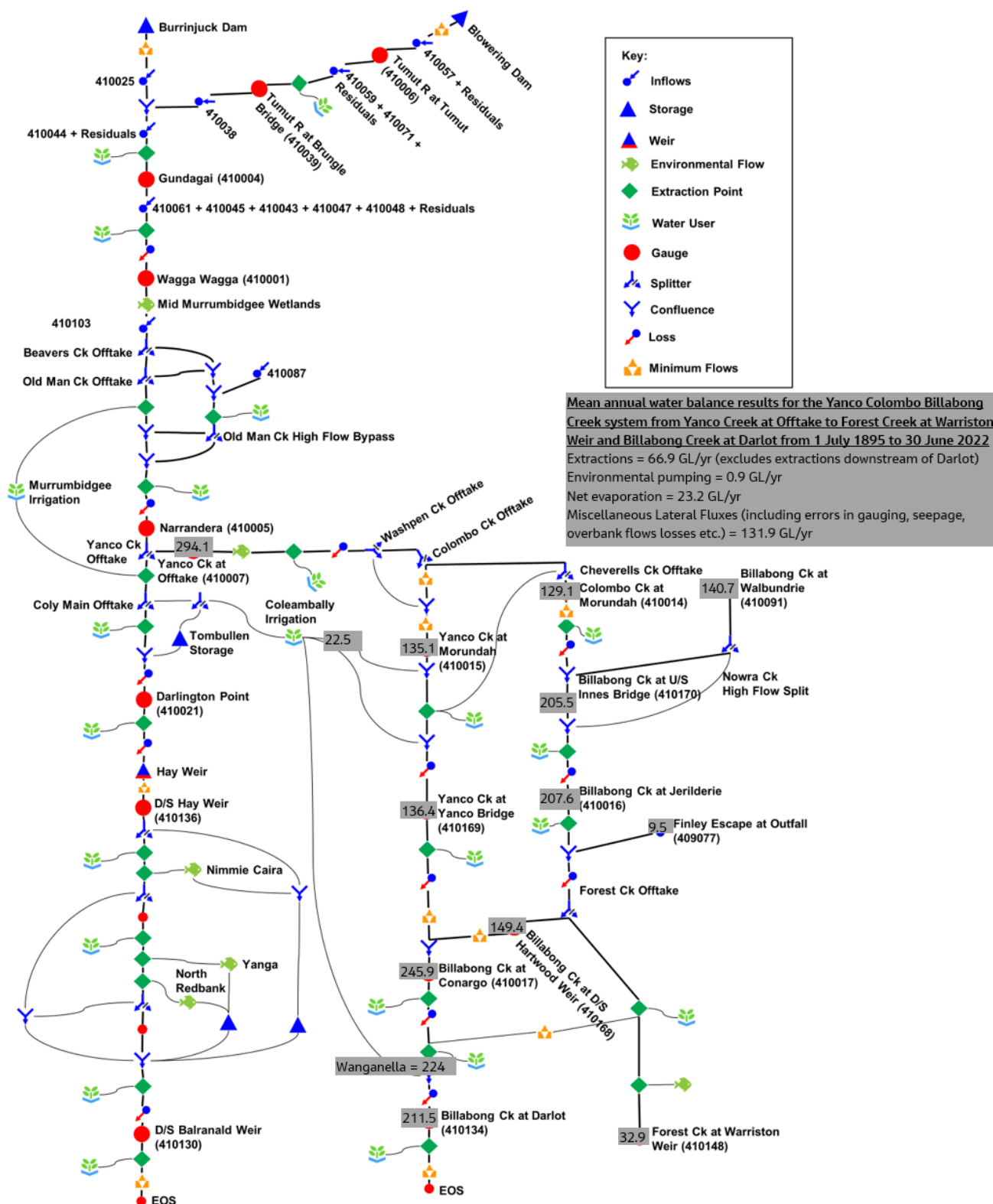


Table 3-2 Mean annual water balance at key locations under the Base Case scenario.

Planning Unit	Key location	Mean annual flows (GL/year)
PU10: Upper Yanco Creek	Yanco Offtake	294.1
PU11: Colombo & Billabong Creeks	Colombo Creek at Morundah	129.1
	Billabong Creek Inflows at Walbundrie	140.7
	Billabong Creek at US Innes Bridge	205.5
	Billabong Creek at Jerilderie	207.6
	Finley Escape inflows	9.5
	Billabong Creek at DS Hartwood Weir	149.4
PU12: Lower Yanco Creek to Lower Billabong Creek	Yanco Creek at Morundah	135.1
	CCD + DC800 irrigation escape inflows	22.5
	CICL escape transmission losses	0.3
	Coly Outfall Drain inflows	0.5
	Yanco Creek at Yanco Bridge	136.4
	Billabong Creek at Conargo	245.9
	Billabong Creek at Wanganella	224.0
PU13: Lower Billabong and Intersecting Streams	Billabong Creek at Darlot	211.5
	Forest Creek at Warriston Weir	32.9
	Flow Down Piccaninny Creek	0.3
Overall (for the Yanco Creek System from Yanco Creek at Offtake to Forest Creek at Warriston Weir and Billabong Creek at Darlot)	Consumptive extractions (Irrigation + Town Water Supply)	66.9
	Environmental Pumping (via Australian Food and Agriculture pumps)	0.9
	Net Evaporation	23.2
	Change in Regulator and River Storage	-0.0
	Miscellaneous Lateral Fluxes (all components not explicitly modelled, including errors in gauging, seepage, overbank flows losses etc.)	131.9

3.2.2 Seasonality of flows

3.2.2.1.1 Upper Yanco, Lower-Yanco and Colombo Creeks

Figure 3-3 and Table 3-3 present the modelled mean monthly flows results at key locations within Yanco and Colombo Creeks under the Base Case scenario. The modelled mean monthly flows display a typical temperate seasonal pattern, with generally higher flows during winter-spring and lower flows during summer-autumn periods. This temporal trend of flow volumes is generally consistent with that under pre-developed conditions (Alluvium 2013). Under the Base Case scenario, higher flows in winter-spring are likely due to unregulated high and intermediate flows entering Upper Yanco Creek through the Yanco Offtake and possibly lower irrigation demand during wetter months.

Although mean annual flow volumes suggest slightly more water flows through Lower Yanco Creek than Colombo Creek, Figure 3-3 indicates some variability in the bifurcation of flows between Lower Yanco and Colombo Creeks throughout the year, with a greater proportion of flow being directed down Colombo Creek between December and May. This aligns with the findings of Alluvium's 2013 Yanco Creek System environmental flow study, where it was found that Yanco Creek carries the major portion of the unregulated flows that generally occur in winter-spring, whereas Colombo Creek carries the major portion of regulated flows in summer-autumn.

Figure 3-3 also indicates that under the Base Case scenario, modelled mean monthly flows are higher at Yanco Bridge compared to Yanco Creek at Morundah from November to May, which reflects the modelled additional flow contributions associated with Coleambally Catchment Drain (CCD) and Drainage Channel 800 (DC800) entering Yanco Creek below Tarabah Weir, as well as flows from Cheverells Creek which rejoins Yanco Creek downstream of Yanco Creek at Morundah.

Figure 3-4 shows modelled mean monthly flow statistics for Murrumbidgee downstream of Yanco Weir (excluding potential outliers) as well as the 15,000 ML/day threshold downstream of Yanco Weir, above which the flow split between Yanco Offtake Cutting and the Murrumbidgee River is controlled by the natural landscape as opposed to the regulation gates at Yanco Weir (Cooling and Gippel 2018). It can be seen that under the Base Case scenario, flows in the Murrumbidgee River exceed this threshold between July – November. Monthly flow analysis at Murrumbidgee River downstream of Yanco Weir for the period 1895-2022 indicate approximately 10-30% of flows exceed the regulating capacity of the Yanco Regulator between July – November (Table 3-4).

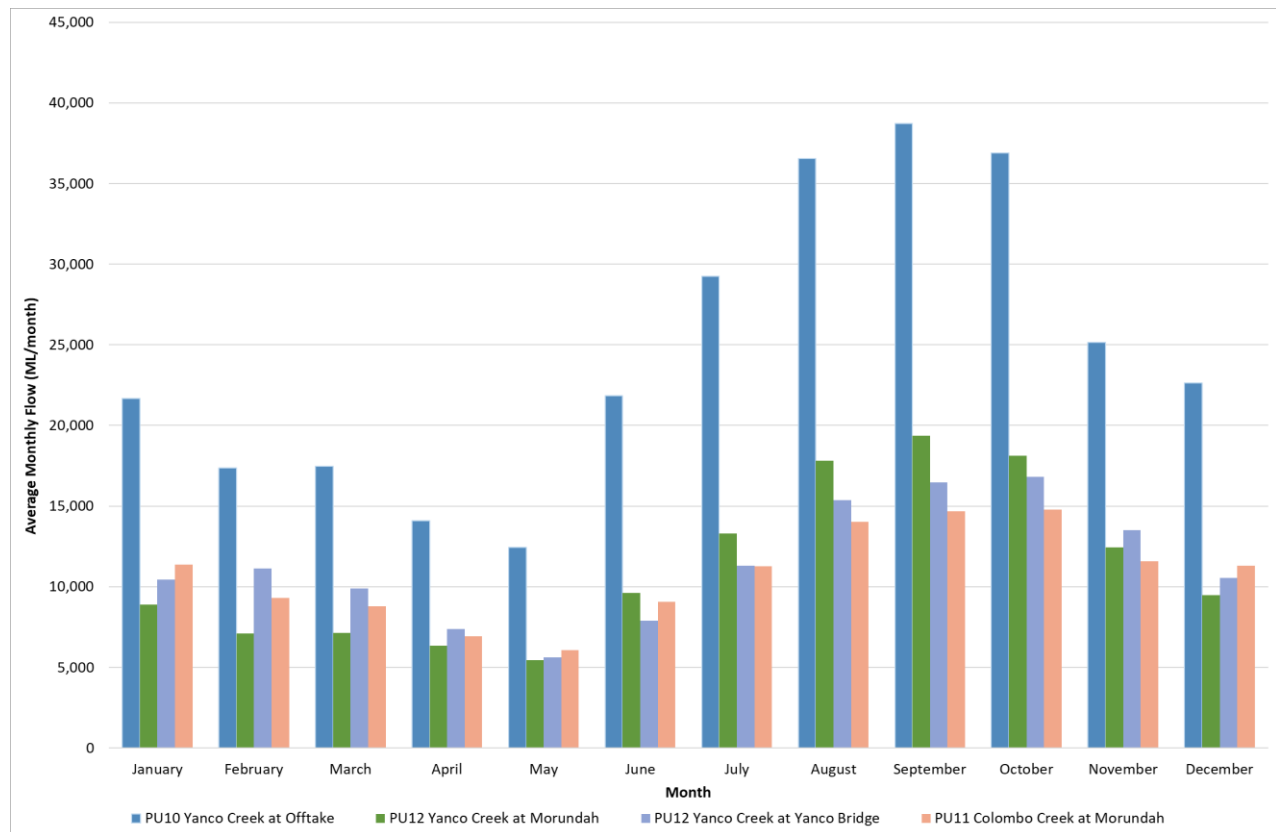


Figure 3-3 Mean monthly flows at key locations for PU reaches in Yanco Creek and Colombo Creek under the Base Case scenario.

Table 3-3 Mean monthly flows at key locations for PU reaches in Yanco Creek and Colombo Creek under the Base Case scenario.

Mean monthly flows (ML/month)	PU10 Yanco Creek at Offtake	PU11 Colombo Creek at Morundah	PU12 Yanco Creek at Morundah	PU12 Yanco Creek at Yanco Bridge
January	21,680	11,358	8,882	10,446
February	17,349	9,308	7,097	11,137
March	17,464	8,794	7,136	9,878
April	14,103	6,912	6,342	7,384
May	12,424	6,061	5,458	5,614
June	21,827	9,065	9,621	7,887
July	29,257	11,282	13,283	11,319
August	36,535	14,020	17,821	15,353
September	38,708	14,681	19,358	16,471
October	36,904	14,788	18,130	16,810
November	25,156	11,574	12,448	13,497
December	22,647	11,289	9,492	10,556

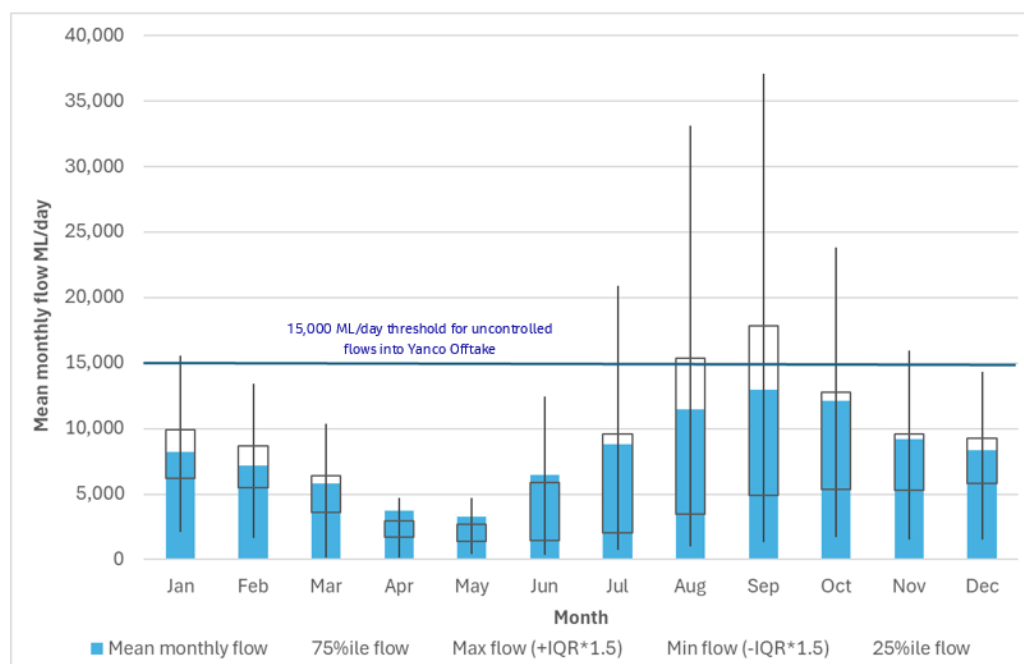


Figure 3-4 Mean monthly flow statistics for Murrumbidgee River downstream of Yanco Weir under Base Case scenario, excluding potential outliers.

Table 3-4 Monthly flow statistics for Murrumbidgee River downstream of Yanco Weir under Base Case scenario for the period 1895-2022

Daily flows (ML/day)	Max daily flow	75%ile daily flow	Median daily flow	25%ile daily flow	Min daily flow	% of days where flow >15,000 ML/day
Jan	44,162	9,937	7,913	6,186	2,131	2%
Feb	61,324	8,670	7,192	5,462	1,656	1%
Mar	179,097	6,375	4,810	3,622	176	2%
Apr	191,656	2,946	2,337	1,751	167	3%
May	82,784	2,719	1,948	1,396	397	2%
Jun	125,204	5,867	2,202	1,470	340	10%
Jul	172,477	9,589	3,533	2,040	760	16%
Aug	92,238	15,360	6,698	3,446	1,014	26%
Sep	180,231	17,837	8,440	4,927	1,343	31%
Oct	105,288	12,788	7,756	5,332	1,704	21%
Nov	102,517	9,572	6,870	5,311	1,538	10%
Dec	78,342	9,235	7,315	5,821	1,537	5%

3.2.2.1.2 Mid and lower Billabong Creek

Figure 3-5 and Table 3-5 present the modelled mean monthly flows under the Base Case scenario at key locations within mid and lower Billabong Creek, which includes the proposal study area. The modelled mean monthly flows display a typical-temperate seasonal pattern, with generally higher flows during winter-spring and lower flows during summer-autumn periods. Under the Base Case scenario, there are higher flows in winter-spring, which could be attributed to higher flows in Yanco and Colombo Creeks in winter-spring (Table 3-4) causing unregulated high and intermediate flows to enter mid and lower Billabong Creek, as well as higher flows from the upper Billabong Creek catchment during wetter periods.

Mean monthly flows are smaller downstream of Hartwood Weir compared to at Jerilderie (Figure 3-5 and Table 3-5) as a result of flow offtake to Forest Creek through the Forest Creek Offtake. Mean monthly flows are modelled to be larger on average at Wanganella and Darlot than at Jerilderie throughout the year, with the exception of June-August. This is potentially the result of unregulated flows into the Yanco Creek System through Yanco Offtake that flow through into Mid-Billabong Creek from Colombo Creek and into Lower-Billabong Creek from Yanco Creek and unregulated flows entering from the upper Billabong Creek catchment upstream of Jerilderie during wetter periods (i.e. June-August).

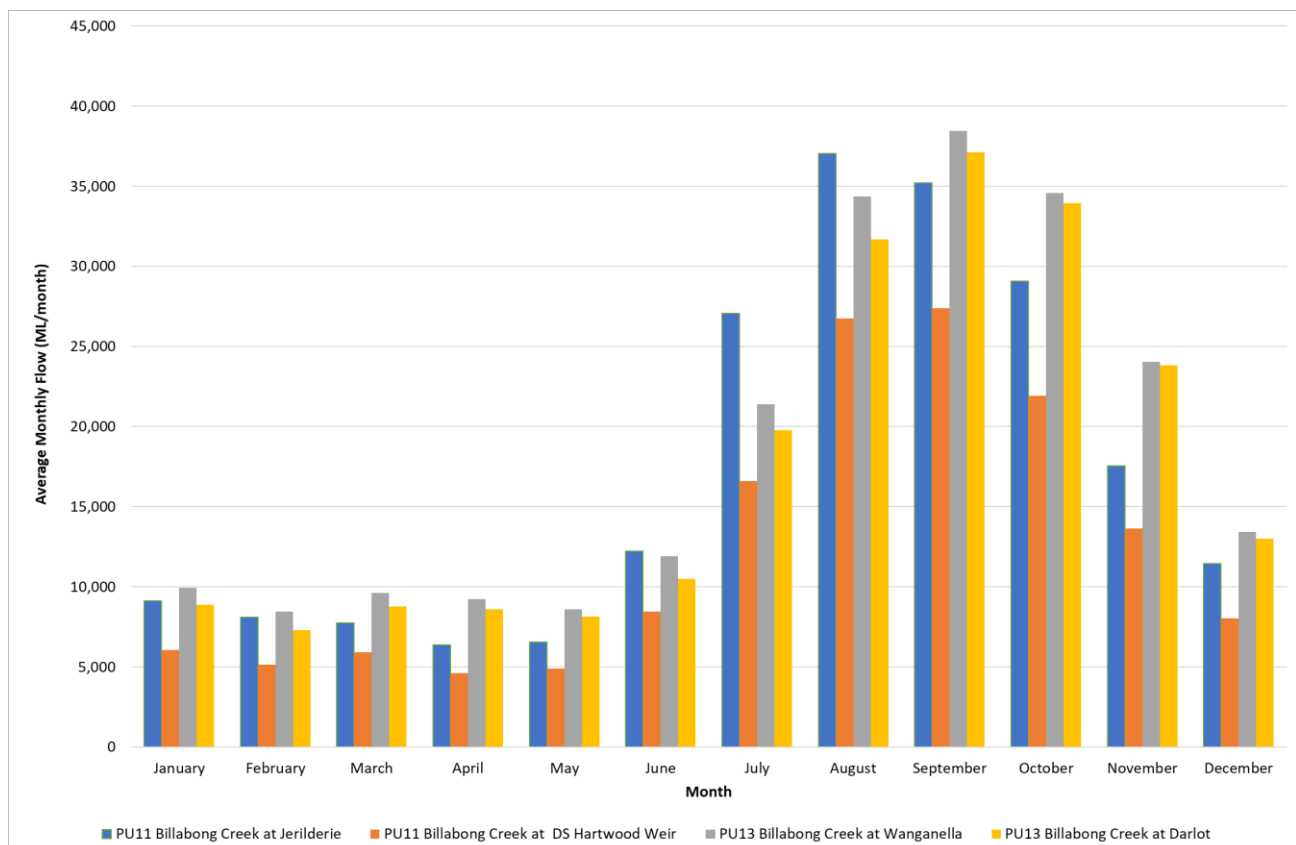


Figure 3-5 Mean monthly flows at key locations for PU reaches in the mid and lower Billabong Creek under the Base Case scenario.

Table 3-5 Mean monthly flows at key locations for PU reaches in the mid and lower Billabong Creek under the Base Case scenario.

Mean monthly flows (ML/month)	PU11 Billabong Creek at Jerilderie	PU11 Billabong Creek at DS Hartwood Weir	PU13 Billabong Creek at Wanganella	PU13 Billabong Creek at Darlot
January	9,139	6,052	9,934	8,870
February	8,092	5,156	8,466	7,286
March	7,742	5,903	9,603	8,780
April	6,390	4,620	9,228	8,605
May	6,555	4,906	8,585	8,132
June	12,228	8,453	11,924	10,512
July	27,074	16,606	21,397	19,772
August	37,056	26,736	34,363	31,666
September	35,213	27,388	38,461	37,122
October	29,069	21,924	34,590	33,954
November	17,559	13,645	24,041	23,823
December	11,443	8,030	13,409	12,983

3.2.3 Flow variability

3.2.3.1 Yanco Creek and Colombo Creek

Figure 3-6 shows modelled total annual flows results for key reaches in Yanco and Colombo Creeks under the Base Case scenario. Under the Base Case scenario, the total annual flow into the Upper Yanco Creek at Yanco Offtake is highly variable. From Figure 3-7, it can be seen that modelled daily flow for the Murrumbidgee River downstream of Yanco Weir exceeds 15,000 ML/day for approximately 11% of days across the time series (for the period 1865-2022), indicating uncontrolled flows into Upper Yanco Creek are not uncommon. Under the Base Case scenario, total annual flows into Upper Yanco Creek are modelled to be >100 GL/year across the modelled time series (Figure 3-6) and there is an absence of near no-flow years under current conditions.

The modelled average daily flow volumes at key locations within Yanco and Colombo Creeks under the Base Case scenario are presented in Figure 3-8. Figure 3-8 indicates average daily flows are highly variable within Yanco and Colombo Creeks, and this is particularly evident in Upper Yanco Creek. In regulated irrigation systems, such as the Yanco Creek System, large flow variability (and corresponding water levels) is known to occur in response to irrigation demand and extraction rates (Sharpe 2018). Highly variable water levels, which are directly associated with the modelled averaged daily flow volumes, evident within Yanco, Colombo and Billabong Creeks, is one reason that Stuart (2022) characterised them as extremely flow modified.

Figure 3-8 also indicates the high variability in modelled average daily flow volumes are particularly evident from December to April which is likely in response to modelled irrigation, consumptive and environmental demands during periods of lower flow. Sharp and Stuart (2014) identified wide fluctuations in average daily discharge, and water level, occur in Yanco and Colombo Creeks during spring/summer to meet varying irrigation needs, but are not part of the natural daily variation of lowland river systems or anabranch systems where variation is buffered.

Modelled average daily flow volumes are somewhat less variable during May to November, with buffer of daily flow variability in wetter months likely associated with unregulated flows from the Murrumbidgee River through Yanco Offtake and tributary streams that pass through the Yanco and Colombo Creeks.

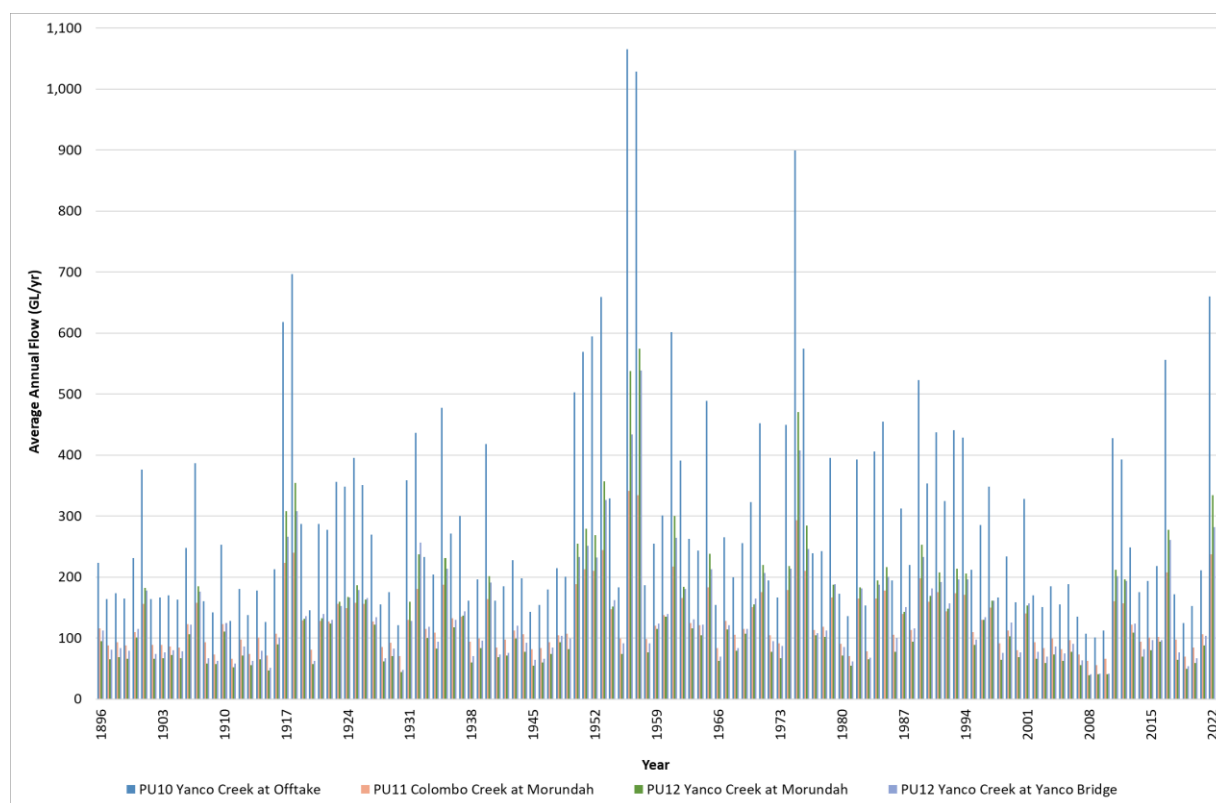


Figure 3-6 Total annual flows at key locations for PU reaches in Yanco Creek and Colombo Creek under the Base Case scenario.

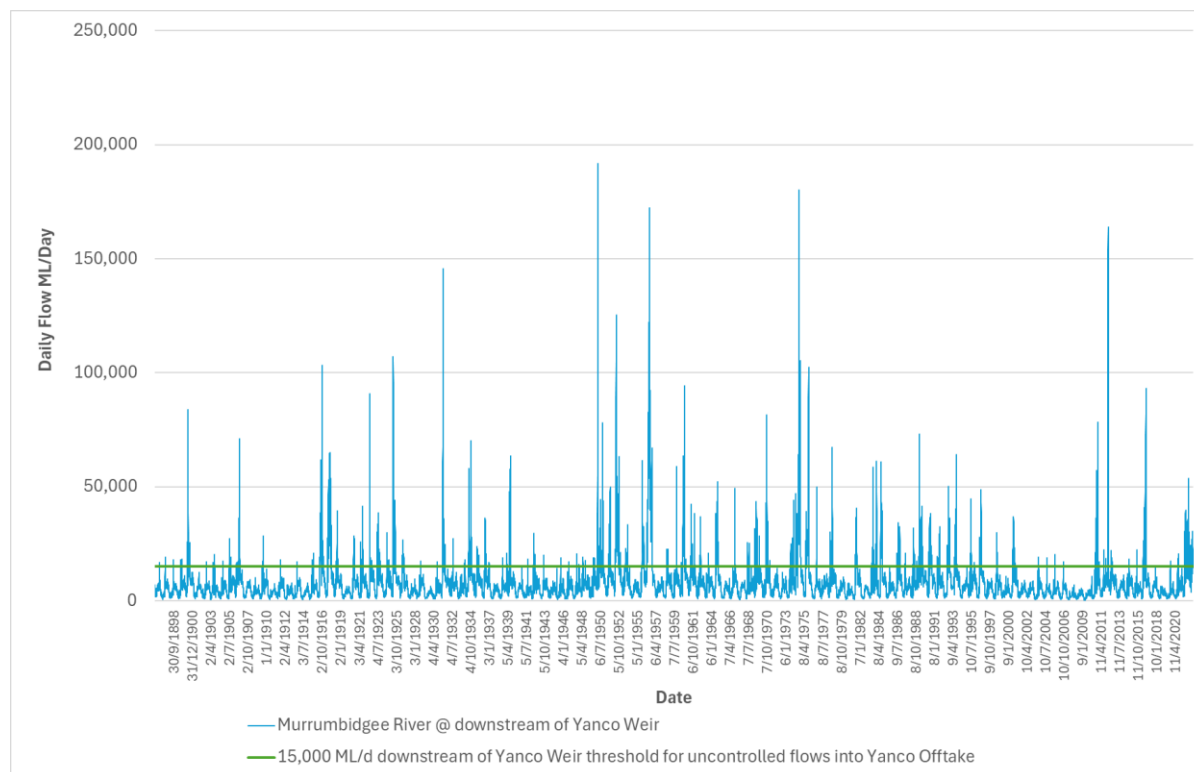


Figure 3-7 Daily flows at Murrumbidgee River downstream of Yanco Weir under Base Case scenario.

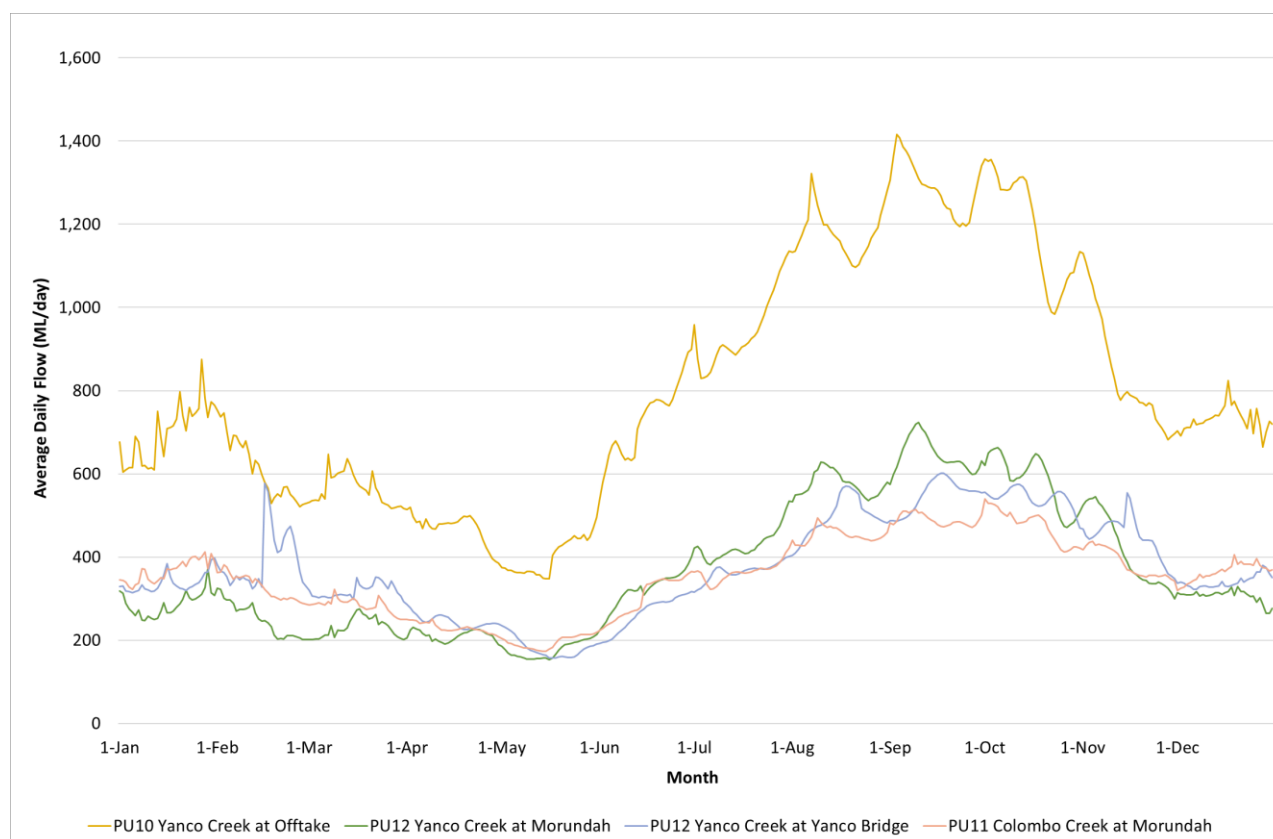


Figure 3-8 Mean daily flows at key locations for PU reaches in Yanco Creek and Colombo Creek under the Base Case scenario.

3.2.3.2 Mid and lower Billabong Creek

Figure 3-9 shows modelled total annual flows for mid and lower Billabong Creek under the Base Case scenario. Under modelled Base Case scenario, the total annual flow in mid and lower Billabong is highly regulated and as a result flows are modelled to be >33.5 GL/year at Jerilderie, >23.9 GL/year at Hartwood, >42 GL/year at Wanganella and >36 GL/year at Darlot across the time series. Although modelled total annual flows are still highly variable at all locations there is an absence of near no-flow years under modelled current conditions (Alluvium 2013).

The modelled average daily flows under the Base Case scenario at key locations within mid and lower Billabong Creek are represented in Figure 3-10. Figure 3-10 indicates average daily flows are highly variable within mid and lower Billabong Creek, and this is particularly evident downstream of Hartwood Weir compared to other locations. The highly variable modelled mean daily flows throughout mid and lower Billabong Creek are evident as a result of irrigation demand and extraction rates (Sharpe 2018) and are characteristic of extreme flow stress (Stuart 2022).

The annual temporal pattern of flow variability within mid and lower Billabong Creek (Figure 3-10) is consistent with that evident in Yanco and Colombo Creeks, with high variability in modelled average daily flow volumes evident from December to April, particularly at downstream of Hartwood Weir, and somewhat less variability at all locations from May to November. The high modelled daily flow variability evident downstream of Hartwood Weir compared to other locations (Figure 3-10) is likely the result of the modelled operation of Forest Creek Offtake to meet irrigation demands and environmental water provisions within Forest Creek. Comparatively less variability in modelled average daily flow volumes at other Billabong Creek sites, Jerilderie, Wanganella and Darlot (Figure 3-10), are likely the result of buffering by unregulated flows from the upper

Billabong Creek catchment at Jerilderie, and inflows from Yanco Creek that moderate daily flow variability at Wanganella and Darlot.

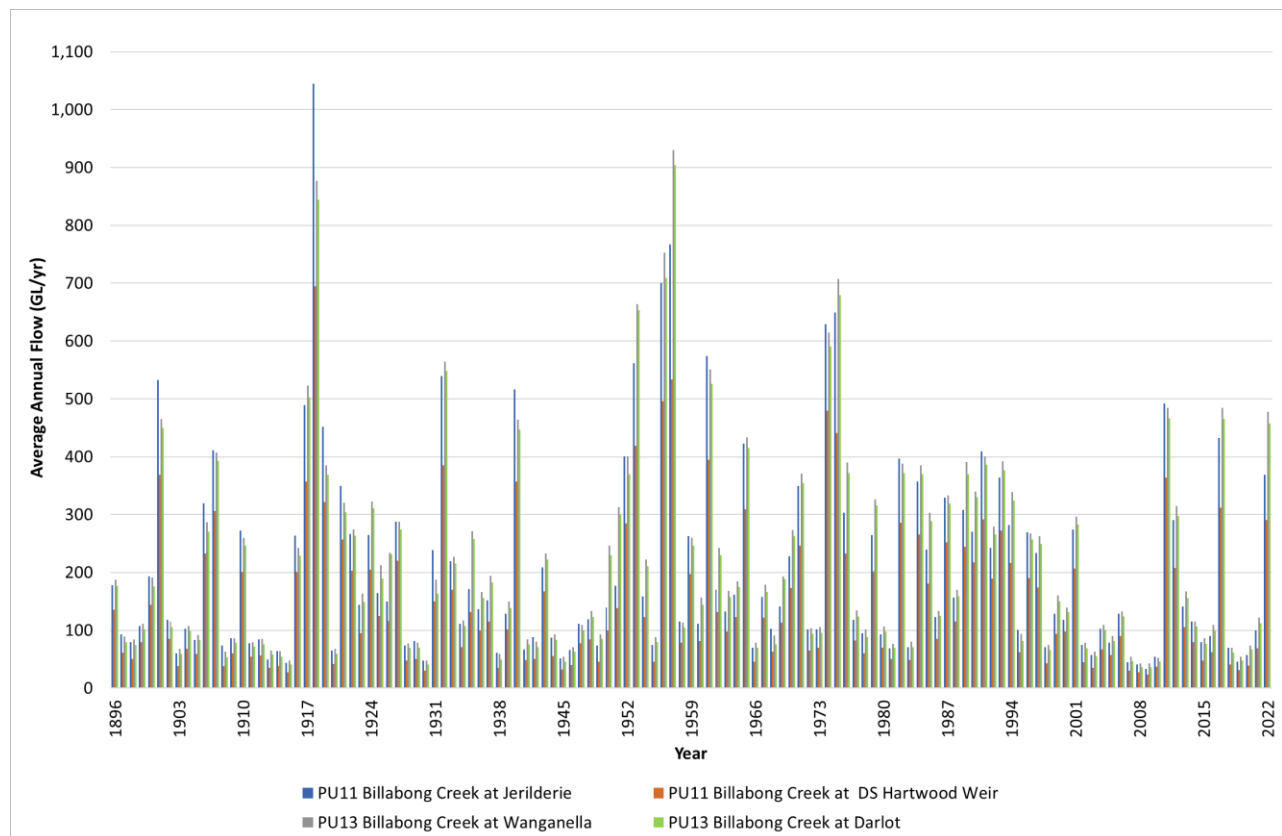


Figure 3-9 Total annual flows at key locations for PU reaches in mid and lower Billabong Creek under the Base Case scenario.

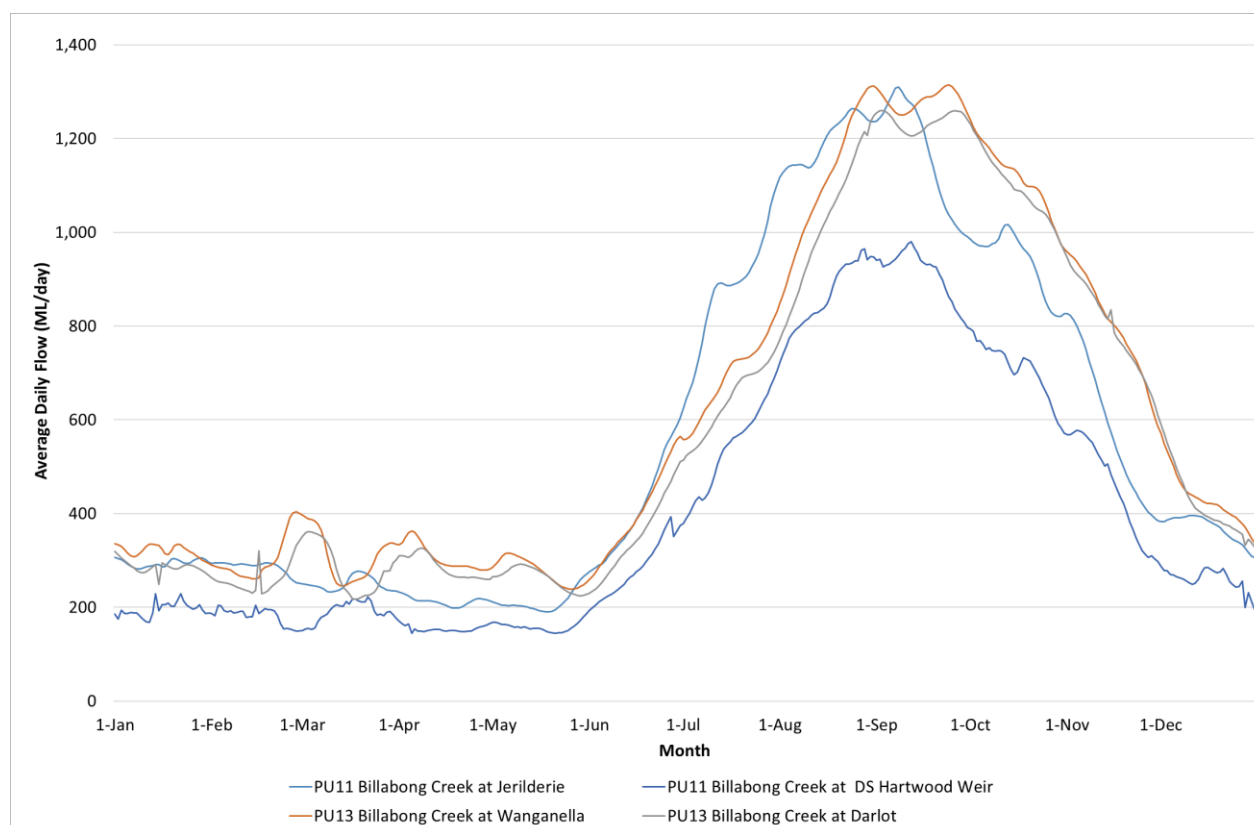


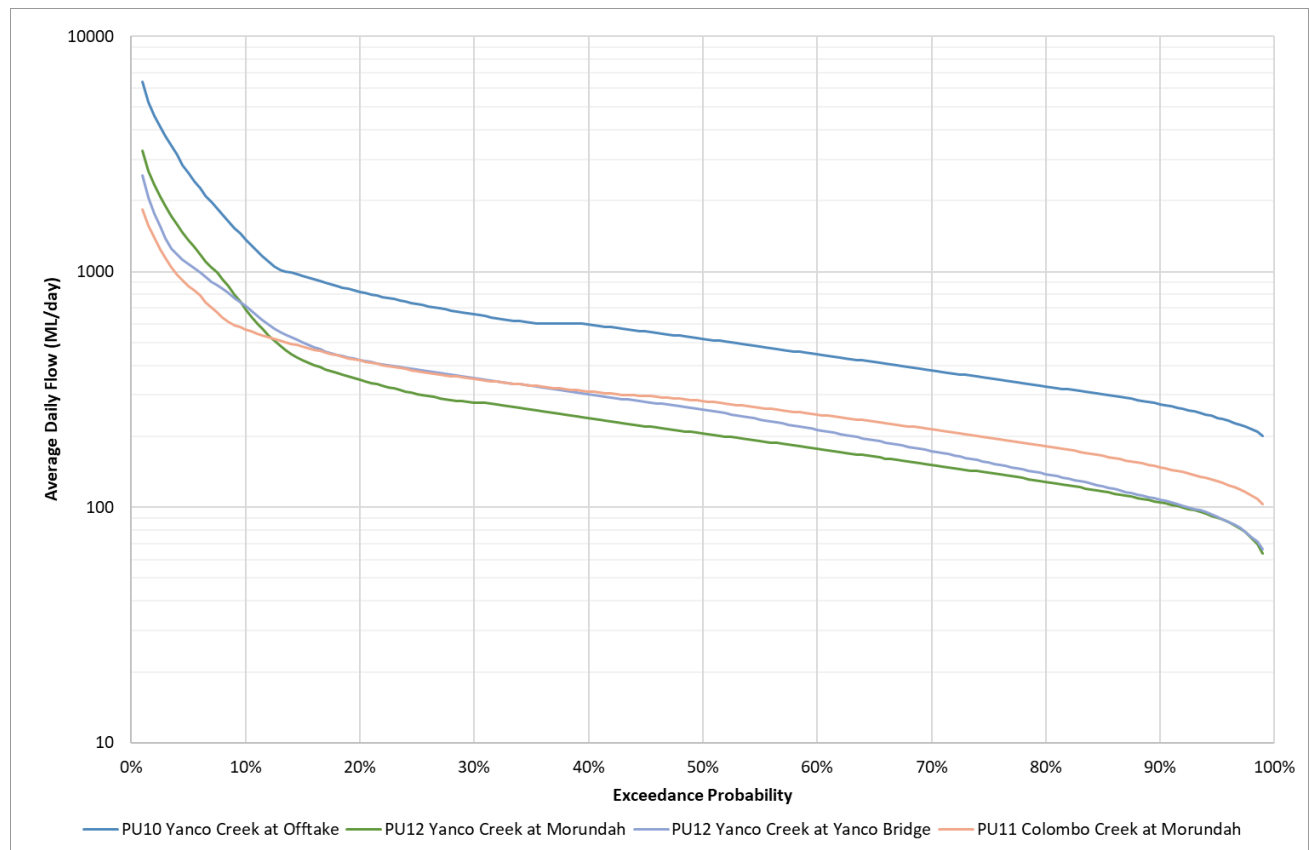
Figure 3-10 Average daily flows at key locations for PU reaches in mid and lower Billabong Creek under the Base Case scenario.

3.2.4 Flow sizes

3.2.4.1 Yanco Creek and Colombo Creek

Figure 3-11 and Table 3-6 present the daily flow size analysis results for Yanco Creek and Colombo Creek. Figure 3-11 and Table 3-6 indicate cease-to-flow (i.e. 0 ML/day) no longer occurs throughout Yanco and Colombo Creeks under the modelled Base Case scenario, which aligns with the modelled minimum operational flow targets of 50 ML/day at Yanco Creek @ Morundah and 65 ML/day at Colombo Creek @ Morundah under current operations.

Table 3-6 shows that small overbank flows are modelled to occur infrequently (less than 10% of the time) within upper and lower Yanco Creek under the Base Case scenario. Although the Water Sharing Plan (NSW Government 2020) sets a limit of 1,400 ML/day on controlled diversions at the Yanco offtake, noting the limit is designed to minimise inundation of private property and to reduce losses associated with overbank flows (Cooling and Gippel 2018). As has already been discussed in Section 3.2.3 uncontrolled flows through Yanco Offtake when Murrumbidgee daily flows exceeds 1,400 ML/day flow threshold downstream of Yanco Weir are not uncommon, and occur approximately 11% of the time for data from 1895-2022. Overbank flows in Yanco and Colombo Creeks are an important component of the environmental water requirements of the system, as these reaches contain high value wetlands and flood runners.



*Note that it has been chosen to exclude the 0% and 100% percentiles from this analysis (discussed further in Table 2-8).

Figure 3-11 Daily flow duration curves at key locations for PU reaches in Yanco Creek and Colombo Creek under the Base Case scenario.

Table 3-6 Percentile table for mean daily flow ML/day at key locations for PU reaches in Yanco Creek and Colombo Creek under the Base Case scenario.

Percentile	PU10 Yanco Creek at Offtake	PU11 Colombo Creek at Morundah	PU12 Yanco Creek at Morundah	PU12 Yanco Creek at Yanco Bridge**
0%*				
5%	2,622	870	1,358	1,076
10%	1,371	569	693	715
15%	959	480	420	500
20%	822	420	348	421
25%	729	379	303	384
30%	658	351	279	353
35%	606	329	260	327
40%	598	310	239	303
45%	557	297	221	280
50%	519	282	206	260
55%	482	265	191	236
60%	445	248	177	214
65%	414	231	164	192
70%	382	214	151	173
75%	353	197	140	155
80%	326	181	128	138
85%	302	165	117	123
90%	274	148	105	108
95%	240	129	90	91
100%*				

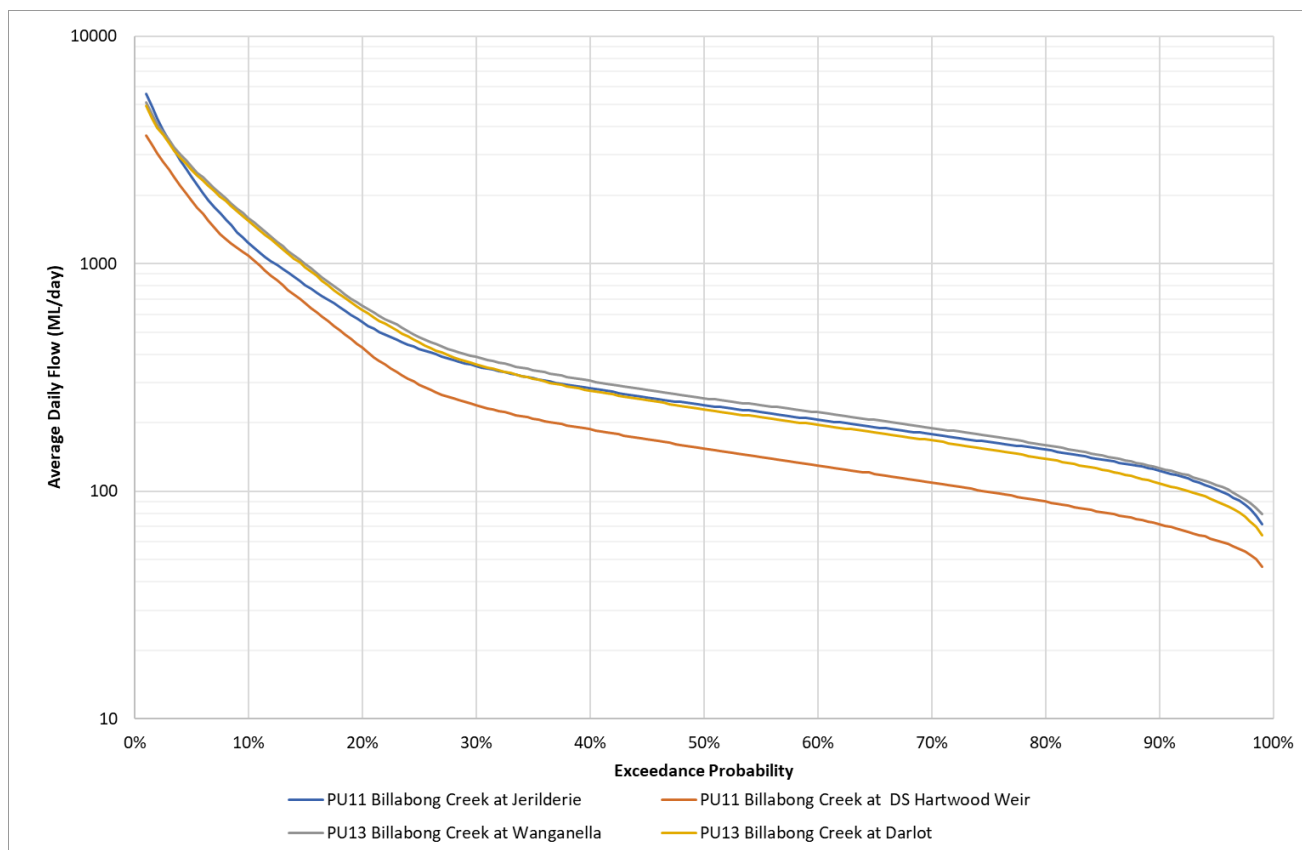
*Note that it has been chosen to exclude the 0% and 100% percentiles from this analysis (discussed further in Table 2-8).

**Note that the following symbology has been used to distinguish between different flow categories. For Yanco Creek at Offtake, Colombo Creek at Morundah and Yanco Creek at Morundah, there are specific flow rate threshold estimates for different flow categories documented in Table 9 of Murrumbidgee Long Term Water Plan Part A: Murrumbidgee catchment (NSW DPIE 2020a). However, this does not exist for Yanco Creek at Yanco Bridge, and as such the flow categories for Yanco Creek at Morundah have been applied. Whilst there are additional inflows and outflows between Yanco Creek at Morundah and Yanco Bridge which may alter flow categorisation, for the purposes of this comparative assessment between scenarios, we believe this is an adequate approach.

Smaller than very low flows	Very low flows	Baseflows	Small freshes	Large freshes	Large freshes: wetland connection	Small overbank	Large overbank
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Mid and lower Billabong Creek Figure 3-12 and Table 3-7 present the daily flow size analysis results for modelled daily flows at key locations within mid and lower Billabong Creek, which includes the proposal study area. Figure 3-12 and Table 3-7 show that under the modelled Base Case scenario, cease-to-flow does not occur throughout this part of the system. It can also be seen from Figure 3-12 that flows downstream of Hartwood Weir are generally smaller than at other locations within mid and lower Billabong Creek. Table 3-7 also suggests that downstream of Hartwood Weir, baseflows are modelled to occur more frequently (approximately 65% of the time) whereas small freshes are modelled to occur less frequently (approximately 5% of the time) compared to other locations in mid and lower Billabong Creek. As previously discussed, this prevalence of baseflows and proportionate reduction on small freshes is considered the result of flow diversion to Forest Creek through the Forest Creek Offtake which occurs upstream of the Hartwood Weir.

Table 3-7 indicates that overbank flows (small and large) and large freshes are modelled to occur infrequently (<15% of the time) within this part of the system under the Base Case scenario. However, the modelled Base Case scenario results also suggest that these high flow categories (i.e. overbank flows and large freshes) occur somewhat less frequently for Lower Billabong Creek at Darlot than other locations with the study area.



*Note that it has been chosen to exclude the 0% and 100% percentiles from this analysis (discussed further in Table 2-8).

Figure 3-12 Daily flow duration curves at key locations for PU reaches in the mid and lower Billabong Creek under the Base Case scenario.

Table 3-7 Daily flow duration table at key locations for PU reaches in the mid and lower Billabong Creek under the Base Case scenario.

Percentile	PU11 Billabong Creek at Jerilderie	PU11 Billabong Creek at DS Hartwood Weir**	PU13 Billabong Creek at Wanganella**	PU13 Billabong Creek at Darlot
0%*				
5%	2,422	1,904	2,678	2,587
10%	1,239	1,082	1,590	1,543
15%	807	670	997	965
20%	554	427	653	625
25%	421	295	476	450
30%	355	239	389	360
35%	314	209	340	313
40%	284	187	305	277
45%	258	169	279	252
50%	239	154	257	230
55%	223	141	239	211
60%	206	130	222	196
65%	192	119	206	181
70%	178	109	189	167
75%	165	100	175	153
80%	152	90	160	139
85%	138	81	143	125
90%	123	72	126	108
95%	102	61	107	90
100%*				

*Note that it has been chosen to exclude the 0% and 100% percentiles from this analysis (discussed further in Table 2-8).

**Note that the following symbology has been used to distinguish between different flow categories. For Billabong Creek at Jerilderie and Billabong Creek at Darlot, there are specific flow rate threshold estimates for different flow categories documented in Table 9 of Murrumbidgee Long Term Water Plan Part A: Murrumbidgee catchment (NSW DPIE 2020a). However, this does not exist for Billabong Creek at DS Hartwood and Wanganella, and as such the flow categories for Billabong Creek at Jerilderie and Darlot have been applied respectively. Whilst there are additional inflows and outflows between these gauges which may alter flow categorisation, for the purposes of this comparative assessment between scenarios, we believe this is an adequate approach.

Smaller than very low flows	Very low flows	Baseflows	Small freshes	Large freshes	Large freshes: wetland connection	Small overbank	Large overbank
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3.2.5 Environmental Water Requirements

3.2.5.1 Yanco and Colombo Creek

For modelled existing conditions (Base Case scenario) the EWR results for Upper Yanco Creek (Table 3-8) indicate a high frequency of attainment across almost all of the specified EWR categories i.e. to the specific flow or inundation regimes that are needed to support key ecological values and related Murrumbidgee Long Term Water Plan (MLTWP) objectives in this Planning Unit (NSW DPIE 2020b). The main exceptions are the Nesting Support for Murray Cod/Trout Cod (NestS1_tcmc) and Nesting Support for Murray Cod (NestS1_tcmc), Baseflow BF1_a, Small fresh SF1_P, Large fresh LF1_P and Floodplain connection flow EWR OB-S2_P. It should be noted that large freshes in Upper Yanco Creek are currently difficult to deliver due to potential impacts on third parties, and also, overbank flows (large or small) cannot currently be delivered in the creek. The flows occur due to tributary rainfall events or dam spills. Deliveries to these areas are currently only possible with pumping or where other infrastructure exists to divert water to the floodplain.

The EWR results for Lower Yanco Creek (Table 3-8) indicate a high frequency of attainment across almost all of the specified EWR categories. The main exceptions are the Nesting Support for Murray Cod (NestS1_mc) and Trout Cod /Murray Cod (NestS1_tcmc), Annual Base Flow in a typical year (BF1_a) EWRs, Small fresh SF1_P and SF2, Large fresh LF1_P and Wetland connection flow W-LF7. It should be noted that, large fresh and small over bank flows that connect wetlands and the floodplain in Lower Yanco Creek are currently difficult, while large over bank flows cannot be delivered, due to potential impacts on third parties or the flows occur due to tributary rainfall events or dam spills respectively. Deliveries of large freshes may only be possible with pumping or where other infrastructure exists to divert water to the floodplain (NSW DPIE 2022b).

The EWR results for Colombo Creek at Morundah to Billabong Creek upstream of Jerilderie (Table 3-8) indicate a high frequency of attainment across almost all of the specified EWR categories. The main exceptions are the Nesting Support EWRs for Murray Cod (NestS1_mc), Trout Cod /Murray Cod (NestS1_tcmc) and the Small Fresh (SF1_P) and Wetland connection flow EWR W-LF7. It should be noted that, large fresh and small over bank flows that connect wetlands and the floodplain in this zone are currently difficult, while large over bank flows cannot be delivered, due to potential impacts on third parties or the flows occur due to tributary rainfall events or dam spills respectively. Deliveries large freshes may only be possible with pumping or where other infrastructure exists to divert water to the floodplain (NSW DPIE 2022b).

3.2.5.2 Mid and lower Billabong Creek

The EWR results for Billabong Creek at Jerilderie to downstream of Hartwood Weir (Table 3-8) indicate a high frequency of attainment across almost all of the specified EWR categories.

The EWR results for Lower Billabong and Intersecting Streams – downstream to Moulamein (Table 3-8) indicate the frequency with which most of the specified EWR categories are modelled to be achieved represents a low degree of hydrological alteration. The main exceptions are the Nesting Support EWRs for Murray Cod (NestS1_mc), Trout Cod /Murray Cod (NestS1_tcmc), Wetland connection flow EWRs W-LF4_P ('preferred seasonal timing'), W-LF4_S ('any time that is considered satisfactory') and Floodplain connection flow EWR OB-S1. It should be noted that, large fresh that connect wetlands in this zone are currently difficult, and small (and large) over bank flows that connect the floodplain cannot be delivered, due to potential impacts on third parties or the flows occur due to tributary rainfall events or dam spills respectively. Deliveries of large freshes may only be possible with pumping or where other infrastructure exists to divert water to the floodplain (NSW DPIE 2022b).

Table 3-8 EWR adjusted frequency score results at key locations for PU reaches in the Yanco Creek System under the Base Case scenario.

Category	EWR	PU10 (Upper Yanco Creek)	PU12 (Lower Yanco Creek to Lower Billabong Creek)	PU11 (Colombo Creek at Morundah to Billabong Creek upstream of Jerilderie)	PU11 (Billabong Creek at Jerilderie to downstream of Hartwood Weir)	PU13 (Lower Billabong and Intersecting Streams)
Cease-to-flow (CtF)	CF1	100	100	100	100	100
Very low flow (VLF)	VF1_a	100	100	100	100	100
	VF1_b	100	100	100	100	100
Baseflow (BF)	BF1_a	68	32	100	100	100
	BF1_b	100	96	100	99	100
Native Fish Nesting Support	NestS1_mc	47	32	61		69
	NestS1_tcmc	36	27	53		57
Small fresh (pulse) (SF)	SF1_P	72	76	77		90
	SF1_S	84	85	90		92
	SF2	100	55	89		100
Large fresh (pulse) (LF)	LF1_P	76	77	80		85
	LF1_S	97	100	100		100
	LF2	98	100	100		100
Wetland connection flow (Wetland-LF)	W-LF4_P					67
	W-LF4_S					70
	W-LF5					96
	W-LF6_P	100	100	100		100
	W-LF6_S	100	100	100		100
	W-LF7	90	71	73		86
	W-LF8	100	100	100		100
Floodplain connection flow (OB)	OB-L1					88
	OB-L1_P	88	92	92		
	OB-L1_S	100	100	100		
	OB-S1					72
	OB-S2		90			98
	OB-S2_P	70		86		
	OB-S2_S	88		100		

Note that the green, yellow and red shading represents high, medium and low degree of EWR attainment as per Table 2-2.

4. Impact assessment

4.1 Construction of the proposal

4.1.1 Construction timing and duration

Construction of the proposal is anticipated to start in 2025 and be completed by 2026. The construction period is anticipated to be around 18 months. Construction would pause during periods of high flow.

4.1.2 Construction method and components

The construction method would be similar for each weir location, and at a high-level needs to be undertaken in two stages:

- Stage 1: Fishway and Lay Flat Gates, and
- Stage 2: Fixed Crest Weir

Key activities of the main construction components are outlined in Table 4-1.

Table 4-1 Proposed activities for construction components of the proposal

Stage	Activities
Fishway and lay flat gates	Construct hardstands for the compound, laydown areas and crane pad(s)
	Install site facilities and mobilise plant
	Demolish small section of existing weir to allow cofferdam through structure
	Install all the temporary cofferdams around new structures and old weirs separately and dewater work zones
	Prepare subgrade and initial earthworks including any remediation if required
	Install permanent sheet pile wall
	Form, reinforce and pour all slabs (fixed crest structure, stilling pool, apron and fishway)
	Form, reinforce and pour all walls (gates and fishway)
	Install scour protection and finalise backfill of new structure
	Demolish existing weir including reshaping of creek bed
	Install and commission lay flat gates and fishway furniture
	Flood cofferdam and remove the sheet piles around the new structure only
Fixed crest structure	Install temporary sheet pile cofferdam for the fixed crest weir section and seal against the new structure (at this point the new gates will be operational)

Stage	Activities
	Remove the cofferdam around the existing weir and reinstall around the other side of the existing weir
	Dewater the two new work zones
	Prepare subgrade and initial earthworks including any remediation if required
	Install remaining permanent sheet pile wall
	Form, reinforce and pour remaining slabs (fixed crest structure, stilling pool and apron)
	Form, reinforce and pour remaining walls (fixed crest structure)
	Install scour protection and finalise backfill of other side
	Demolish other side of the existing weir including reshaping of creek bed
	Flood both cofferdams and remove the sheet pile
	Rehabilitate work areas and demobilise from site

4.1.3 Water management

One of the major challenges for construction of the proposal is water management and the need to maintain operational flows to meet irrigation and consumptive demand and environmental flow requirements. At each respective proposal site, the existing weir will remain in place for the majority of the construction timeframe, only being demolished once the new regulator is fully installed and therefore will continue to influence hydrology during the construction period. The reason the existing weirs need to be left in place is so that there is always a weir operational (new or old) to retain the water and not allow the creek to become unregulated.

Undertaking construction of the regulators in two stages will allow half of the creek to remain partially unobstructed to maintain passing flow, while construction is undertaken on the other side. Temporary partial cofferdams, sumps and pumps would be used to separate and dewater the half of the creek undergoing construction as shown in Figure 4-1.

The partial cofferdams would allow for passing flows, or flow diversion, to maintain operational flows (to meet irrigation and consumptive demand and environmental flow requirements) during the construction period.

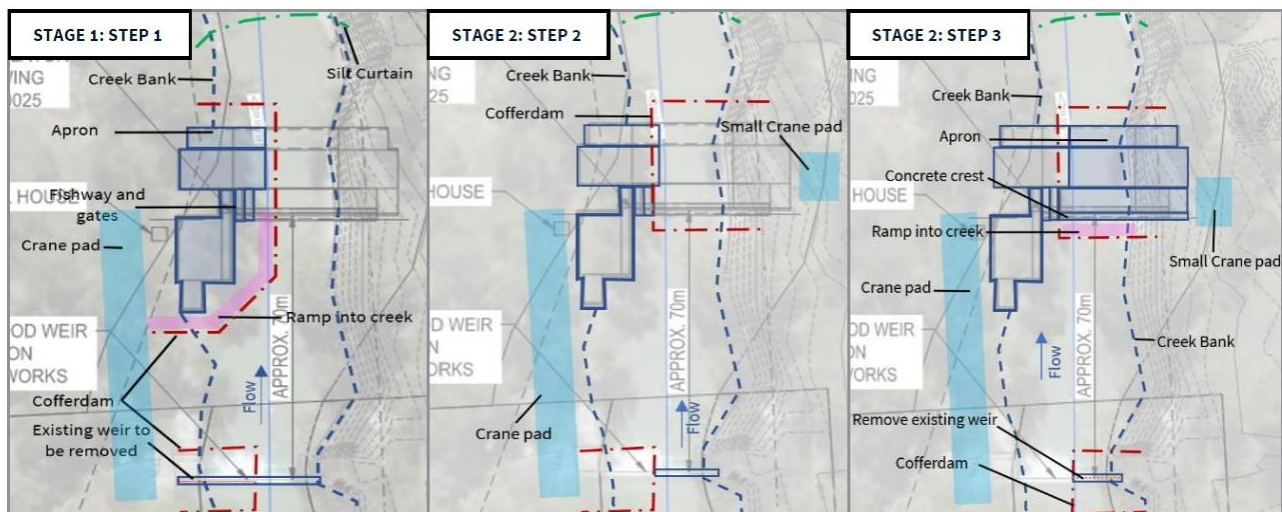


Figure 4-1 Indicative phasing of works at each site.

4.1.3.1 Cofferdams

During the construction of the proposal the key components that have a potential to impact on the hydrology of that study area are the temporary cofferdams that are to be utilised at each site.

The Stage 1 cofferdam will extend out into the creek to include the lay flat gate assembly. In this stage, a cofferdam will also be installed to the halfway point of the creek (Figure 4-1). Once the construction of the in-situ concrete works and gate installation is complete the cofferdam from Stage 1 can be flooded and then be removed.

The Stage 2 cofferdam (for the new weir structure) can be driven and sealed up against the newly constructed sloping wall after the lay flat gates are operational. Once the stage 2 cofferdam is in place, the Stage 1 cofferdam can be removed and flow will be passed through the regulator gates and fishway. The existing weir will remain in place (operational) until the lay flat gates are fully operational to retain the water and not allow the creek to become unregulated.

Removal of the existing weir structure will require a temporary cofferdam either side to create a dry platform to work from inside the cofferdam. The existing weirs would be demolished using an excavator and a rock breaker once dewatered. Earthworks would be carried out to the proposed design levels and the creek reshaped.

Once a cofferdam is installed (for either Stage 1, 2 or weir removal) the construction zone will then be dewatered. This will most likely include multiple pumps that will be operational for 24hrs/day and monitored until all water is removed. The water will be discharged at a point downstream of the cofferdam, but upstream of the silt curtain.



Figure 4-2 Example of a temporary partial cofferdam configuration.

4.1.4 Hydrology impacts during construction

Based on the proposed construction methods, components and phasing of works associated with the proposal the potential adverse hydrology impacts on Billabong Creek, either upstream or downstream during construction of the proposal are considered to be low.

The respective existing weirs (i.e. Hartwood and Wanganella weirs) will remain in place for majority of the construction timeframe, to retain the water and not allow the creek to become unregulated, only being demolished once the new regulator is fully installed.

In addition, the proposal construction methods, components and phasing will require only partial cofferdamming of Billabong Creek within the construction timeframes for the construction of each respective regulator. Therefore, the construction of the proposal allows for the need to provide passing flows to meet irrigation and consumptive demands and environmental water provisions. If there were to be any potential changes in the hydrology of Billabong Creek, either upstream or downstream, the affects would be localised and short-term (i.e. within the construction timeframes of the proposal) and would not adversely affect irrigation and consumptive demands and environmental water provisions.

4.1.5 NSW River Flow Objectives

Given the above findings, it is also considered unlikely that construction of the proposal would adversely impact the relevant River Flow Objectives applicable to the proposal study area (mid and lower Billabong Creek) during the proposal construction period.

An assessment of potential River Flow Objectives impacts of the proposal during construction, to the extent of proposal influence up and down stream, has been undertaken in Table 4-2.

Table 4-2 Potential impacts to River Flow Objectives with construction of the proposal

NSW river flow objective	Description	River Flow Objectives impacts during operation
Protect natural low flows	Protect natural low flows	Given the construction methods, components and phasing allows for the need to provide passing flows, and that the existing weirs (i.e. Hartwood and Wanganella weirs) will remain in place for majority of the construction timeframe to retain the water and not allow the creek to become unregulated, construction of the proposal is not expected to result in adverse impacts to low flows (i.e. unnatural prolonged drying) within the proposal study area and the broader Yanco Creek System.
Protect important rises in water levels	Protect or restore a proportion of moderate flows ('freshes') and high flows	Given the construction methods, components and phasing allows for the need to provide passing flows, and that the existing weirs (i.e. Hartwood and Wanganella weirs) will remain in place for majority of the construction timeframe to retain the water and not allow the creek to become unregulated, construction of the proposal is not expected to result in adverse impacts to moderate flows ('freshes') and high flows.
Maintain wetland and floodplain inundation	Maintain or restore the natural inundation patterns and distribution of floodwaters supporting natural wetland and floodplain ecosystems	Given the construction methods, components and phasing allows for the need to provide passing flows, and that the existing weirs (i.e. Hartwood and Wanganella weirs) will remain in place for majority of the construction timeframe to retain the water and not allow the creek to become unregulated, construction of the proposal is not expected to result in adverse impacts to the natural inundation patterns and distribution of floodwaters supporting natural wetland and floodplain ecosystems.
Mimic natural drying in temporary waterways	Mimic the natural frequency, duration and seasonal nature of drying periods in naturally temporary waterways	Given the construction methods, components and phasing allows for the need to provide passing flows, and that the existing weirs (i.e. Hartwood and Wanganella weirs) will remain in place for majority of the construction timeframe to retain the water and not allow the creek to become unregulated, construction of the proposal is not expected to result in adverse impacts to the natural frequency, duration and seasonal nature of drying periods in naturally temporary waterways.
Maintain natural flow variability	Maintain or mimic natural flow variability in all streams	Given the construction methods, components and phasing allows for the need to provide passing flows, and that the existing weirs (i.e. Hartwood and Wanganella weirs) will remain in place for majority of the construction timeframe to retain the water and not allow the creek to become unregulated, construction of the proposal is not expected to result in adverse impacts to mean daily flow volumes within lower Billabong Creek, including the proposal study area.

NSW river flow objective	Description	River Flow Objectives impacts during operation
Maintain natural rates of change in water levels	Maintain rates of rise and fall of river heights within natural bounds	Given the construction methods, components and phasing allows for the need to provide passing flows, and that the existing weirs (i.e. Hartwood and Wanganella weirs) will remain in place for majority of the construction timeframe to retain the water and not allow the creek to become unregulated, construction of the proposal is not expected to result in adverse impacts to rates of rise and fall of river heights.
Manage groundwater for ecosystems	Maintain groundwater within natural levels and variability, critical to surface flows and ecosystems	Dewatering will not be required at Hartwood based on the design from February 2024 and the groundwater elevation recorded at the site, hence, construction is not expected to result in adverse impacts to groundwater ecosystems or surface flows. Minor dewatering is expected at Wanganella. It is likely that the extent of the effect of dewatering will be restricted to 250 m. Due to the ongoing influence of recharge from the creek to groundwater, the drawdown experienced within the radius of influence will be less than 0.5 m and occur only during the period of dewatering which will be shorter than the full construction program. Billabong Creek is partially disconnected and losing to groundwater hence, the proposal is not expected to result in reduced surface flows during construction.
Minimise effect of weirs and other structures	Minimise the impact of instream structures	Given the construction methods, components and phasing allows for the need to provide passing flows, and that the existing weirs (i.e. Hartwood and Wanganella weirs) will remain in place for majority of the construction timeframe to retain the water and not allow the creek to become unregulated, construction of the proposal is not expected to result in adverse impacts to existing river extents with unimpeded fish passage.

4.2 Operation of the proposal (Modelled Change Case scenario)

The following sections summarise the modelled hydrological regime under operation of the proposal and other system changes specified in the Yanco Creek System Operations Plan (NSW DCCEEW 2023b), as characterised by the Change Case scenario Source model results for data from 1 July 1895 to 30 June 2022.

For Yanco and Colombo creek reaches, the Change Case scenario model includes existing weirs, changed no order flow limits for the irrigation escapes (CCD and DC800) and adjusted or new environmental baseflow provisions for specific reach locations as detailed in the Yanco Creek System Operations Plan (NSW DCCEEW 2023b).

For the Billabong Creek reach from Jerilderie to downstream of Hartwood regulator, the Change Case scenario model includes the Hartwood regulator (and applicable operating principles and targets including allowing water orders from the regulator), changed no order flow limits for the Finley irrigation escape and the environmental baseflow provisions for downstream of Hartwood regulator as detailed in the Yanco Creek System Operations Plan (NSW DCCEEW 2023b).

For the lower Billabong Creek from Wanganella to Darlot, the Change Case scenario model includes the Wanganella regulator (and applicable operating principles and targets including allowing water orders from the regulator), the environmental baseflow provisions an additional environmental small fresh provision at Darlot as detailed in the Yanco Creek System Operations Plan (NSW DCCEEW 2023b).

4.2.1 Annual water balance

Figure 4-3 and Table 4-3 summarise the modelled mean annual water balance for key parameters and key locations within the Yanco Creek System under the Change Case scenario. In summary, all differences in mean annual flows when comparing the modelled Change and Base Case scenarios represent a low degree of hydrological change (-11.1% to +2.1%) from the Base Case scenario for key parameters and key locations within the Yanco Creek System assessed. The low degree of changes in mean annual flows within the Yanco Creek System are considered the product of modelled differences between the Change Case and Base Case scenarios, including the new regulators and broader system changes specified in the Yanco Creek System Operations Plan (NSW DCCEEW 2023b). However, due to the modelling approach taken, it is difficult to determine how much of these changes can be attributed directly to the operation of the proposed regulators within the context of additional broader system changes. Nevertheless, the Change Case scenario is still representative of the proposal, as it intended that the new regulators and the broader operational changes documented in the Yanco Creek System Operations Plan will be implemented at the same time.

The following sections discuss potential reasons behind the changes modelled in the mean annual water balance for the Change Case scenario compared to the Base Case scenario. This discussion is split into the area of investigation upstream of the study area (Yanco and Colombo Creeks and upper Billabong Creek) and the study area (Mid and lower Billabong Creek).

Yanco and Colombo Creeks and upper Billabong Creek

The low degree of changes in mean annual flows in Yanco and Colombo Creeks and upper Billabong Creek upstream of Jerilderie are considered the product of the following differences between the Change and Base Case scenarios, which is discussed in further detail below:

- Environmental baseflow, native fish environmental flow and additional environmental provisions
- The ability of the new regulators to regulate flows within Billabong Creek itself to meet environmental and water supply demands
- New normal regulated flow operational limits on the use of irrigation escapes

The annual water balance results indicate a consistent minor increase in mean annual flows along Upper and Lower Yanco Creek in the Change Case scenario when compared to the Base Case scenario (Table 4-3). The slight increase in flows at Yanco Creek at Offtake (+1.1 GL/year or +0.4%) could be attributed to the new environmental baseflow provision for Yanco Creek at Offtake of 250 ML/day when General Security allocations are equal to or greater than 15%. Further downstream, the slight increase (+2.8 GL/year or +2.1%) in flows along Yanco Creek at Morundah could be attributed to the upstream increase in flows at Yanco Creek at Offtake, the increase in minimum flow target for Yanco Creek at Morundah from 50 ML/day to 100 ML/day when General Supply allocations are equal to or greater than 15%. This is discussed further in the paragraph below. The increase at Yanco Creek at Morundah is then passed on in part further downstream to Yanco Creek at Yanco Bridge. However, the decrease in inflows from Coleambally Catchment Drain (CCD) and Drainage Channel 800 (DC800) Irrigation Escapes means that Yanco Creek at Yanco Bridge sees a smaller increase in mean annual flows of +1.8 GL/year or +1.3%. This decrease in irrigation escape inflows is a result of new limits of no orders until flows are forecast to be greater than or equal to 130 ML/day in Yanco Creek at Morundah specified in the Yanco Creek System Operations Plan (NSW DCCEEW 2023b). This is discussed further in Section 4.2.4.

The annual water balance results also indicate a consistent minor decrease in mean annual flows at Colombo Creek at Morundah and upper Billabong Creek upstream of Innes Bridge in the Change Case scenario when compared to the Base Case scenario (Table 4-3). This could be attributed to the smaller increase in minimum flow target for Colombo Creek at Morundah (from 65 ML/day to 100 ML/day) compared to Yanco Creek at Morundah (from 50 ML/day to 100 ML/day) when General Security allocations are equal to or greater than 15% (NSW DCCEEW 2023). This decrease in annual flow volume in Colombo Creek at Morundah is then passed further downstream to Billabong Creek at upstream of Innes Bridge, which sees a similar decrease of -1.6 GL/year or -0.8% in mean annual flows.

Mid and lower Billabong Creek

The low degree of changes in mean annual flows in mid and lower Billabong Creek from Jerilderie to Darlot are considered the product of the following differences between the Change and Base Case scenarios, which is discussed in further detail below:

- Environmental baseflow, native fish environmental flow and additional environmental provisions
- The ability of the new regulators to regulate flows within Billabong Creek itself to meet environmental and water supply demands
- New normal regulated flow operational limits on the use of irrigation escapes

The mean annual flow results for mid and lower Billabong Creek from downstream of Hartwood regulator to Darlot (end of system in the Source model) reflect the re-regulation (i.e. flow control) function of the Hartwood and Wanganella regulators requiring less upstream flows to meet consumptive (irrigation, stock and water supply) and environmental water requirements within Billabong Creek and that their re-regulation function will reduce unplanned flows in Billabong Creek to downstream at Darlot.

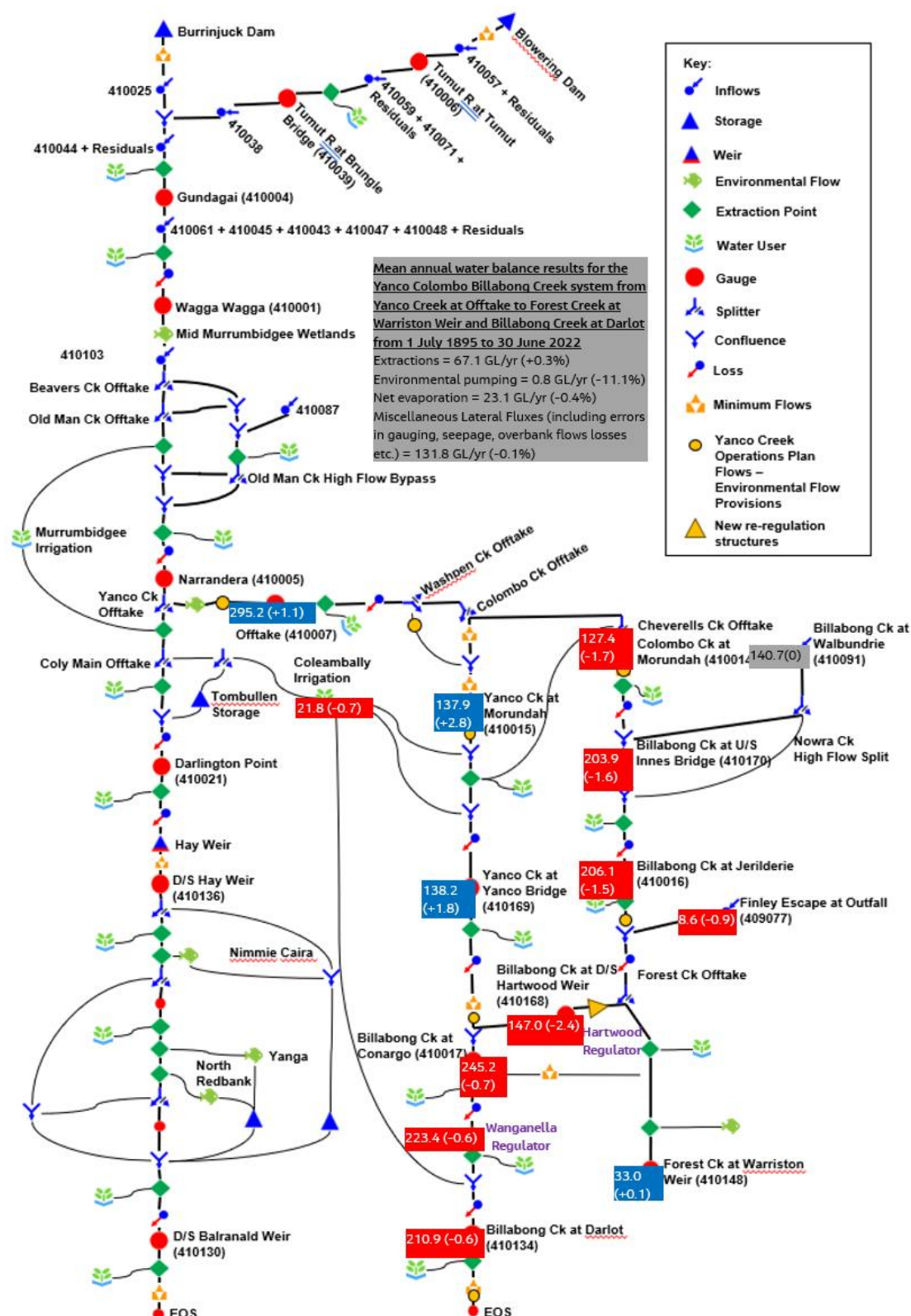
The annual water balance results in Table 4-3 show that the decrease in mean annual flows evident at Billabong Creek at upstream of Innes Bridge (-1.6 GL/year or -0.8%) is passed downstream to Billabong Creek at Jerilderie, which sees an equivalent decrease in mean annual flows (-1.5 GL/year or -0.7%). Therefore, this change could be attributed to upstream changes in flows within Colombo Creek, the potential reasons behind which have been discussed in the previous section. This includes the reduced need for diversion into Colombo and Billabong Creeks as a result of the ability of the new regulators to regulate flows within Billabong Creek itself to meet environmental and water supply demands.

For the reach of mid Billabong Creek from Jerilderie to downstream of Hartwood Weir, the decrease in mean annual flows modelled at Billabong Creek downstream of Hartwood Weir (-2.4 GL/year or -1.6%) in the Change Case scenario is the equivalent to the sum of upstream changes in Billabong Creek at Jerilderie (-1.5 GL/year or -0.7%) and Finley Escape at Outfall (-0.9 GL/year or -9.5%). The decrease in flows from Finley

Escape at Outfall are potentially due to the new limits of no orders from Finley Escape until Colombo Creek at Morundah reaches 130 ML/day and Billabong Creek at Jerilderie reaches 70 ML/day. The decrease in flows from Finley Escape at Outfall could also be because of the reduced need to order water as a result of the ability of the new regulators to regulate flows within Billabong Creek itself to meet environmental and water supply demands. This is discussed further in Section 4.2.4.

This decrease is further passed on downstream to Billabong Creek at Conargo. However, the addition of flows from Yanco Creek at the Yanco Billabong confluence just upstream means that Billabong Creek at Conargo sees a smaller decrease in mean annual flows of -0.7 GL/year or -0.3%, which is equivalent to the sum of the modelled mean annual flow changes at Billabong Creek downstream of Hartwood Weir (-2.4 GL/year or -1.6%) and Yanco Creek at Yanco Bridge (+1.8 GL/year or +1.3%).

The decrease in mean annual flows modelled at Billabong Creek at Wanganella (-0.6 GL/year or -0.3%) is very similar to the decrease in mean annual flows modelled at Billabong Creek at Conargo (-0.7 GL/year or -0.3%) and are therefore attributed to those upstream flow reductions. This decrease is then passed on, almost in full, further downstream to Billabong Creek at Darlot (-0.6 GL/year). This could be attributed to a variety of reasons, including the ability of the regulators to hold back unplanned water to meet consumptive (irrigation, stock and town water supply) and environmental water requirements, thereby reducing unplanned end of system flows in Billabong Creek at Darlot. This is discussed further in Section 4.2.4.



Note that a red box indicates a decrease in mean annual flows compared to the Base Case scenario, whereas a blue box indicates an increase in mean annual flows compared to the Base Case scenario.

Figure 4-3 Schematic of the Change Case scenario Source model with mean annual water balance results and changes from Base Case scenario results.

Table 4-3 Mean annual water balance at key locations within the Yanco Creek System under the Change Case scenario compared to Base Case scenario.

Planning Unit	Location	Mean annual flows (GL/year) under Base Case scenario	Mean annual flows (GL/year) under Change Case scenario	Change from Base Case (GL/year)	% Change from Base Case	Change Case from Base Case rating (as per Table 2-2)
PU10: Upper Yanco Creek	Yanco Offtake	294.1	295.2	1.1	0.4	Low
PU11: Colombo & Billabong Creeks	Colombo Creek at Morundah	129.1	127.4	-1.7	-1.3	Low
	Billabong Creek Inflows at Walbundrie	140.7	140.7	0.0	0.0	Low
	Billabong Creek at US Innes Bridge	205.5	203.9	-1.6	-0.8	Low
	Billabong Creek at Jerilderie	207.6	206.1	-1.5	-0.7	Low
	Finley Escape inflows	9.5	8.6	-0.9	-9.5	Low
	Billabong Creek at DS Hartwood Weir	149.4	147.0	-2.4	-1.6	Low
PU12: Lower Yanco Creek to Lower Billabong Creek	Yanco Creek at Morundah	135.1	137.9	2.8	2.1	Low
	CCD + DC800 irrigation escape inflows	22.5	21.8	-0.7	-3.1	Low
	CICL escape transmission losses	0.3	0.3	0.0	0.0	Low
	Coly Outfall Drain inflows	0.5	0.5	0.0	0.0	Low
	Yanco Creek at Yanco Bridge	136.4	138.2	1.8	1.3	Low
	Billabong Creek at Conargo	245.9	245.2	-0.7	-0.3	Low
	Billabong Creek at Wanganella	224.0	223.4	-0.6	-0.3	Low
PU13: Lower Billabong and Intersecting Streams	Billabong Creek at Darlot	211.5	210.9	-0.6	-0.3	Low
	Forest Creek at Warriston Weir	32.9	33.0	0.1	0.3	Low

Planning Unit	Location	Mean annual flows (GL/year) under Base Case scenario	Mean annual flows (GL/year) under Change Case scenario	Change from Base Case (GL/year)	% Change from Base Case	Change Case from Base Case rating (as per Table 2-2)
	Flow Down Piccaninny Creek	0.3	0.3	0.0	0.0	Low
Overall (for the Yanco Creek system from Yanco Creek at Offtake to Forest Creek at Warriston Weir and Billabong Creek at Darlot)	Consumptive extractions (Irrigation + Town Water Supply)	66.9	67.1	0.2	0.3	Low
	Environmental Pumping (via Australian Food and Agriculture pumps)	0.9	0.8	-0.1	-11.1	Low
	Net Evaporation	23.2	23.1	-0.1	-0.4	Low
	Change in Regulator and River Storage	0	0	0.0	0.0	Low
	Miscellaneous Lateral Fluxes (all components not explicitly modelled, including errors in gauging, seepage, overbank flows losses etc.)	131.9	131.8	-0.1	-0.1	Low

4.2.1.1 Water extractions

The results in Table 4-4 provide a summary of modelled consumptive extractions (Irrigation + Town Water Supply) for the Yanco Colombo Billabong System from Yanco Creek at Offtake to Forest Creek at Warriston Weir and Billabong Creek at Darlot, from the period 1895-2022. The Source model consumptive extractions results indicate consumptive take can increase by 0.2 GL/year based on water availability in the Yanco Creek System under the Change Case scenario. Based on these results no reduction in water availability to meet Water Access Licenses is expected with operation of the proposal.

Table 4-4 Modelled consumptive extractions (Irrigation + Town Water Supply) between Yanco Offtake and Darlot, for data from the period 1895-2022.

Water Balance Component	Base Case	Change Case
Extractions (GL/year)	66.9	67.1
Difference from Base Case (GL/year)	0	+0.2

Note: excludes extractions downstream of Billabong Creek @ Darlot

4.2.2 Seasonality of flows

4.2.2.1 Yanco and Colombo Creeks

Figure 4-4 and Table 4-5 present the modelled mean monthly flows results at key locations along Yanco and Colombo Creeks under the Change Case scenario. This shows that the typical temperate seasonal pattern of higher flows during winter-spring and lower flows during summer-autumn periods which was observed under the Base Case scenario has been retained in the Change Case scenario. Table 4-5 and Figure 4-5 also show the differences (as ML/month and % change respectively) in modelled mean monthly flows between Base Case and Change Case scenarios. The difference in mean monthly flows between Base Case and Change Case scenarios is characterised as low given the mean monthly flow differences range from -6.8% to +7.1%.

The low degree of changes in mean monthly flows in Yanco and Colombo Creeks and upper Billabong Creek upstream of Jerilderie are considered the product of the suite of differences between the Change Case and Base Case scenario, including the new regulators and broader system changes specified in the Yanco Creek System Operations Plan.

Under the Change Case scenario there are minor increases in mean monthly flows predicted between March – November inclusive up to +1,096 ML/month which could be attributable to new environmental baseflow provisions for specific locations within Yanco and Colombo Creeks under the Yanco Creek System Operations Plan (see Section 2.2.4.2).

Reductions in mean monthly flows are predicted for all reaches within Yanco and Colombo Creeks during December – February inclusive (ranging from -17 to -947 ML/month). For Yanco Creek at Yanco Bridge, these decreases could be attributed to the decrease in inflows from Coleambally Catchment Drain (CCD) and Drainage Channel 800 (DC800) Irrigation Escapes as a result of new no order limits. For Colombo Creek at Morundah, these reductions could be attributed to the new flow target of 100 ML/day at Yanco Creek at Morundah applied in the Source model, which is a larger increase in the flow target compared to Colombo Creek at Morundah resulting in less flow being directed into Colombo Creek.

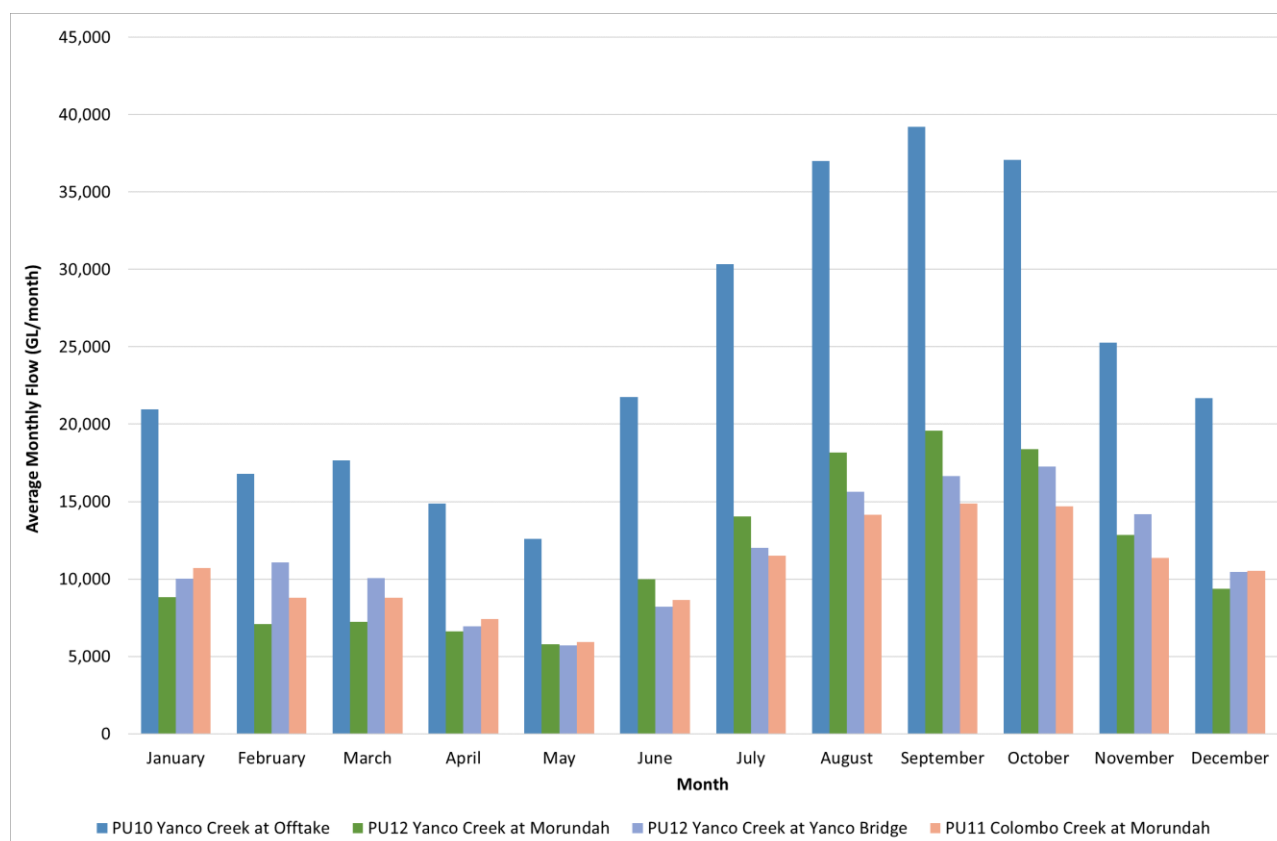


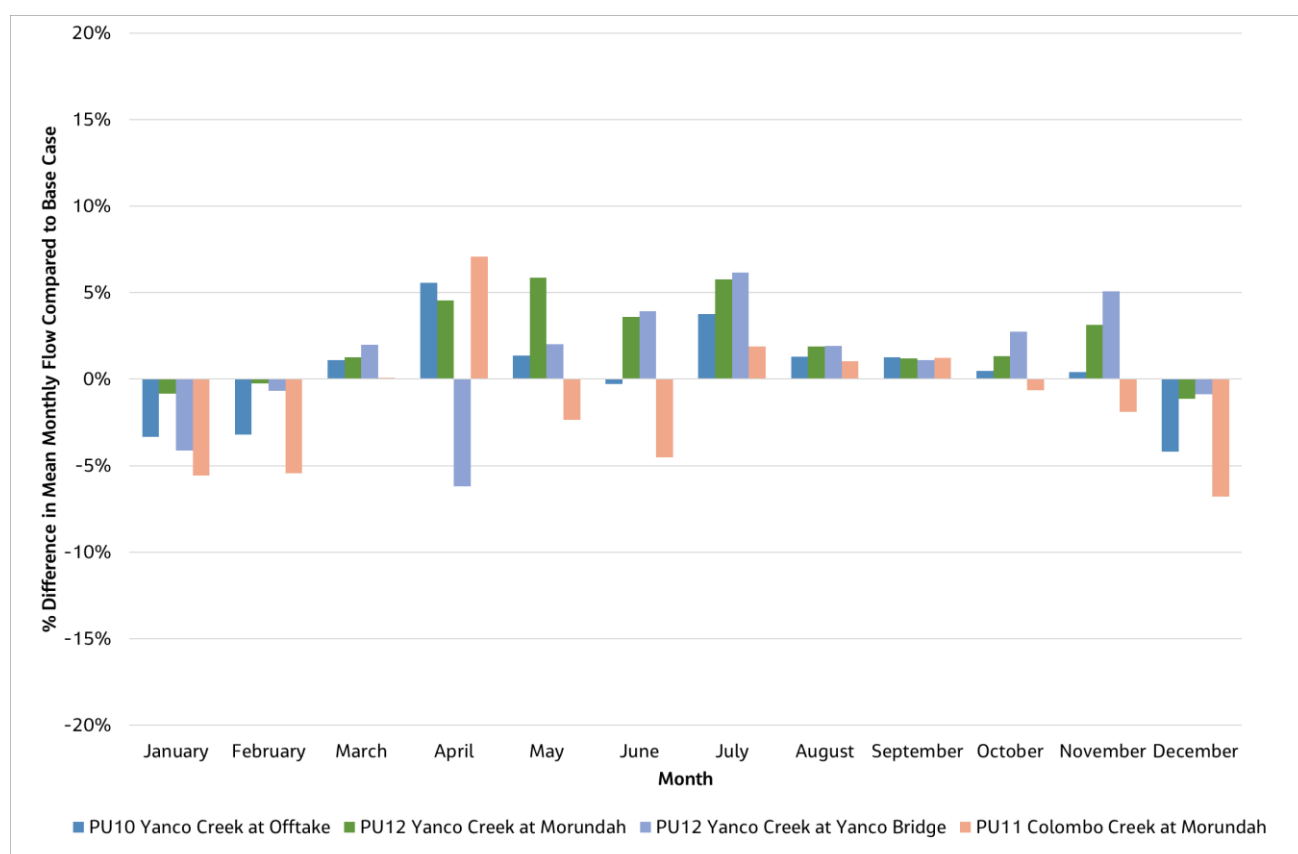
Figure 4-4 Mean monthly flows at key locations for PU reaches in Yanco Creek and Colombo Creek under the Change Case scenario.

Table 4-5 Mean monthly flows under the Change Case scenario and change from Base Case scenario at key locations along Yanco and Colombo Creeks

Guide: 'Flow size ML/day' ('+/- flow size difference to Base Case scenario')

Mean monthly flows (ML/month)	PU10 Yanco Creek at Offtake	PU11 Colombo Creek at Morundah	PU12 Yanco Creek at Morundah	PU12 Yanco Creek at Yanco Bridge
January	20953 (-727)	10726 (-632)	8807 (-75)	10013 (-433)
February	16793 (-556)	8800 (-508)	7080 (-17)	11063 (-74)
March	17656 (+192)	8802 (+8)	7226 (+90)	10072 (+194)
April	14888 (+785)	7400 (+488)	6630 (+288)	6928 (-456)
May	12593 (+169)	5919 (-142)	5778 (+320)	5726 (+112)
June	21768 (-59)	8655 (-410)	9968 (+347)	8197 (+310)
July	30353 (+1096)	11495 (+213)	14049 (+766)	12017 (+698)
August	37007 (+472)	14166 (+146)	18160 (+339)	15649 (+296)
September	39196 (+488)	14860 (+179)	19593 (+235)	16652 (+181)

Mean monthly flows (ML/month)	PU10 Yanco Creek at Offtake	PU11 Colombo Creek at Morundah	PU12 Yanco Creek at Morundah	PU12 Yanco Creek at Yanco Bridge
October	37076 (+172)	14691 (-97)	18370 (+240)	17270 (+460)
November	25259 (+103)	11355 (-219)	12837 (+389)	14182 (+685)
December	21700 (-947)	10524 (-765)	9384 (-108)	10464 (-92)



Note: Hydrological alteration categories (as per Table 2-2) – Low: <20% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; Medium: 20-50% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; High: >50% difference (+/-) from Base Case scenario conditions.

Figure 4-5 Percentage difference in mean monthly flows at key locations for PU reaches in Yanco Creek and Colombo Creek under the Change Case scenario in comparison to the Base Case scenario.

4.2.2.2 Mid and lower Billabong Creek

Figure 4-4 presents the modelled mean monthly flows at key locations along mid and lower Billabong Creek under the Change Case scenario. This shows that the typical temperate seasonal pattern of higher flows during winter-spring and lower flows during summer-autumn periods which was observed under the Base Case scenario has been retained in the Change Case scenario. Table 4-6 shows the difference in modelled mean monthly flows (as ML/month and % change respectively) between Change Case and Base Case scenarios. In summary, all the differences in modelled mean monthly flows between Change and Base Case scenarios are characterised as low given the mean monthly flow differences range from -17.6% to +5.3%.

The low degree of changes in mean monthly flows in mid and lower Billabong Creek are considered the product of the suite of differences between the Change Case and Base Case scenario, including the new regulators and broader system changes specified in the Yanco Creek System Operations Plan. This is discussed in further detail below.

Comparatively larger modelled reductions in mean monthly flows are predicted at Billabong Creek downstream of Hartwood regulator (-734 to -1,064 ML/month) during the summer months (December-February) and with somewhat lesser reductions between April – August (-14 to -276 ML/month). For the Billabong Creek reach from Jerilderie to downstream of Hartwood regulator, the Change Case model includes the Hartwood regulator (and applicable operating principles and targets), allows water orders from the regulator, changed no order flow limits for the Finley irrigation escape and the environmental baseflow provision for Billabong Creek @ Jerilderie (70ML/day). Therefore, between Change Case and Base Case scenarios, the modelled differences in monthly flows downstream of Hartwood regulator can be attributed to upstream system changes and operation of the Hartwood regulator.

For the lower Billabong Creek at Wanganella and Darlot, the Change Case model includes the Wanganella regulator and applicable operating principles and targets, allows water orders from the regulator, environmental baseflow and native fish provisions at Darlot of 50ML/day (plus downstream orders), 200ML/day (small fresh) for the period 1 to 14 March inclusive and maximum daily rate of fall of 9% per day (by volume) while creek flows are equal to or between 50 and 700ML/day during the period 14 September to 16 November inclusive. In general, the modelled mean monthly flows differences at both Wanganella and Darlot are consistent with those predicted downstream of Hartwood Weir i.e. proportionally large reductions in modelled mean monthly flows from December-February and with somewhat lesser reductions between April – June (Table 4-6). These results suggest the modelled differences in monthly flows, between Base Case and Change Case scenarios at Wanganella and Darlot, are generally consistent with downstream of Hartwood regulator and therefore associated with upstream system operation changes (i.e. irrigation escape flows no order limits and new or adjusted environmental baseflow provisions) and the re-regulation (i.e. flow control) function of the regulators and their associated operating principles and targets. However, the magnitude of flow differences (i.e. ML/month) between Change Case and Base Case scenarios at Wanganella and Darlot is smaller than those apparent at Hartwood. This moderation of flow reductions is potentially due to Yanco Creek inflows to Billabong Creek that occur upstream of Wanganella and minor inflows from Picaninny Creek (1ML/day).

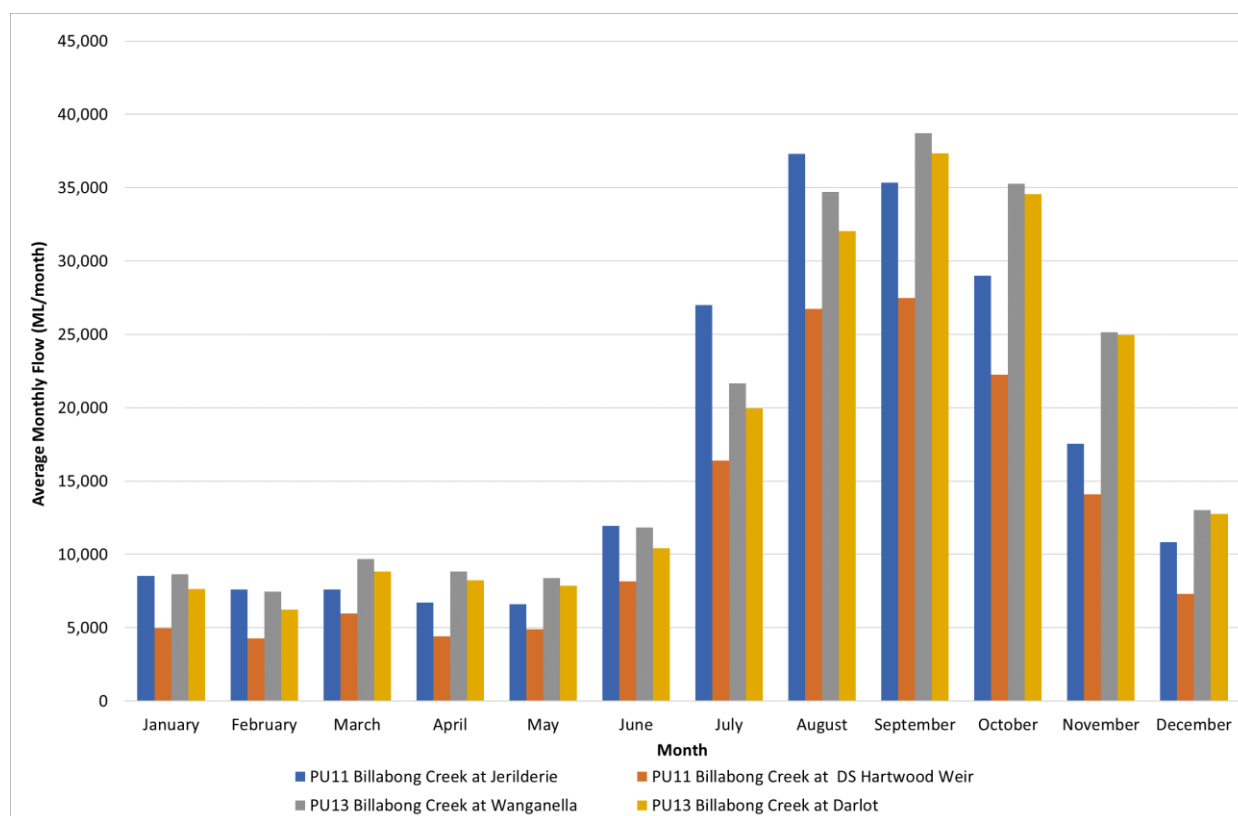
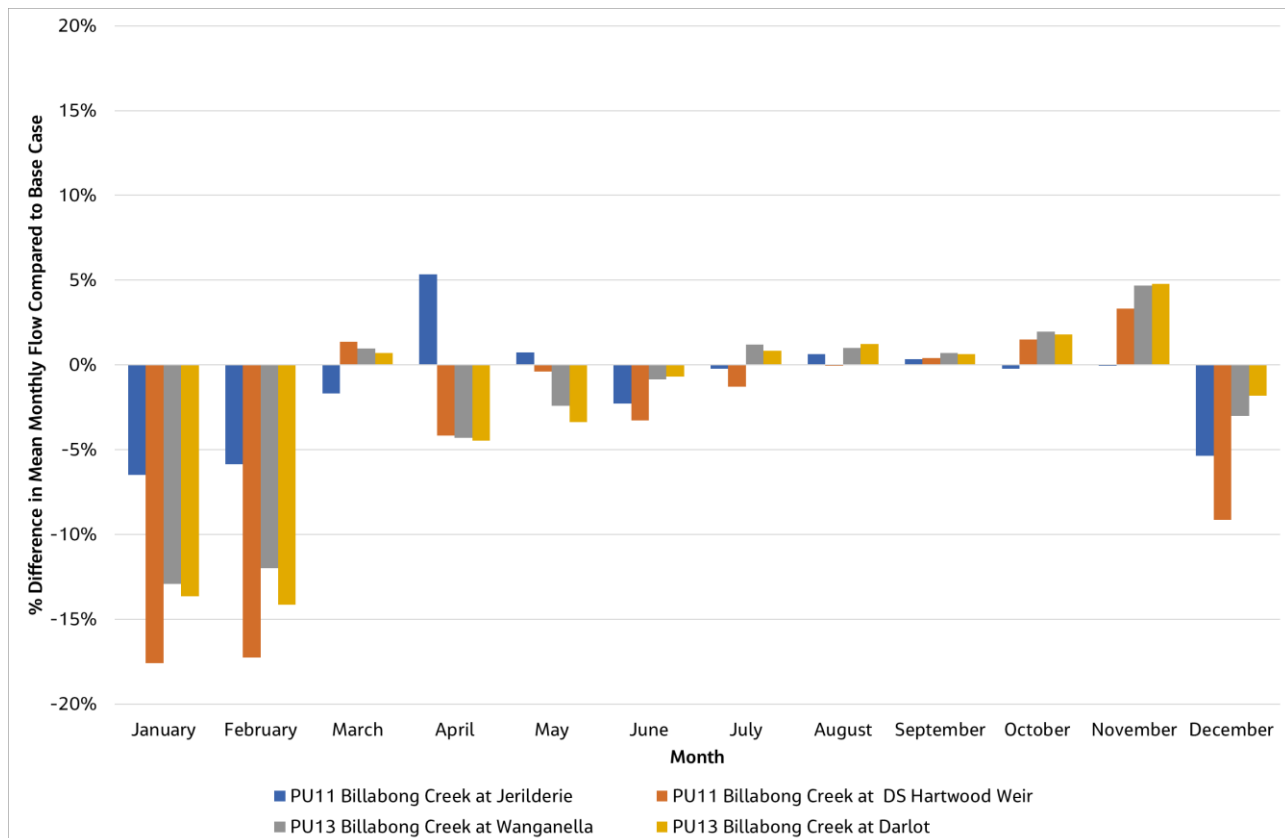


Figure 4-6 Mean monthly flows at key locations for PU reaches in mid and lower Billabong Creek under the Change Case scenario.

Table 4-6 Mean monthly flows at key locations for PU reaches in mid and lower Billabong Creek under the Change Case scenario, also showing change to Base Case scenario.

Guide: 'Flow size ML/day' ('+/- flow size difference to Base Case scenario')

Mean monthly flows (ML/month)	PU11 Billabong Creek at Jerilderie	PU11 Billabong Creek at DS Hartwood Weir	PU13 Billabong Creek at Wanganella	PU13 Billabong Creek at Darlot
January	8545 (-594)	4988 (-1064)	8649 (-1285)	7659 (-1211)
February	7618 (-474)	4267 (-889)	7452 (-1014)	6254 (-1032)
March	7611 (-131)	5983 (+80)	9697 (+94)	8840 (+60)
April	6731 (+341)	4427 (-193)	8833 (-395)	8222 (-383)
May	6602 (+47)	4887 (-19)	8379 (-206)	7857 (-275)
June	11950 (-278)	8177 (-276)	11822 (-102)	10440 (-72)
July	27010 (-64)	16395 (-211)	21651 (+254)	19939 (+167)
August	37293 (+237)	26722 (-14)	34706 (+343)	32053 (+387)
September	35330 (+117)	27495 (+107)	38733 (+272)	37357 (+235)
October	29008 (-61)	22250 (+326)	35266 (+676)	34566 (+612)
November	17546 (-13)	14098 (+453)	25162 (+1121)	24960 (+1137)
December	10828 (-615)	7296 (-734)	13005 (-404)	12745 (-238)



Note: Hydrological alteration categories (as per Table 2-2) – Low: <20% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; Medium: 20-50% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; High: >50% difference (+/-) from Base Case scenario conditions.

Figure 4-7 Percentage difference in mean monthly flows at key locations for PU reaches in mid and lower Billabong Creek under the Change Case scenario compared to the Base Case scenario.

4.2.3 Flow variability

4.2.3.1 Yanco and Colombo Creeks

Figure 4-8 shows modelled total annual flows for key reaches within Yanco and Colombo creeks under the Change Case scenario. Consistent with modelled Base Case scenario, modelled total annual flow (GL/year) throughout Yanco and Colombo creeks can be seen to be highly variable under the Change Case scenario. Figure 4-9 presents a comparison (as percentage difference) of modelled Change Case scenario annual flow volumes results compared to the Base Case scenario. These results show that most differences in annual flow volumes over the modelled time period are low (-1.1% to +3.5%) across Yanco and Colombo Creeks when comparing the Change Case scenario to the Base Case scenario. These small differences are considered the product of the suite of differences between the Change Case and Base Case scenario, including the new regulators and broader system changes specified in the Yanco Creek System Operations Plan.

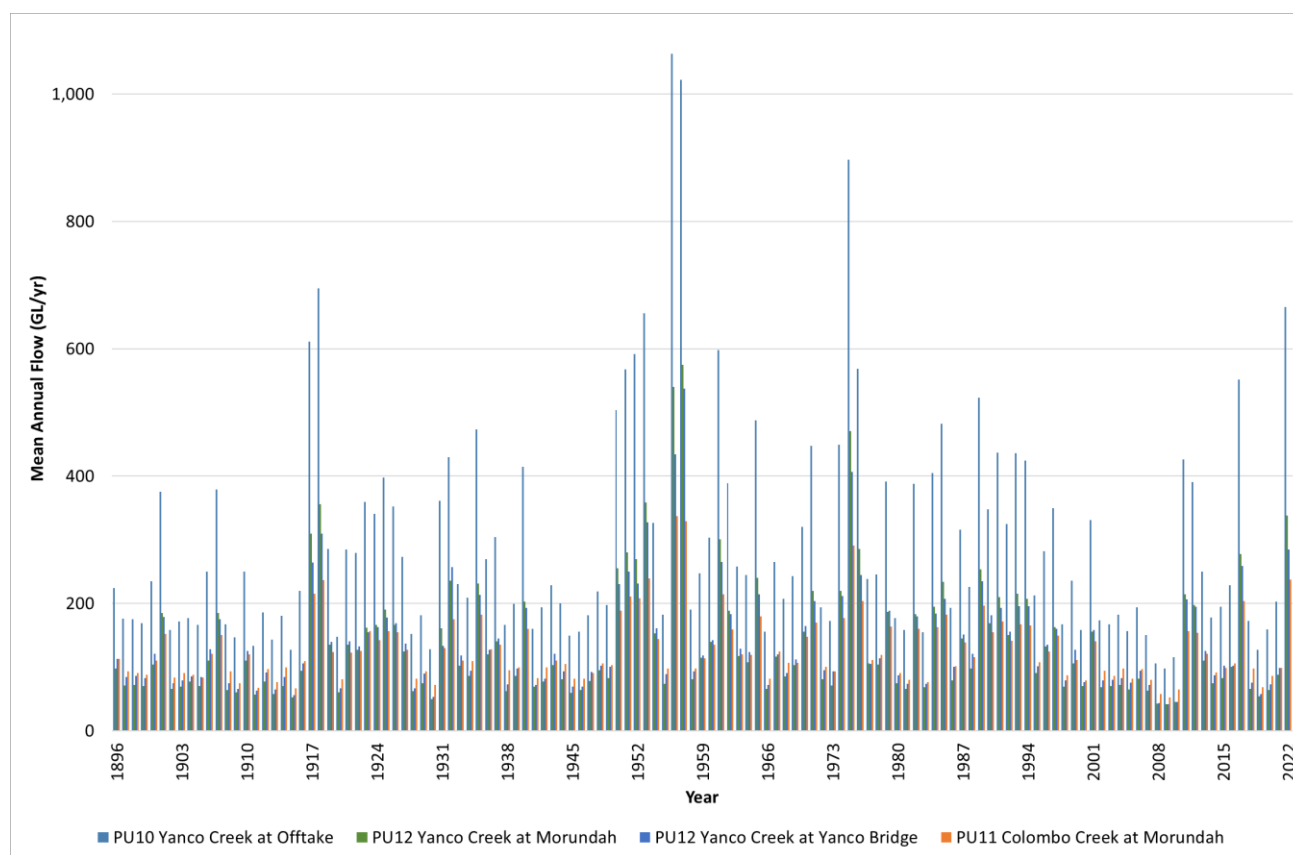
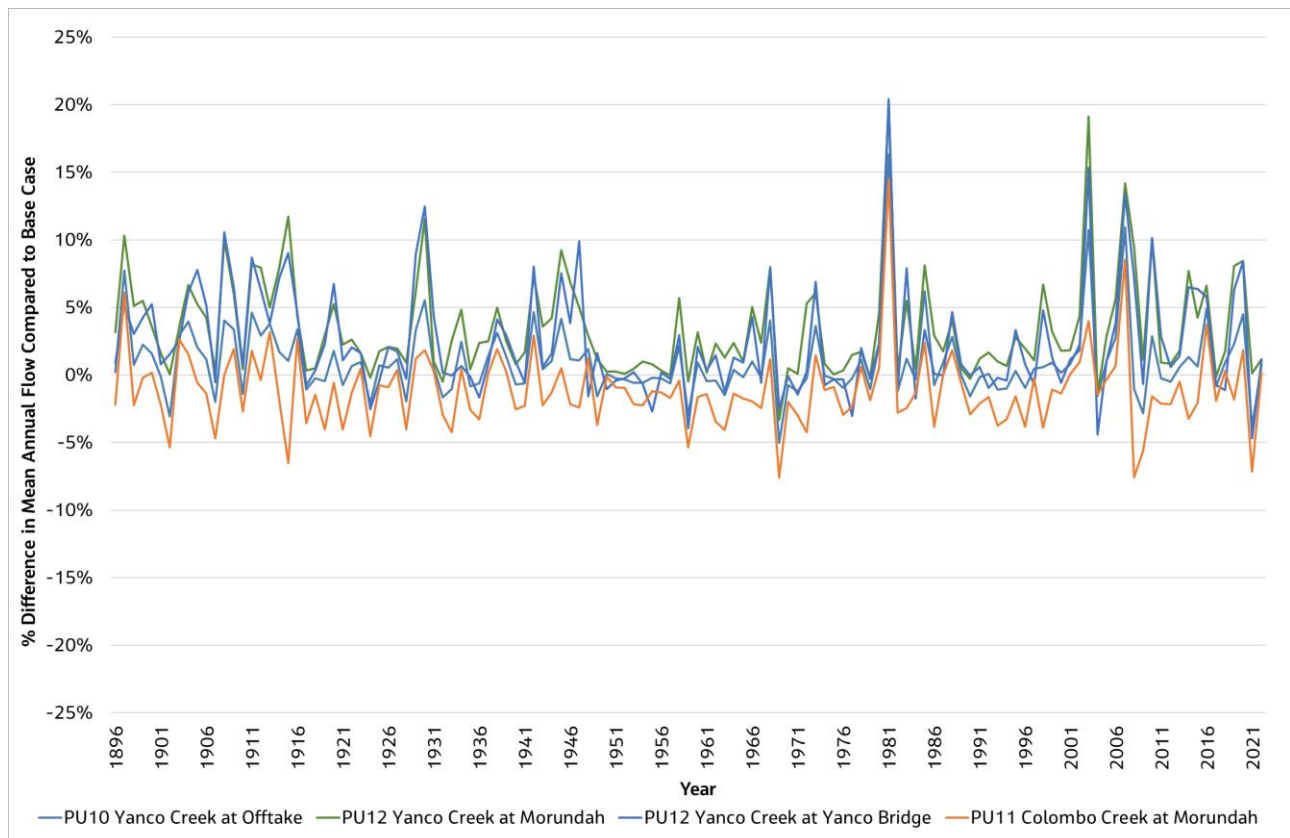


Figure 4-8 Total annual flows at key locations for PU reaches in Yanco Creek and Colombo Creek under the Change Case scenario.



Note: Hydrological alteration categories (as per Table 2-2) – **Low:** <20% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; **Medium:** 20-50% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; **High:** >50% difference (+/-) from Base Case scenario conditions.

Figure 4-9 Percentage difference in total annual flows at key locations for PU reaches in Yanco Creek and Colombo Creek under the Change Case scenario compared to the Base Case scenario.

Figure 4-10 presents modelled mean daily flows for key locations within Yanco and Colombo Creeks under the modelled Change Case scenario. Consistent with the Base Case scenario mean daily flows results (see Section 3.2.3), Figure 4-10 indicates mean daily flows remain highly variable within Yanco and Colombo Creeks and this is particularly evident in Upper Yanco Creek. Change Case scenario results are compared to Base Case in Figure 4-11. Although changes in mean daily flows of up to -10 to +15% occur across locations, the averaged (across the time series) changes in mean daily flow are low (-1.3% to +2.2%). These small differences are considered the product of the suite of differences between the Change Case and Base Case scenario, including the new regulators and broader system changes specified in the Yanco Creek System Operations Plan.

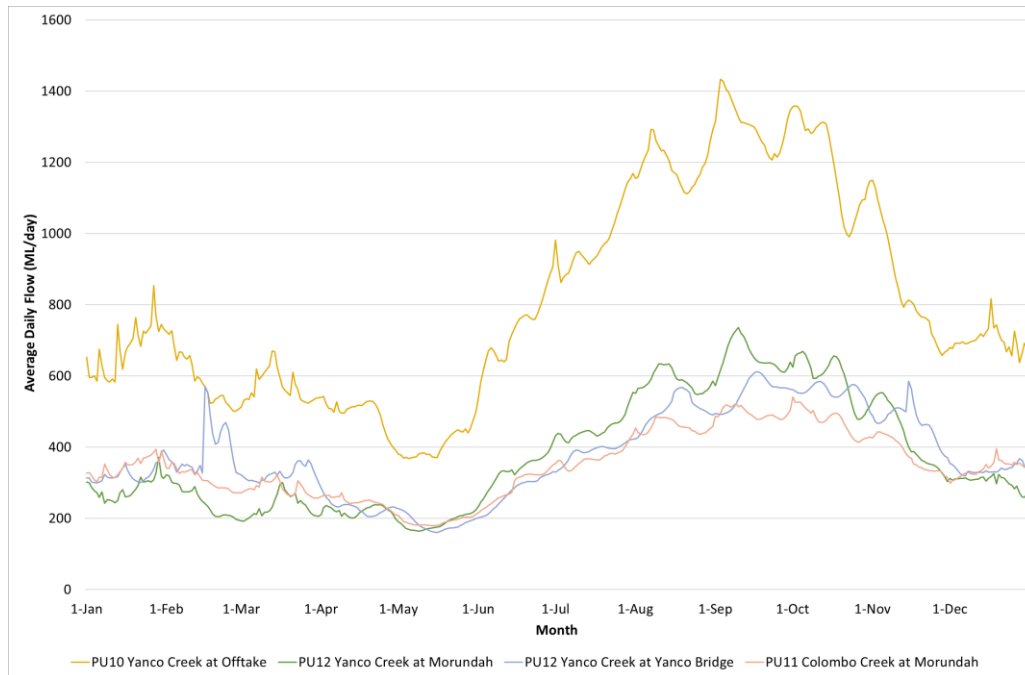
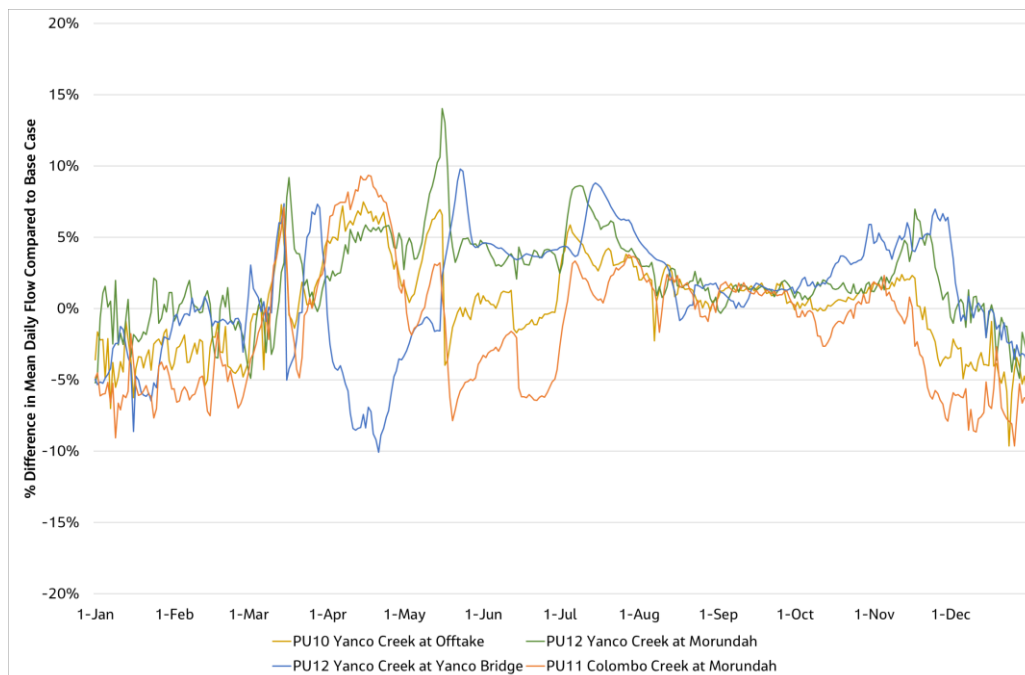


Figure 4-10 Mean daily flows at key locations for PU reaches in Yanco Creek and Colombo Creek under the Change Case scenario.



Note: Hydrological alteration categories (as per Table 2-2) – Low: <20% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; Medium: 20-50% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; High: >50% difference (+/-) from Base Case scenario conditions.

Figure 4-11 Percentage difference in mean daily flows at key locations for PU reaches in Yanco Creek and Colombo Creek under the Change Case scenario compared to the Base Case scenario.

4.2.3.2 Mid and lower Billabong Creek

Figure 4-12 shows modelled total annual flows for mid and lower Billabong Creek under Change Case scenario. Again, consistent with modelled Base Case scenario, modelled total annual flows (GL/year) remain highly variable at all locations under the Change Case scenario and there is an absence of near no-flow years. Figure 4-13 presents a comparison (as percentage difference) of modelled Change Case scenario annual flow volumes results compared to the Base Case scenario, which shows that the majority of change in annual flow volumes over the 127-year time period is low as the average flow volume change ranges from -2.0% to -0.9% across Billabong Creek. These differences are considered the product of the suite of differences between the Change Case and Base Case scenario, including the new regulators and broader system changes specified in the Yanco Creek System Operations Plan.

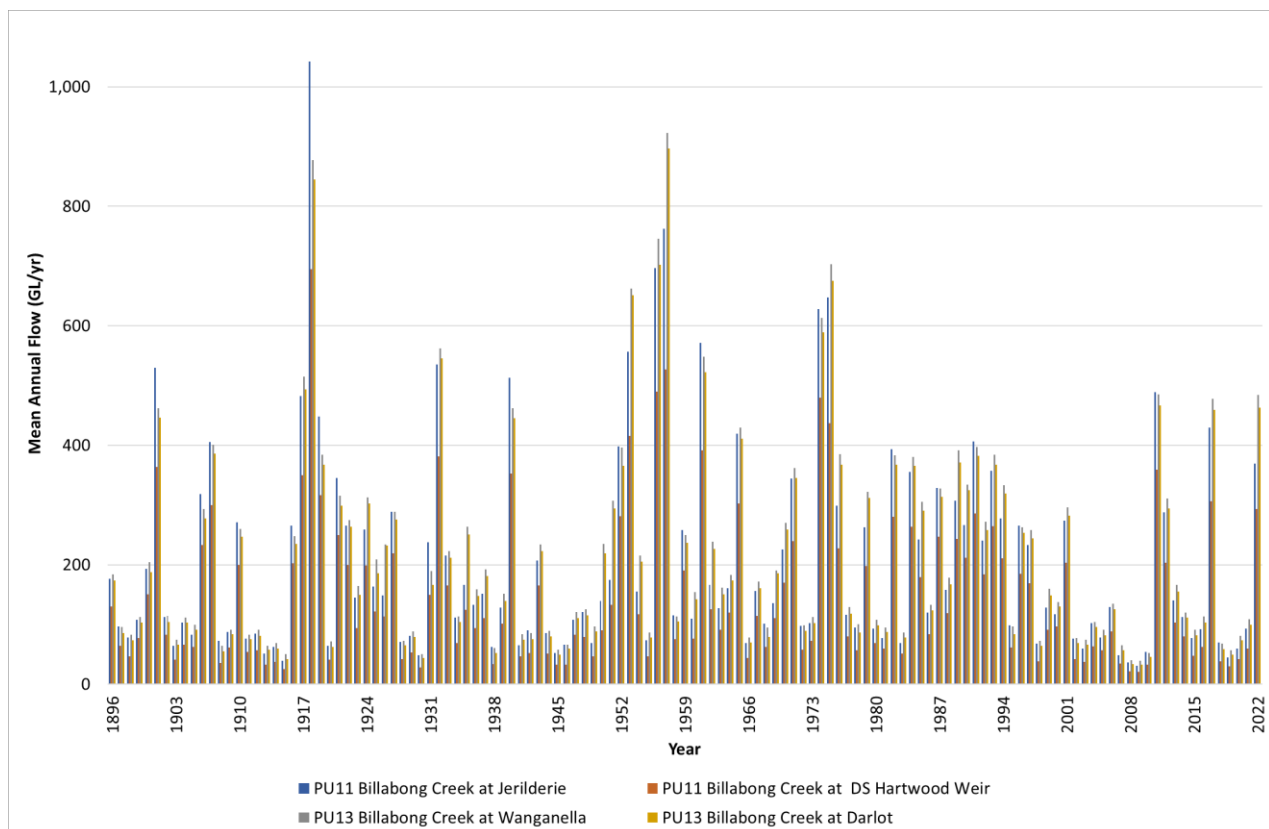
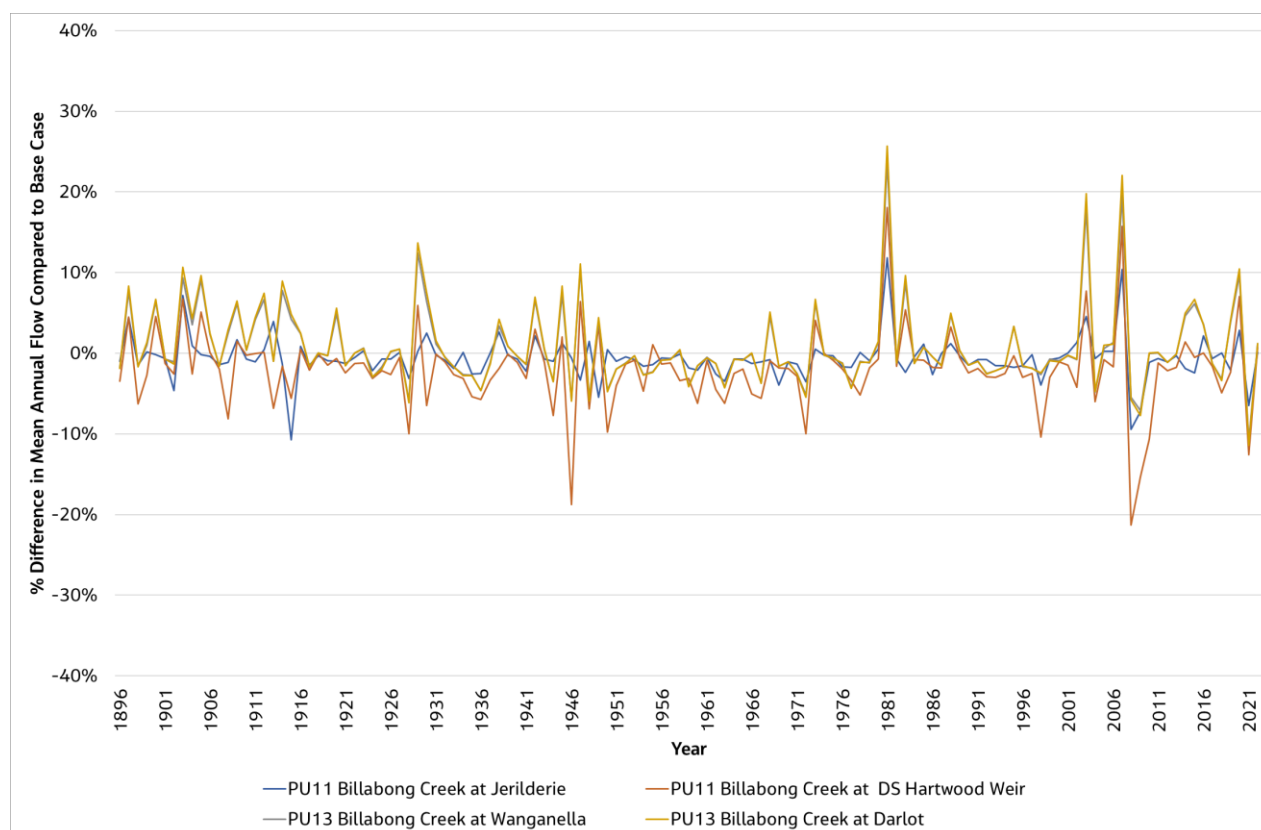


Figure 4-12 Total annual flows at key locations for PU reaches in mid and lower Billabong Creek under the Change Case scenario.



Note: Hydrological alteration categories (as per Table 2-2) – **Low:** <20% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; **Medium:** 20-50% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; **High:** >50% difference (+/-) from Base Case scenario conditions.

Figure 4-13 Percentage difference in total annual flows at key locations for PU reaches in mid and lower Billabong Creek under the Change Case scenario compared to the Base Case scenario.

Figure 4-14 presents the modelled mean daily flows for key reaches along mid and lower Billabong Creek under the Change Case scenario. Consistent with the Base Case scenario mean daily flows results (see Section 3.2.3), Figure 4-14 indicates that although the temporal variability in mean daily flow within mid and lower Billabong Creek is broadly consistent with that evident in Yanco and Colombo Creeks (i.e. higher variability in modelled averaged daily flow volumes evident from December to April, and somewhat less variability at all locations from May to November) the degree of variability in mean daily flow within mid and lower Billabong Creek is generally less than that evident in Yanco and Colombo Creeks - likely the result of buffering by unregulated flows from the upper Billabong Creek catchment at Jerilderie and Hartwood, and inflows from Yanco Creek that moderate daily flow variability at Wanganella and Darlot. Again consistent with the Base Case scenario results, Figure 4-14 indicates higher modelled daily flow variability (compared to other locations in mid and lower Billabong Creek) is evident downstream of Hartwood Regulator under the Change Case scenario.

Modelled mean daily flows for mid and lower Billabong Creek under the Change Case results are compared to the modelled Base Case scenario results in Figure 4-15. Although changes in mean daily flows of up to -30 to +25% occur across locations, the averaged (across the time series) changes in mean daily flow are low (-3.9% to -1.3%). These differences are considered the product of the suite of differences between the Change Case and Base Case scenario, including the new regulators and broader system changes specified in the Yanco Creek System Operations Plan. It is difficult to determine whether changes in mean daily flow variability are associated with the direct re-regulation (i.e. flow control) function of the Hartwood and Wanganella regulators and associated operational principles and targets (including extraction demand and rates) or broader system changes (e.g. no order flow limits for the Finley irrigation escape).

Based on these results, the temporal pattern of mean daily flows in lower and mid Billabong Creek does not substantially change under the modelled Change Case scenario. However, there is a potential minor increase in mean daily flow variability predicted at downstream of Hartwood regulator and at Wanganella and Darlot between December – May, which could potentially be attributed to the new regulators which may be holding back unplanned flows in December - February to meet environmental and water supply demands in March.

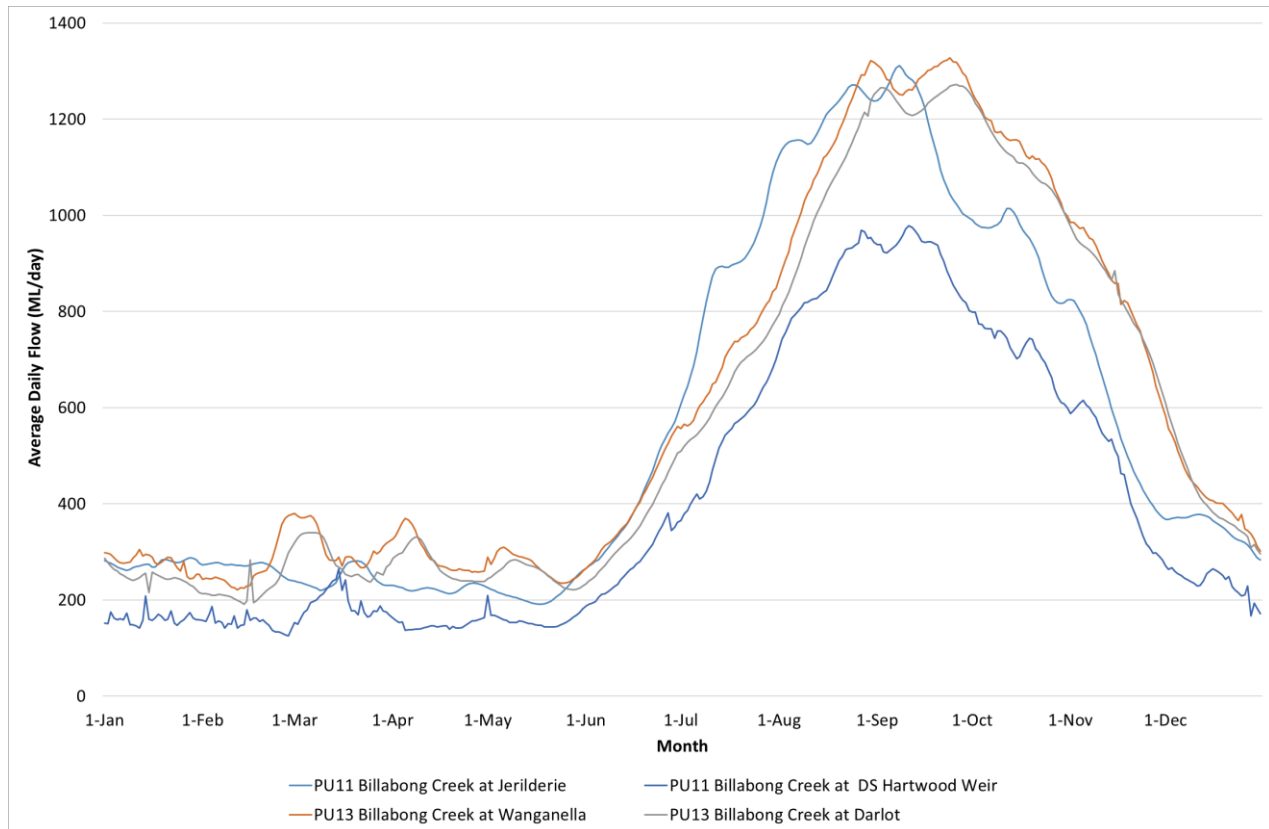


Figure 4-14 Mean daily flows at key locations for PU reaches in mid and lower Billabong Creek under the Change Case scenario.



Note: Hydrological alteration categories (as per Table 2-2) – **Low**: <20% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; **Medium**: 20-50% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; **High**: >50% difference (+/-) from Base Case scenario conditions.

Figure 4- 15 Percentage difference in mean daily flows at key locations for PU reaches in mid and lower Billabong Creek under the Change Case scenario compared to the Base Case scenario.

4.2.4 Flow sizes

4.2.4.1 Yanco and Colombo Creeks

Figure 4-16 and Table 4-7 present the flow size analysis results for modelled daily flows (ML/day) at key locations on Yanco and Colombo Creeks under the Change Case scenario. Also shown in Table 4-7 are the flow (in ML/day) and percentage (%) differences when comparing the Change Case scenario to the Base Case scenario.

The low degree of change in daily flows across the flow frequency spectrum in Yanco and Colombo Creeks and upper Billabong Creek upstream of Jerilderie are considered the product of the suite of differences between the Change Case and Base Case scenario, including the new regulators and broader system changes specified in the Yanco Creek System Operations Plan.

The flow size results for the Change Case scenario (Figure 4-16 and Table 4-7) indicate that there will be an increase in flow sizes for Yanco Creek at Offtake for the flow frequencies corresponding to the baseflows category, which is expected given the new environmental baseflow provision for Yanco Creek at Offtake of 250 ML/day when General Security allocations exceed 15%.

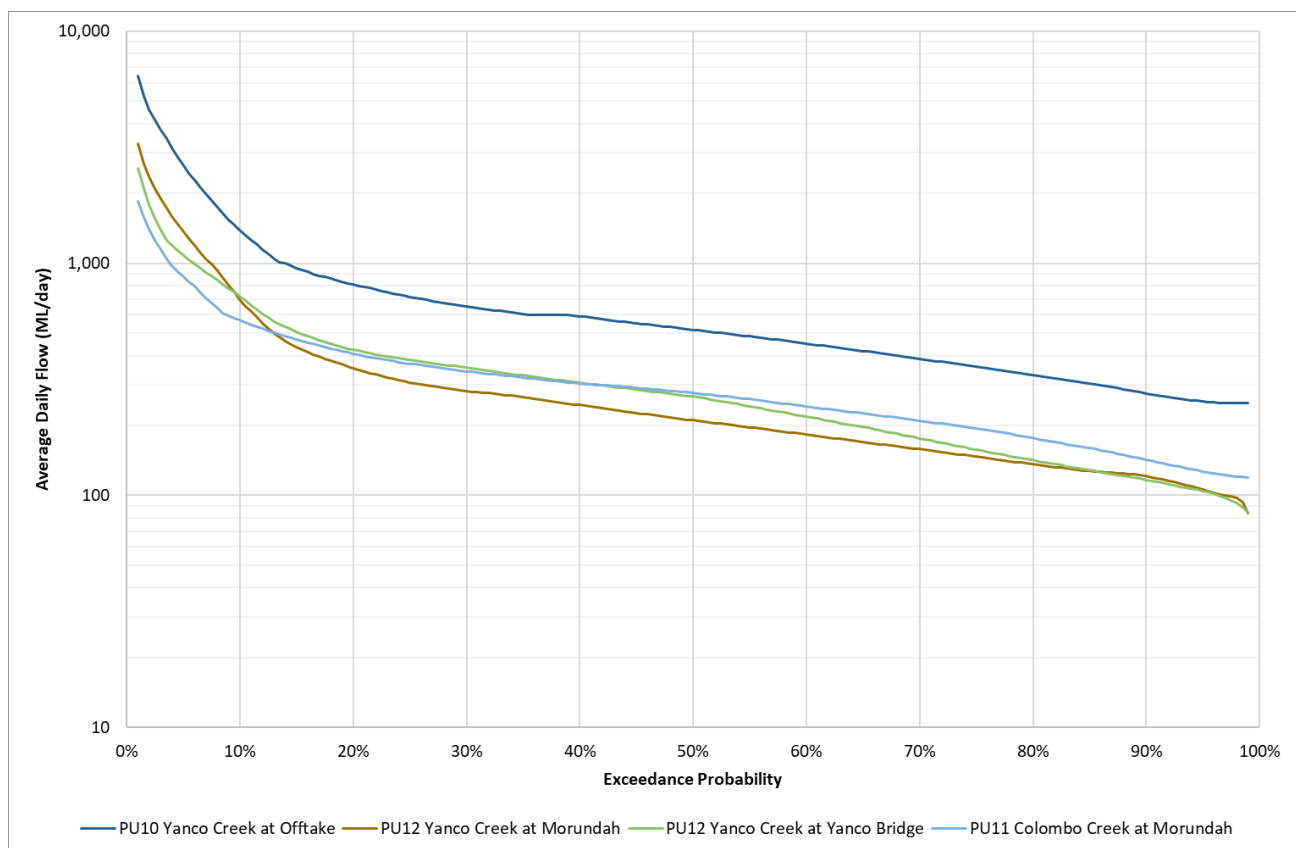
A minor reduction in flow sizes (up to -3%) for Colombo Creek at Morundah is modelled to occur across all flow frequencies except for the 5%ile (i.e. except wetland connection flows). The decreases could potentially

be due to the increased need for diversion to Yanco Creek to meet the new minimum flow target of Yanco Creek at Morundah (from 50 ML/day to 100 ML/day).

Increases in flow sizes for Yanco Creek at Morundah and Yanco Bridge are modelled to occur across all flow frequencies but in particular for very low flows, where there are 9-18% increases in the 85-95%ile flow frequencies. These results are considered a reflection of the changes to the minimum flow target for Yanco Creek at Morundah from 65 as specified in the Yanco Creek System Operations Plan (NSW DPIE 2023).

Lastly, Figure 4-16 and Table 4-7 indicate cease-to-flow will not occur throughout Yanco and Colombo Creeks under the Change Case scenario, which remains consistent with Base Case scenario. In addition, a comparison of Change Case (Table 4-7) to Base Case (see Table 3-6) flow size results indicate no material change in the proportion of flow categories for Yanco and Colombo Creeks between the Change and Base Case scenarios.

It should be noted however that this is a high-level daily flow size analysis and does not take into account when these flows occur throughout the year and whether these flows satisfy the timing criteria of the environmental water requirements. This is addressed through the EWR analysis discussed in Section 4.2.5.



* Note that the 0% and 100% percentiles have been excluded from this graph. This is discussed further in Table 2-8.

Figure 4-16 Daily flow duration curves at key locations for PU reaches in Yanco Creek and Colombo Creek under the Change Case scenario.

Table 4-7 Percentile table for mean daily flow size ML/day at key locations for in Yanco Creek and Colombo Creek under the Change Case scenario, with comparison to Base Case.

Guide: 'Flow size ML/day' ('+/- flow size difference to Base Case scenario', '+/- percentage difference to Base Case scenario')

Percentile	PU11 Billabong Creek at Jerilderie	PU11 Billabong Creek at DS Hartwood Weir**	PU13 Billabong Creek at Wanganella**	PU13 Billabong Creek at Darlot
0%*				
5%	2431 (+9, +0.4%)	1916 (+12, +1%)	2695 (+17, +1%)	2602 (+15, +1%)
10%	1249 (+10, +1%)	1074 (-8, 1%)	1607 (+17, +1%)	1553 (+10, +1%)
15%	815 (+8, +1%)	674 (+4, +1%)	1018 (+21, +2%)	987 (+22, +2%)
20%	553 (-1, -0.1%)	428 (+1, 0, +2%)	669 (+16, +2%)	643 (+18, +3%)
25%	411 (-10, -2%)	299 (+4, +1%)	490 (+14, +3%)	461 (+11, +2%)
30%	338 (-17, -5%)	239 (0, 0%)	394 (+5, +1%)	367 (+7, +2%)
35%	297 (-17, -5%)	202 (-7, -3%)	343 (+3, +1%)	315 (+2, +1%)
40%	269 (-15, -5%)	177 (-10, -5%)	304 (-1, -0.3%)	275 (-2, -1%)
45%	247 (-11, -4%)	157 (-12, -7%)	272 (-7, -3%)	245 (-7, -3%)
50%	230 (-9, -4%)	143 (-11, -7%)	247 (-10, -4%)	221 (-9, -4%)
55%	214 (-9, -4%)	129 (-12, -9%)	226 (-13, -5%)	200 (-11, -5%)
60%	200 (-6, -3%)	117 (-13, -10%)	208 (-14, -6%)	183 (-13, -7%)
65%	188 (-4, -2%)	106 (-13, -11%)	192 (-14, -7%)	168 (-13, -7%)
70%	177 (-1, -1%)	96 (-13, -12%)	178 (-11, -6%)	155 (-12, -7%)
75%	164 (-1, -1%)	87 (-13, -13%)	165 (-10, -6%)	142 (-11, -7%)
80%	152 (0, 0%)	78 (-12, -13%)	151 (-9, -6%)	129 (-10, -7%)
85%	137 (-1, -1%)	69 (-12, -15%)	136 (-7, -5%)	116 (-9, -7%)
90%	121 (-2, -2%)	60 (-12, -17%)	120 (-6, -5%)	102 (-6, -6%)
95%	102 (0, 0%)	46 (-15, -25%)	99 (-8, -7%)	84 (-6, -7%)
100*				

*Note that it has been chosen to exclude the 0% and 100% percentiles from this analysis (discussed further in Table 2-8).

**Note that the following symbology has been used to distinguish between different flow categories. For Yanco Creek at Offtake, Colombo Creek at Morundah and Yanco Creek at Morundah, there are specific flow rate threshold estimates for different flow categories documented in Table 9 of Murrumbidgee Long Term Water Plan Part A: Murrumbidgee catchment (NSW DPIE 2020a). However, this does not exist for Yanco Creek at Yanco Bridge, and as such the flow categories for Yanco Creek at Morundah have been applied. Whilst there are additional inflows and outflows between Yanco Creek at Morundah and Yanco Bridge which may alter flow categorisation, for the purposes of this comparative assessment between scenarios, we believe this is an adequate approach.

Smaller than very low flows	Very low flows	Baseflows	Small freshes	Large freshes	Large freshes: wetland connection	Small overbank	Large overbank
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4.2.4.2 Mid and lower Billabong Creek

Figure 4-17 and Table 4-8 present the flow size analysis results for modelled daily flows (ML/day) at key locations within mid and lower Billabong Creek, inclusive of the proposal study area, under the Change Case scenario. Also shown in Table 4-7 are the flow (in ML/day) and percentage differences when comparing the Change Case scenario to the Base Case scenario.

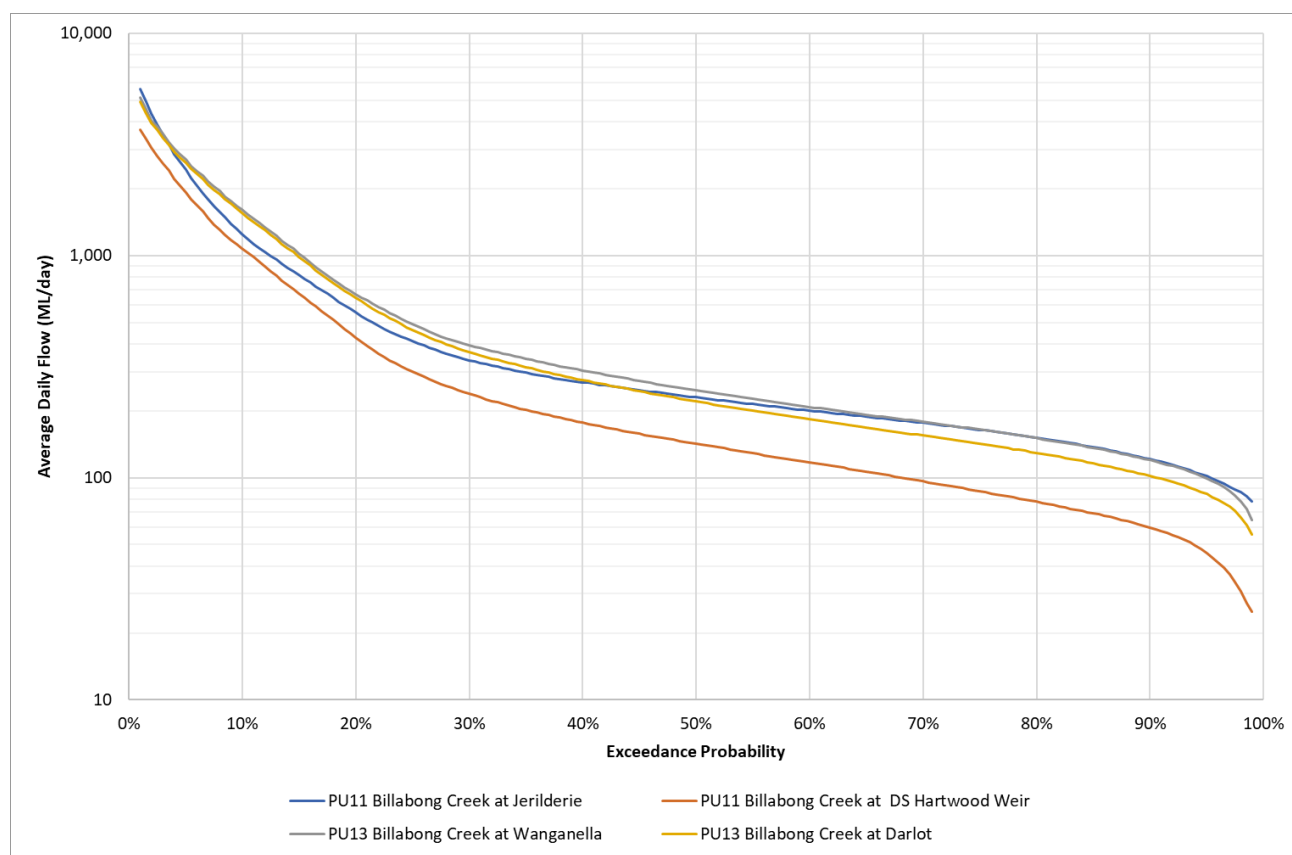
With the exception of the 95%ile at Billabong Creek at downstream of Hartwood Regulator which sees a 25% decrease in flow size, there is a low degree of change in daily flows across the flow frequency spectrum in mid and lower Billabong Creek. These changes are considered the product of the suite of differences between the Change Case and Base Case scenario, including the new regulators and broader system changes specified in the Yanco Creek System Operations Plan.

The flow size results for the Change Case scenario (Figure 4-17 and Table 4-8) suggest very minor increases in flow sizes for less than the 35%ile flow frequencies (i.e. for flow categories large than small freshes) at downstream of Hartwood regulator (up to +12 ML/day or +1%) and at Wanganella (up to +17 ML/day or +1%) and Darlot (up to +15 ML/day or +1%) compared to the modelled Base Case scenario.

In contrast, the modelled Change Case scenario results suggest minor decrease in flow sizes greater than 35%ile flow frequencies (i.e. for baseflow and smaller flow categories) at downstream of Hartwood regulator (up to -15 ML/day or -25%) and at Wanganella (up to -8 ML/day or -7%) and Darlot (up to -6 ML/day or -7%) compared to the modelled Base Case scenario. This is potentially due to the new regulators, which have the ability to hold back unplanned water to meet environmental and water supply requirements, thereby reducing unplanned end of system flows in Billabong Creek at Darlot. The 25% decrease in flow size at the 95%ile is potentially also due to the new limits of no orders from Finley Escape until Colombo Creek at Morundah reaches 130 ML/day, which is not modelled to occur at the 95%ile (Table 4-7). As such, flows smaller than very low flow will potentially be reinstated at very low frequencies (i.e. approx. 5% of the flow period) in Billabong Creek at DS Hartwood Weir.

A comparison of Change Case scenario flow frequency results (Table 4-8) to Base Case (see Table 3-6) indicate no material change in the proportion of flow categories for mid and lower Billabong Creek with operation of the proposal.

It should be noted that this is a high-level daily flow size analysis and does not take into account when these flows occur throughout the year and whether these flows satisfy the timing criteria of the environmental water requirements. This is addressed through the EWR analysis discussed in Section 4.2.6.



*Note that it has been chosen to exclude the 0% and 100% percentiles from this analysis (discussed further in Table 2-8).

Figure 4-17 Daily flow duration curves at key locations for PU reaches in mid and lower Billabong Creek under the Change Case scenario.

Table 4-8 Percentile table for daily flow durations at key locations for PU reaches in mid and lower Billabong Creek under the Change Case scenario, with comparison to Base Case.

Guide: 'Flow size ML/day' ('+/- flow size difference to Base Case scenario', '+/- percentage difference to Base Case')

Percentile	PU11 Billabong Creek at Jerilderie	PU11 Billabong Creek at DS Hartwood Weir**	PU13 Billabong Creek at Wanganella**	PU13 Billabong Creek at Darlot
0%*				
5%	2431 (+9, +0.4%)	1916 (+12, +1%)	2695 (+17, +1%)	2602 (+15, +1%)
10%	1249 (+10, +1%)	1074 (-8, -1%)	1607 (+17, +1%)	1553 (+10, +1%)
15%	815 (+8, +1%)	674 (+4, +1%)	1018 (+21, +2%)	987 (+22, +2%)
20%	553 (-1, -0.1%)	428 (+1, +0.2%)	669 (+16, +2%)	643 (+18, +3%)
25%	411 (-10, -2%)	299 (+4, +1%)	490 (+14, +3%)	461 (+11, +2%)
30%	338 (-17, -5%)	239 (0, 0%)	394 (+5, +1%)	367 (+7, +2%)
35%	297 (-17, -5%)	202 (-7, -3%)	343 (+3, +1%)	315 (+2, +1%)
40%	269 (-15, -5%)	177 (-10, -5%)	304 (-1, -0.3%)	275 (-2, -1%)
45%	247 (-11, -4%)	157 (-12, -7%)	272 (-7, -3%)	245 (-7, -3%)
50%	230 (-9, -4%)	143 (-11, -7%)	247 (-10, -4%)	221 (-9, -4%)
55%	214 (-9, -4%)	129 (-12, -9%)	226 (-13, -5%)	200 (-11, -5%)
60%	200 (-6, -3%)	117 (-13, -10%)	208 (-14, -6%)	183 (-13, -7%)
65%	188 (-4, -2%)	106 (-13, -11%)	192 (-14, -7%)	168 (-13, -7%)
70%	177 (-1, -1%)	96 (-13, -12%)	178 (-11, -6%)	155 (-12, -7%)
75%	164 (-1, -1%)	87 (-13, -13%)	165 (-10, -6%)	142 (-11, -7%)
80%	152 (0, 0%)	78 (-12, -13%)	151 (-9, -6%)	129 (-10, -7%)
85%	137 (-1, -1%)	69 (-12, -15%)	136 (-7, -5%)	116 (-9, -7%)
90%	121 (-2, -2%)	60 (-12, -17%)	120 (-6, -5%)	102 (-6, -6%)
95%	102 (0, 0%)	46 (-15, -25%)	99 (-8, -7%)	84 (-6, -7%)
100%*				

*Note that it has been chosen to exclude the 0% and 100% percentiles from this analysis (discussed further in Table 2-8).

**Note that the following symbology has been used to distinguish between different flow categories. For Billabong Creek at Jerilderie and Billabong Creek at Darlot, there are specific flow rate threshold estimates for different flow categories documented in Table 9 of Murrumbidgee Long Term Water Plan Part A: Murrumbidgee catchment (NSW DPIE 2020a). However, this does not exist for Billabong Creek at DS Hartwood and Wanganella, and as such the flow categories for Billabong Creek at Jerilderie and Darlot have been applied respectively. Whilst there are additional inflows and outflows between these gauges which may alter flow categorisation, for the purposes of this comparative assessment between scenarios, we believe this is an adequate approach.

Smaller than very low flows	Very low flows	Baseflows	Small freshes		Large freshes	Large freshes: wetland connection	Small overbank	Large overbank
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4.2.5 Environmental water requirements

4.2.5.1 Yanco and Colombo creeks

The EWR results for Upper Yanco Creek (Table 4-9) indicate either no reduction or an increase in the frequency with which EWR categories are modelled to be achieved compared to Base Case scenario results (see Section 3.2.5). The EWR results indicate a +32% increase in the frequency with which Baseflow BF1_a ('typical year' minimum durations for baseflow) is predicted to be achieved compared to the Base Case scenario, meaning that Baseflow BF1_a are predicted to be achieved in 100% of years. There are also predicted to be a 9% and 8% improvement in the frequency with which the Native Fish Nesting Support NestS1_mc (Murray Cod) and NestS1_tcmc (Trout Cod/Murray Cod) EWRs are achieved. These EWRs relate to avoiding rapid changes in water levels (rate of fall) during cod breeding season which is a priority in the Upper Yanco section where Trout Cod particularly are known to occur. There are also predicted improvements in the frequency (+1 to +6%) with which the Small freshes (SF1_P 'preferred seasonal timing' and SF1_S 'any time that is considered satisfactory') and Large fresh (LF1_P, LF1_S and LF2) EWRs are achieved compared to Base Case scenario results.

The EWR results for Lower Yanco to Lower Billabong Creek (Table 4-9) indicate either no reduction or an increase in the frequency with which EWR categories are modelled to be achieved compared to Base Case scenario results (see Section 3.2.5). The EWR modelling results indicate a +14% increase in the frequency with which Baseflow BF1_a ('typical year' minimum durations for baseflow) is predicted to be achieved, meaning that Baseflow BF1_a is predicted to be achieved in 46% of years. There are also predicted minor improvements in the frequency with which the Native Fish Nesting Support NestS1_mc (+3%) and NestS1_tcmc (+1%) EWRs are achieved. There are also predicted improvements in the frequency (+3 to +5%) with which the Small freshes (SF1_P, SF1_S and SF2) and Large fresh LF1_P (+5%) EWRs are achieved.

The EWR results (Table 4-9) for Colombo Creek at Morundah to Billabong Creek upstream of Jerilderie indicate a very minor (-1%) reduction in the frequency with which Very low flow VF1_b ('dry year' minimum durations for very low flows) and Baseflow BF1_b ('dry or very dry year' minimum durations for baseflows) are achieved compared to Base Case scenario results (see Section 3.2.5). However, the minimum flow targets as specified in the Yanco Creek System Operations for Colombo Creek @ Morundah is 100 ML/day when General Security allocations are equal to or greater than 15%, which is larger than the required flow magnitudes for the VF1_b and BF_1 EWRs of 40 and 70 ML/day respectively. As such, these very minor reductions in very low flows and baseflows will not eventuate in reality. These reductions, in addition to the -4% reduction in the Large Floodplain Connection Flows OB-L1_P ('preferred seasonal timing') EWR, are likely artifacts of the limitations of the Source model, which are discussed in Table 2-8. The Source model models flows reliably within the regulated flow range, but does not model flows outside the regulated range well, including very low flows/baseflows and very high flows/overbank flows. In addition, issues with the Source model's "water forecast to arrive" and water ordering modelling functions mean that the modelled operation of the Hartwood and Wanganella re-regulators is not necessarily aligned with its anticipated on-ground operation, especially outside the regulated flow range.

The EWR results for Colombo Creek at Morundah to Billabong Creek upstream of Jerilderie also indicate there will be increases in the frequency (+2% to +9%) with which the specific flow or inundation regime for Small fresh (SF1_P, SF1_S and SF2) and Large fresh (LF1_P) EWRs are achieved. There is also a predicted +4% improvements in the frequency with which the NestS1_tcmc (Trout Cod/Murray Cod) EWR is achieved, which is a priority in the upper section of Colombo Creek where Trout Cod are known to occur.

4.2.5.2 Mid and lower Billabong Creek

The EWR results for Billabong Creek at Jerilderie to downstream of Hartwood Weir (Table 4-9) indicate a very minor (-1%) reduction in the frequency with which Cease-to-flow CF1 and the specific flow or inundation regimes for Very low flow VF1_b ('dry year' minimum durations for very low flows) are predicted to be achieved

compared to Base Case scenario results (see Section 3.2.5). However, the minimum flow targets as specified in the Yanco Creek System Operations for Billabong Creek @ Jerilderie is 70 ML/day when General Security allocations are equal to or greater than 15%, which is larger than the required flow magnitudes for the CF1 and VF1_b EWRs of 0 and 50 ML/day respectively. As such, these very minor reductions in cease to flow and very low flows attainment will not eventuate in reality. These reductions are likely artifacts of the limitations of the Source model, which are discussed in Table 2-8.

The EWR results (Table 4-9) for Lower Billabong and Intersecting Streams downstream to Moulamein indicate a very minor reduction in the frequency with which Cease-to-flow CF1 (-1%) EWR is achieved. However, the minimum flow targets as specified in the Yanco Creek System Operations for Billabong Creek @ Darlot is 50 ML/day plus downstream orders, which is larger than the required flow magnitude for the CF1 EWR of 0 ML/day respectively. As such, these very minor reductions in cease to flow attainment will not eventuate in reality. These reductions, in addition to the very minor reduction (-2%) in the frequency with which the specific flow or inundation regimes for Small Overbank Floodplain Connection Flow OB-S1 and OB-S2 is achieved, are likely artifacts of the limitations of the Source model, which are discussed in Table 2-8.

Importantly, the EWR results (Table 4-9) for Lower Billabong and Intersecting Streams downstream to Moulamein indicate that there are increases in the frequency with which the specific flow or inundation regime for Floodplain Connection Flow EWR Large Overbank OB-L1 (+4%), EWRs W-LF4_P ('preferred seasonal timing') and W-LF4_S ('any time that is considered satisfactory') (+1%), Small Freshes EWR SF1 (+4 to +5%) and Native Fish Nesting Support EWRs NestS1_mc and NestS1_tcmc (+5 to +7%) are achieved compared to Base Case scenario results (see Section 3.2.5).

Table 4-9 EWR adjusted frequency score results at key locations for PU reaches in the Yanco Creek System under the Change Case scenario, with comparison to Base Case.

Note that the green, yellow and red shading represents high, medium and low degree of EWR attainment as per Table 2-2. In addition, +/- indicates an increase/decrease in EWR adjusted frequency score compared to the Base Case scenario.

Category	EWR	PU10 (Upper Yanco Creek)	PU12 (Lower Yanco to Lower Billabong Creek)	PU11 (Colombo Creek at Morundah to Billabong Creek upstream of Jerilderie)	PU11 (Billabong Creek at Jerilderie to downstream of Hartwood Weir)	PU13 (Lower Billabong and Intersecting Streams)
Cease-to-flow (CtF)	CF1	100 (0)	100 (0)	100 (0)	99 (-1)	99 (-1)
Very low flow (VLF)	VF1_a	100 (0)	100 (0)	100 (0)	100 (0)	100 (0)
	VF1_b	100 (0)	100 (0)	99 (-1)	99 (-1)	100 (0)
Baseflow (BF)	BF1_a	100 (+32)	46 (+14)	100 (0)	100 (0)	100 (0)
	BF1_b	100 (0)	97 (+1)	99 (-1)	99 (0)	100 (0)
Native Fish Nesting Support	NestS1_mc	56 (+9)	35 (+3)	61 (0)		76 (+7)
	NestS1_tcmc	44 (+8)	28 (+1)	57 (+4)		63 (+5)
Small fresh (pulse) (SF)	SF1_P	78 (+6)	81 (+5)	86 (+9)		95 (+5)
	SF1_S	86 (+2)	88 (+3)	92 (+2)		96 (+4)
	SF2	100 (0)	60 (+5)	93 (+4)		100 (0)
Large fresh (pulse) (LF)	LF1_P	81 (+5)	83 (+5)	87 (+7)		85 (0)
	LF1_S	99 (+1)	100 (0)	100 (0)		100 (0)
	LF2	100 (+2)	100 (0)	100 (0)		100 (0)
Wetland connection flow (Wetland-LF)	W-LF4_P					68 (+1)
	W-LF4_S					71 (+1)
	W-LF5					96 (0)
	W-LF6_P	100 (0)	100 (0)	100 (0)		100 (0)
	W-LF6_S	100 (0)	100 (0)	100 (0)		100 (0)
	W-LF7	90 (0)	71 (0)	73 (0)		87 (+1)
	W-LF8	100 (0)	100 (0)	100 (0)		100 (0)
Floodplain connection flow (OB)	OB-L1					92 (+4)
	OB-L1_P	88 (0)	92 (0)	88 (-4)		
	OB-L1_S	100 (0)	100 (0)	100 (0)		
	OB-S1					70 (-2)
	OB-S2		90 (0)			96 (-2)
	OB-S2_P	70 (0)		86 (0)		
	OB-S2_S	88 (0)		100 (0)		

4.2.6 Effective General Security Allocations

Effective General Security Allocations have been modelled on 3 key dates, opening allocation (1-July), summer planning decision dates (15-September and 1-October), and end the Year (30-June) (Table 4-10). It can be seen from Table 4-10 that effective General Security Allocations are predicted to increase marginally under the Change Case scenario, compared to Base Case, for opening allocation and summer planning decision dates.

A very minor decrease is predicted for end of the year, which does not occur in the modelled Cumulative Change Case, but this is likely an artifact of the limitations of the Source model, which are discussed in Table 2-8. In addition, this modelled reduction in effective General Security Allocations at the end of the year does not occur under the Cumulative Change Case scenario (refer to Section 4.3.6).

Table 4-10 Modelled General Security Effective Allocations (AWDs + Carryover)

Key date	Description	Base Case	Change Case
1-Jun	Opening allocation	48.2	48.4
15-Sep	Summer planning decision dates	57.5	57.7
1-Oct		58.8	58.9
30-Jun	End the Year	84.9	84.8 ¹

¹ This modelled reduction in effective General Security Allocations at the end of the year does not occur under the Cumulative Change Case scenario (refer to Section 4.3.6).

4.2.7 NSW River Flow Objectives

An assessment of potential River Flow Objectives impacts of the proposal during operation, to the extent of proposal influence up and down stream, has been undertaken in Table 4-11.

Table 4-11 Potential impacts to River Flow Objectives with operation of the proposal

NSW river flow objective	Description	River Flow Objectives impacts during operation
Protect natural low flows	Protect natural low flows	The flow variability and frequency and size analysis results for the Change Case scenario (see Section 4.2) indicate operation of the proposal is not expected to result in adverse impacts to low flows (i.e. unnatural prolonged drying) within the proposal study area and the broader Yanco Creek System. Very minor reductions are modelled in some instances, but these are likely modelling artifacts due to the limitations of the Source model. Environmental baseflow provisions specified in the Yanco Creek System Operations Plan (NSW DCCEW 2023b) include at (among other locations) Billabong Creek @ Jerilderie of 70 ML/day (when general security allocations are equal to or greater than 15%), Billabong Creek @ downstream Hartwood Regulator of 25 ML/day (at all times) and Billabong Creek @ Darlot (410134) – 50 ML/day plus downstream orders (at all times).
Protect important rises in water levels	Protect or restore a proportion of moderate flows ('freshes') and high flows	The flow frequency and size analysis for the Change Case scenario (see Section 4.2) indicate no material change in the proportion of moderate flows ('freshes') and high flows will occur within the study area with operation of the proposal.
Maintain wetland and floodplain inundation	Maintain or restore the natural inundation patterns and distribution of floodwaters supporting natural wetland and floodplain ecosystems	The analysis of EWR (Environmental Water Requirements) attainments for the Change Case scenario (see Section 4.2) indicate, with some exceptions, mostly no change or some minor improvements in the frequency in the expected frequency of over bank wetland connection or floodplain connection flows within the study area (i.e. lower Billabong Creek) with operation of the proposal. Very minor reduction in the frequency of small overbank floodplain connection flows (EWRs OB-S1 and OB-S2) predicted for lower Billabong Creek, but this is likely a modelling artifact due to the limitations of the Source model.
Mimic natural drying in temporary waterways	Mimic the natural frequency, duration and seasonal nature of drying periods in naturally temporary waterways	The annual water balance results (see Section 4.2.1) indicate no material change in the overall water balance of the Yanco Creek System with operation of the proposal that is considered likely to result in changes to the current frequency, duration and seasonal nature of drying periods in naturally temporary waterways within the Yanco Creek System.

NSW river flow objective	Description	River Flow Objectives impacts during operation
Maintain natural flow variability	Maintain or mimic natural flow variability in all streams	The flow variability analysis results (see Section 4.2) indicate no material change in the overall annual flow variability within the Yanco Creek System with operation of the proposal. Operation of the proposal is also not expected to seriously impact mean daily flow volumes within lower Billabong Creek, including the proposal study area.
Maintain natural rates of change in water levels	Maintain rates of rise and fall of river heights within natural bounds	Operation of the proposal is expected to result in an improvement in the rates of change in water levels within the proposal study area and the broader Yanco Creek System. The Yanco Creek System operations plan includes normal regulated flow operational limits for 'Pool Maximum Daily Rate of Rise' of 0.30m for Hartwood and Wanganella regulators. The Yanco Creek System operations plan also includes 'Native fish environmental flow provisions' of a maximum rate of fall of 9% (by volume) between the 14th September and 16th November inclusive for Yanco Creek at Yanco Offtake and Billabong Creek at Darlot, to better align with the EWR for fish nesting in the long-term watering plan.
Manage groundwater for ecosystems	Maintain groundwater within natural levels and variability, critical to surface flows and ecosystems	During operation, minor watertable change is expected at Hartwood and Wanganella. The operation of the proposal is not expected to result in adverse impacts to water dependent ecosystems as the change in groundwater level expected from the proposal is minor. Billabong Creek is partially disconnected and losing to groundwater hence, the proposal is not expected to result in reduced surface flows during operation.
Minimise effect of weirs and other structures	Minimise the impact of instream structures	Operation of the proposal will not have a significant adverse impact on the occurrence of high-quality flowing habitat or water quality within the proposal study area. The design of the Hartwood and Wanganella regulators includes fishways that will allow an increase in river extent with unimpeded fish passage.

4.3 Cumulative impacts (Modelled Cumulative Change Case scenario)

The following sections details key aspects of the predicted hydrological regime within the proposal study area and broader area of investigation with operation of the proposal, other system changes specified in the Yanco Creek System Operations Plan (NSW DCCEEW 2023b) and the inclusion of the Forest Creek Return Flows Project, as characterised by the Cumulative Change Case scenario Source model results for data from 1 July 1895 to 30 June 2022.

For Yanco and Colombo creeks, all components of the Cumulative Change Case Source model remain unchanged from the Base Case scenario. For mid and lower Billabong Creeks, applicable components of the Forest Creek Return Flows Project have been applied, but otherwise all elements of the Cumulative Change Case scenario remain unchanged from the Change Case scenario.

Note, this report does not include an assessment of the potential direct impacts associated with the Forest Creek Return Flows Project. The Forest Creek Return Flows Project is subject to its own separate assessment and approvals process. Results for the Cumulative Change Case scenario are discussed only where they are considered relevant for the assessment of cumulative impacts of the proposal in the context of implementation of broader system changes specified in the Yanco Creek System Operations Plan and the Forest Creek Return Flows Project.

4.3.1 Annual water balance

Figure 4-18 and Table 4-12 summarise the modelled annual water balance for key parameters at key locations within the Yanco Creek System under the Cumulative Change scenario. These show that all changes in mean annual flows when compared to the Base Case scenario, except for Piccaninny Creek, are low (-1.1% to +2.1%) for key parameters and key locations within the Yanco Creek System assessed.

The predominantly low degree of changes in mean annual flows within the Yanco Creek System are considered the product of the suite of differences between the Cumulative Change Case and Base Case scenario, including the new regulators, broader system changes specified in the Yanco Creek System Operations Plan and the Forest Creek Return Flows Project. However, due to the modelling approach taken, it is difficult to determine how much of these changes can be attributed directly to the operation of the proposed regulators within the context of additional broader system changes.

The following sections discuss potential reasons behind the changes modelled in the mean annual water balance for the Cumulative Change Case scenario compared to the Base Case scenario. This discussion is split into the area of investigation upstream of the study area (Yanco and Colombo Creeks and upper Billabong Creek) and the study area (Mid and lower Billabong Creek).

Yanco, Colombo and Upper Billabong Creeks

When comparing the Cumulative Change scenario to the Change Case scenario results, it is seen that the mean annual flows are consistent between scenarios, and only very minor increases are modelled at Yanco Creek at Offtake (+0.3 GL/year or +0.1%), Colombo Creek at Morundah (+0.2 GL/year or 0.1%) and Billabong Creek at U/S Innes Bridge (+0.2 GL/year or 0.1%). As such, the proposal is not anticipated to have any major additional cumulative effects within Yanco and Colombo Creeks beyond those observed under the Change Case, when taking into consideration potential cumulative effects associated with the Forest Creek Return Flows Project.

The very minor increases from the Change Case scenario are considered the result of the inclusion of the new environmental flow provision for Forest Creek at Offtake of 10 ML/day for the Cumulative Change case model. The new environmental flow provision for Forest Creek at Offtake is the only change that has been added since the Change Case scenario which could impact modelled flows upstream of Forest Creek at Offtake. This may be

causing the Source model to direct more flows down Yanco Creek at Offtake and pass on this increase in flows via Colombo and Billabong Creeks before finally reaching Forest Creek at Offtake.

Thus, in summary, the low degree of changes in mean annual flows in Yanco and Colombo Creeks and upper Billabong Creek upstream of Jerilderie are considered the product of the following differences between the Cumulative Change and Base Case scenarios:

- Environmental baseflow, native fish environmental flow and additional environmental provisions, including the new environmental flow provision for Forest Creek at Offtake of 10 ML/day
- The ability of the new regulators to regulate flows within Billabong Creek itself to meet environmental and water supply demands
- New normal regulated flow operational limits on the use of irrigation escapes

Mid and Lower Billabong Creek

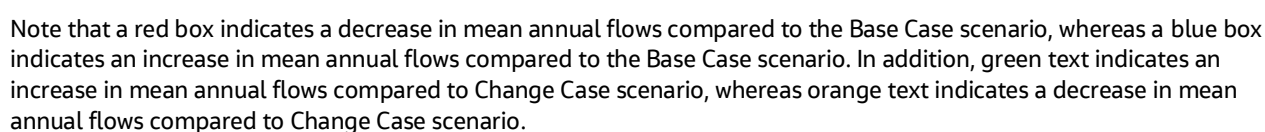
When comparing the Cumulative Change scenario to the Change Case scenario results, it is seen that the mean annual flows along Billabong Creek are consistent between scenarios. Only minor decreases in mean annual flows are modelled down Billabong Creek at downstream of Hartwood Weir (-0.6 GL/year or -0.4%), Conargo (-0.7 GL/year or -0.3%) and Jerilderie (+0.1 GL/year or +0.1%), and only minor increases are modelled in mean annual flows at Billabong Creek at Wanganella and Darlot (+2.4 GL/year or +1.1%). As such, the proposal is not anticipated to have any major additional cumulative effects within mid and lower Billabong Creeks beyond those observed under the Change Case, when taking into consideration potential cumulative effects associated with the Forest Creek Return Flows Project.

The very minor decreases in mean annual flows at Billabong Creek at Hartwood, Conargo and Jerilderie from the Change Case scenario are considered the result of the inclusion of the new environmental flow provision for Forest Creek at Offtake of 10 ML/day for the Cumulative Change case model. This may be causing the Source model to direct more flows down Billabong Creek at Jerilderie to increase flows at Forest Creek at Offtake, which will in turn result in less flows down Billabong Creek at D/S Hartwood Weir and Conargo. The minor increases in mean annual flows at Billabong Creek at Wanganella and Darlot under the modelled Cumulative Change case scenario compared to Change Case are considered the result of additional flow contributions to lower Billabong Creek from Piccaninny Creek.

The Forest Creek Return Flows Project includes a new operational principle to divert unplanned flows down Piccaninny Creek (and ultimately back into Billabong Creek) to assist in preventing unplanned flows in Forest Creek downstream of Warriston Weir during normal regulated periods. This results in lower mean annual flows for Forest Creek at Warriston Weir (-2.4 GL/year or -7.3%) and higher mean annual flows (+3.2 GL/year or +1066.7%) down Piccaninny Creek. However, the Source model may not model very small flows accurately, which is what Forest Creek at Warriston Weir and Piccaninny Creek have been modelled to experience most of the time. As such, there is uncertainty around how much of the modelled change is due to the new operational principle vs the limitations of the Source model.

Thus, in summary, the low degree of changes in mean annual flows in mid and lower Billabong Creek are considered the product of the following differences between the Cumulative Change and Base Case scenarios:

- New operational principle to divert unplanned flows down Piccaninny Creek to assist in preventing unplanned flows in Forest Creek downstream of Warriston Weir during normal regulated periods
- Environmental baseflow, native fish environmental flow and additional environmental provisions, including the new environmental flow provision for Forest Creek at Offtake of 10 ML/day
- The ability of the new regulators to regulate flows within Billabong Creek itself to meet environmental and water supply demands
- New normal regulated flow operational limits on the use of irrigation escapes



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Table 4-12 Mean annual water balance at key locations within the Yanco Creek System under the Cumulative Change scenario compared to Base Case scenario.

Planning Unit	Location	Mean annual flows (GL/year) under Base Case scenario	Mean annual flows (GL/year) under EIS Cumulative Change scenario	Change from Base Case (GL/year)	% Change from Base Case	Change from Base Case rating (as per Table 2-2)
PU10: Upper Yanco Creek	Yanco Offtake	294.1	295.5	1.4	0.5	L
PU11: Colombo & Billabong Creeks	Colombo Creek at Morundah	129.1	127.6	-1.5	-1.2	L
	Billabong Creek Inflows at Walbundrie	140.7	140.7	0.0	0.0	L
	Billabong Creek at US Innes Bridge	205.5	204.0	-1.5	-0.7	L
	Billabong Creek at Jerilderie	207.6	206.2	-1.4	-0.7	L
	Finley Escape inflows	9.5	8.6	-0.9	-9.5	L
	Billabong Creek at DS Hartwood Weir	149.4	146.4	-3.0	-2.0	L
PU12: Lower Yanco Creek to Lower Billabong Creek	Yanco Creek at Morundah	135.1	137.9	2.8	2.1	L
	CCD + DC800 irrigation escape inflows	22.5	21.7	-0.8	-3.6	L
	CICL escape transmission losses	0.3	0.3	0.0	0.0	L
	Coly Outfall Drain inflows	0.5	0.5	0.0	0.0	L
	Yanco Creek at Yanco Bridge	136.4	138.2	1.8	1.3	L
	Billabong Creek at Conargo	245.9	244.6	-1.3	-0.5	L
PU13: Lower Billabong and Intersecting Streams	Billabong Creek at Darlot	211.5	213.3	1.8	0.9	L
	Forest Creek at Warriston Weir	32.9	30.5	-2.4	-7.3	L
	Flow Down Piccaninny Creek	0.3	3.5	3.2	1066.7	H

Planning Unit	Location	Mean annual flows (GL/year) under Base Case scenario	Mean annual flows (GL/year) under EIS Cumulative Change scenario	Change from Base Case (GL/year)	% Change from Base Case	Change from Base Case rating (as per Table 2-2)
Overall (across model extent)	Consumptive extractions (Irrigation + Town Water Supply)	66.9	67.1	0.2	0.3	L
	Environmental Pumping (via Australian Food and Agriculture pumps)	0.9	0.8	-0.1	-11.1	L
	Net Evaporation	23.2	23.2	0.0	0.0	L
	Change in Regulator and River Storage	0	0	0.0	0.0	L
	Miscellaneous Lateral Fluxes (all components not explicitly modelled, including errors in gauging, seepage, overbank flows losses etc.)	131.9	132	0.1	0.1	L

4.3.1.1 Water extractions

The results in Table 4-13 provide a summary of modelled consumptive extractions (Irrigation + Town Water Supply), for data from the period 1895-2022. The Source model consumptive extractions results indicate no change in the predicted consumptive take increase under the Cumulative Change Case scenario compared to the Change Case scenario (+0.2 GL/year) based on water availability in the Yanco Creek System. Based on these results no reduction in water availability to meet Water Access Licenses is expected when taking into consideration potential cumulative impacts associated with the Forest Creek Return Flows Project.

Table 4-13 Modelled consumptive extractions (Irrigation + Town Water Supply) between Yanco Offtake and Darlot, for data from the period 1895-2022.

Water Balance Component	Base Case	Change Case	Cumulative Change Case
Extractions (GL/year)	66.9	67.1	67.1
Difference from Base Case (GL/year)	0	+0.2	+0.2

Note: excludes extractions downstream of Billabong Creek @ Darlot

4.3.2 Seasonality of flows

4.3.2.1 Yanco and Colombo Creeks

Figure 4-19 and Table 4-14 present the modelled mean monthly flows at key locations along Yanco and Colombo Creeks under the Cumulative Change scenario. The mean monthly flows modelled under the Cumulative Change scenario are generally consistent with the Change Case scenario results (see Section 4.2.2) with changes within -0.5% to +0.7%. As such, the proposal is not anticipated to have any major additional cumulative effects within Yanco and Colombo Creeks beyond those observed under the Change Case, when taking into consideration potential cumulative effects associated with the Forest Creek Return Flows Project.

The very minor changes from the Change Case scenario are considered the result of the inclusion of the new environmental flow provision for Forest Creek at Offtake of 10 ML/day for the Cumulative Change case model. This may be causing the Source model to direct more flows down Yanco Creek at Offtake and pass on this increase in flows via Colombo and Billabong Creeks before finally reaching Forest Creek at Offtake. However, in general, the Cumulative Change and Change Case scenario results are consistent, and as such, the same findings discussed in Section 4.2.1 relative to the Base Case are also relevant for the Cumulative Change Case.

Figure 4-19 and Table 4-14 indicate the typical temperate seasonal pattern of higher flows during winter-spring and lower flows during summer-autumn periods which was observed under the Base Case scenario has been retained in the Cumulative Change scenario. When comparing the Cumulative Change scenario results to the Base Case results (Table 4-14 and Figure 4-20), the predicted differences in mean monthly flows (+7 to -7%) represent only a low degree of hydrological change.

The low degree of changes in mean monthly flows in Yanco and Colombo Creeks and upper Billabong Creek upstream of Jerilderie are considered the product of the suite of differences between the Cumulative Change Case and Base Case scenario, including the new regulators, broader system changes specified in the Yanco Creek System Operations Plan and the Forest Creek Return Flows Project. These include increases in mean monthly flows across all months except for the summer months (Table 4-14), which could be attributable to new environmental baseflow provisions for Yanco Creek at Offtake and at Morundah under the Yanco Creek System Operations Plan (NSW DPIE 2023). Also consistent with the Change Case results are the reductions in mean monthly flows predicted during December – February inclusive and between April – June within some reaches (ranging from -35 to -917 ML/month) (Table 4-14), which could be attributable to the new no order limits for CCD and DC800 irrigation escapes.

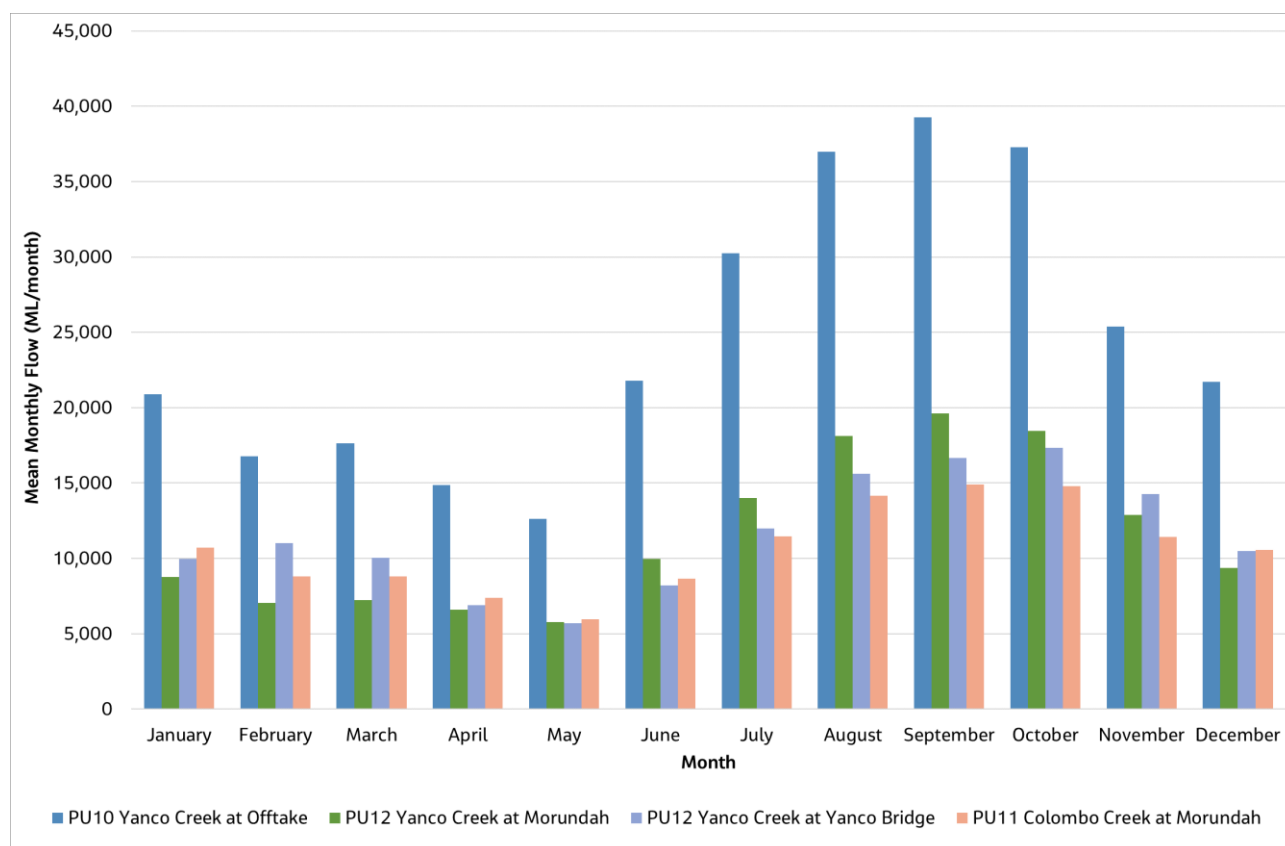


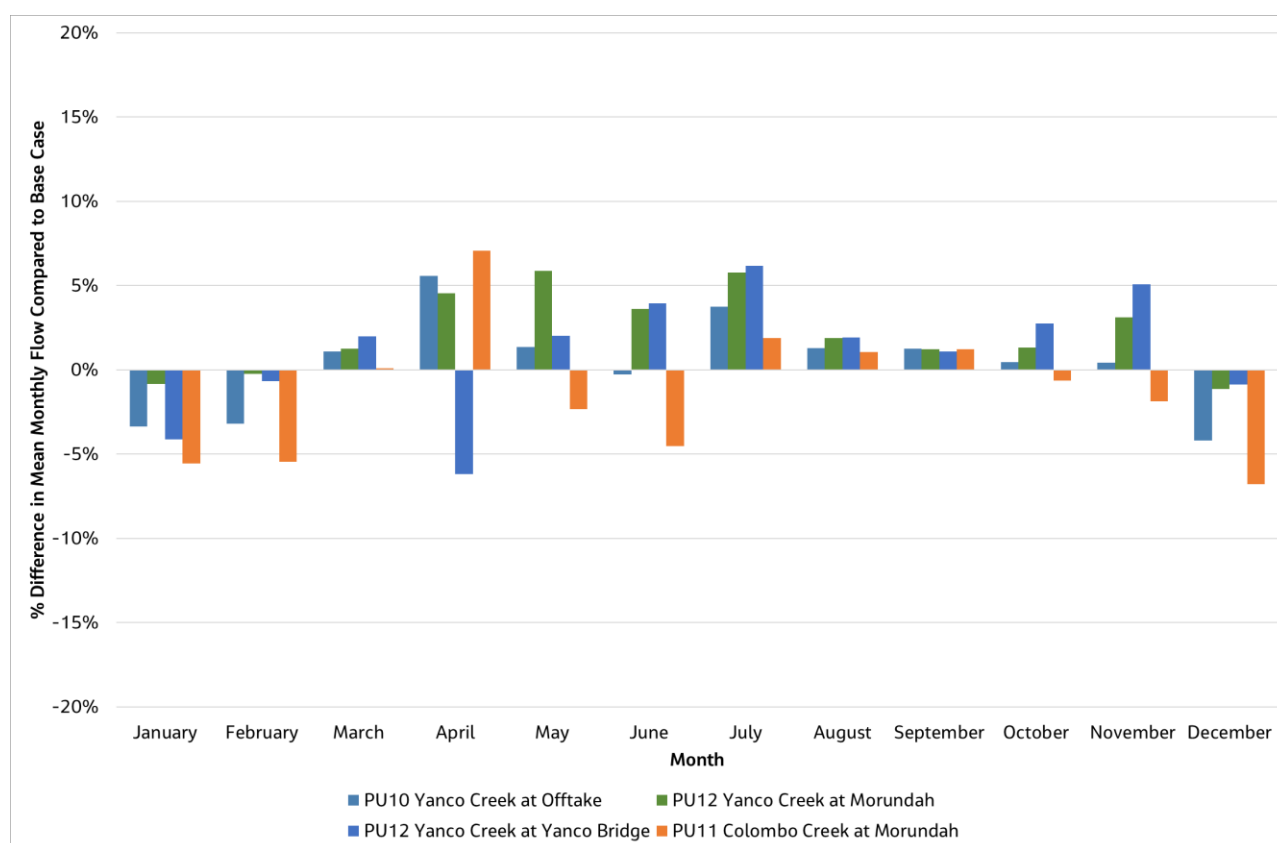
Figure 4-19 Mean monthly flows at key locations along Yanco and Colombo Creeks under the Cumulative Change scenario.

Table 4-14 Mean monthly flows under the Cumulative Change scenario and change from Base Case scenario at key locations along Yanco and Colombo Creeks

Guide: 'Flow size ML/day' ('+/- flow size difference to Base Case scenario')

Mean monthly flow (ML/day)	PU10 Yanco Creek at Offtake	PU11 Colombo Creek at Morundah	PU12 Yanco Creek at Morundah	PU12 Yanco Creek at Yanco Bridge
January	20910 (-770)	10719 (-639)	8771 (-111)	9971 (-475)
February	16782 (-567)	8801 (-507)	7065 (-32)	11030 (-107)
March	17650 (+186)	8802 (+8)	7231 (+95)	10031 (+153)
April	14873 (+770)	7395 (+483)	6617 (+275)	6892 (-492)
May	12613 (+189)	5945 (-116)	5771 (+313)	5716 (+102)
June	21774 (-53)	8658 (-407)	9966 (+345)	8192 (+305)
July	30229 (+972)	11448 (+166)	13994 (+711)	11976 (+657)
August	36978 (+443)	14144 (+124)	18136 (+315)	15611 (+258)
September	39259 (+551)	14899 (+218)	19612 (+254)	16656 (+185)

Mean monthly flow (ML/day)	PU10 Yanco Creek at Offtake	PU11 Colombo Creek at Morundah	PU12 Yanco Creek at Morundah	PU12 Yanco Creek at Yanco Bridge
October	37293 (+389)	14791 (+3)	18473 (+343)	17353 (+543)
November	25371 (+215)	11418 (-156)	12894 (+446)	14257 (+760)
December	21730 (-917)	10558 (-731)	9384 (-108)	10474 (-82)



Note: Hydrological alteration categories (as per Table 2-2) – Low: <20% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; Medium: 20-50% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; High: >50% difference (+/-) from Base Case scenario conditions.

Figure 4-20 Percentage difference in mean monthly flows at key locations along Yanco and Colombo Creeks under the Cumulative Change scenario compared to the Base Case scenario.

4.3.2.2 Mid and lower Billabong Creek

Figure 4-21 and Table 4-15 present the modelled mean monthly flows at key locations along mid and lower Billabong under the Cumulative Change scenario. Although results for Forest Creek at Warriston Weir are also shown in Figure 4-21 and Table 4-15, the impacts of the Forest Creek Return Flows Project are being assessed via a different environmental approvals process, and are only discussed here to determine if there are any cumulative effects with the proposal.

The mean monthly flows modelled under the Cumulative Change scenario are generally consistent with the Change Case scenario results (see Section 4.2.2) with changes within -2.6% to +2.5% along mid and lower Billabong Creek, except for Forest Creek at Warriston weir. As such, the proposal is not anticipated to have any

major additional cumulative effects within mid and lower Billabong Creeks beyond those observed under the Change Case, when taking into consideration potential cumulative effects associated with the Forest Creek Return Flows Project.

The very minor decreases and increases are considered the result of the inclusion of the Forest Creek Return Flows Project. The minor additional (-6 to -132 ML/month) reduction in modelled mean monthly flows downstream of Hartwood regulator under the Cumulative Change when compared to the Change Case scenario could be attributed to the new 10ML/day environmental baseflow provision for Forest Creek at Offtake. The minor predicted increase in mean monthly flows predicted at both Wanganella and Darlot (averaged at 203 ML/month and 197 ML/month respectively) compared to those modelled under the Change Case scenario could be attributed to additional inflows to lower Billabong Creek via Piccaninny Creek (+3.2 GL/year) with the inclusion of the Forest Creek Return Flows Project in the Cumulative Change Case model. Likewise, the low to moderate decrease in inflows to Forest Creek at Warriston weir is likely due to the new operational principle to divert unplanned flows down Piccaninny Creek to assist in preventing unplanned flows in Forest Creek downstream of Warriston Weir during normal regulated periods. However, in general, the Cumulative Change and Change Case scenario results are consistent, and as such, the same findings discussed in Section 4.2.1 relative to the Base Case are also relevant for the Cumulative Change Case.

Figure 4-21 and Table 4-15 indicate the typical temperate seasonal pattern of higher flows during winter-spring and lower flows during summer-autumn periods which was observed under the Base Case scenario has been retained in the Cumulative Change scenario. When comparing the mid and lower Billabong Creek Cumulative Change scenario results to the Base Case results (Figure 4-20), the proportional predicted differences in mean monthly flows (-18% to +6%) represent only a low degree of hydrological change.

The low degree of changes in mean monthly flows in mid and lower Billabong Creek are considered the product of the suite of differences between the Cumulative Change Case and Base Case scenario, including the new regulators, broader system changes specified in the Yanco Creek System Operations Plan and the Forest Creek Return Flows Project. These include reductions in mean monthly flow volumes for Billabong Creek at Jerilderie (October – March) compared to the Base Case scenario, which could be attributable to the reduced need for diversion into Colombo and Billabong Creeks as a result of the ability of the new regulators to regulate flows within Billabong Creek itself to meet environmental and water supply demands.

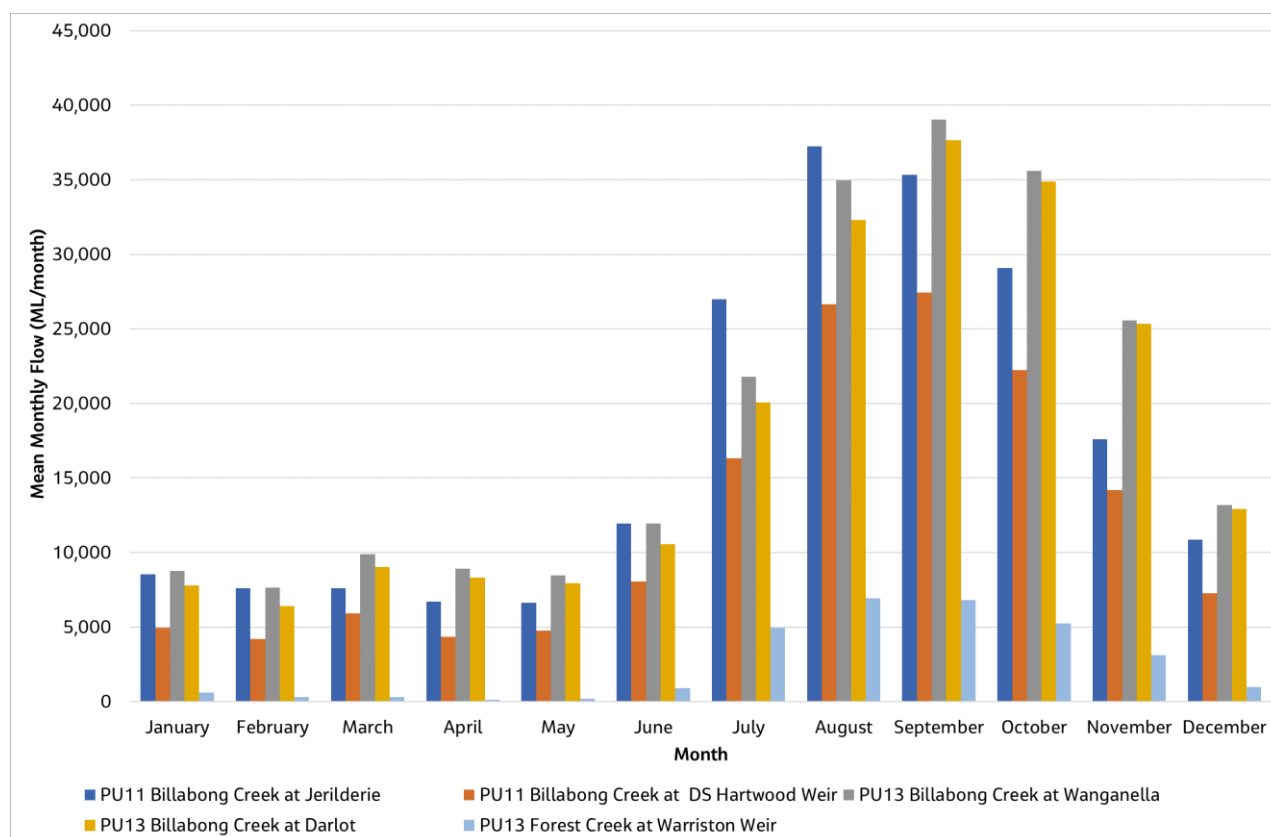
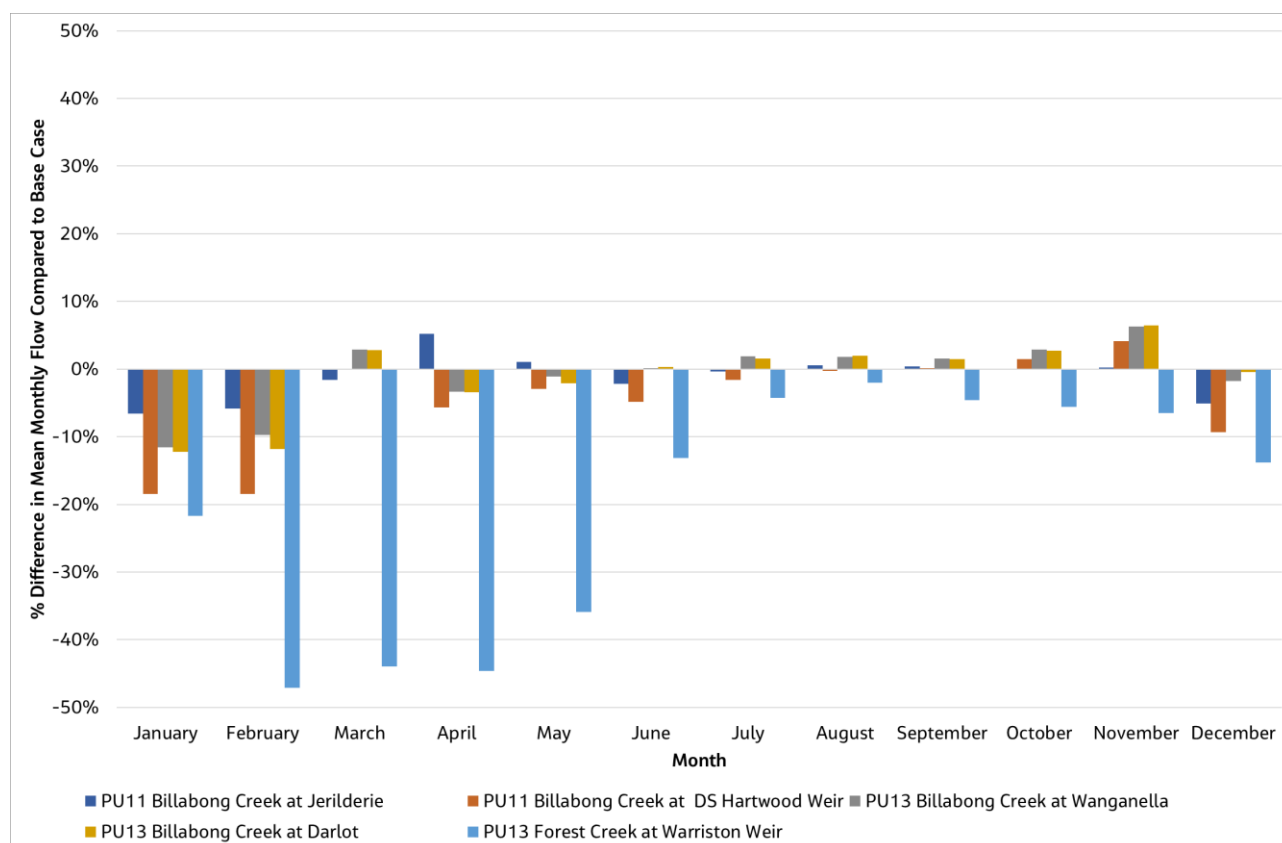


Figure 4-21 Mean monthly flows at key locations along Billabong and Forest Creeks under the Cumulative Change scenario.

Table 4-15 Mean monthly flows at key locations along Billabong and Forest Creeks under the Cumulative Change scenario, also showing change to Base Case scenario.

Guide: 'Flow size ML/day' ('+/- flow size difference to Base Case scenario')

Mean monthly flows (ML/month)	PU11 Billabong Creek at Jerilderie	PU11 Billabong Creek at DS Hartwood Weir	PU13 Billabong Creek at Wanganella	PU13 Billabong Creek at Darlot	PU13 Forest Creek at Warriston Weir
January	8538 (-601)	4935 (-1117)	8784 (-1150)	7784 (-1086)	612 (-170)
February	7617 (-475)	4205 (-951)	7638 (-828)	6424 (-862)	311 (-277)
March	7619 (-123)	5907 (+4)	9876 (+273)	9023 (+243)	295 (-231)
April	6723 (+333)	4358 (-262)	8918 (-310)	8309 (-296)	137 (-111)
May	6624 (+69)	4761 (-145)	8486 (-99)	7963 (-169)	189 (-106)
June	11960 (-268)	8045 (-408)	11936 (+12)	10547 (+35)	897 (-136)
July	26988 (-86)	16337 (-269)	21808 (+411)	20082 (+310)	4954 (-220)
August	37255 (+199)	26655 (-81)	34970 (+607)	32299 (+633)	6938 (-140)
September	35346 (+133)	27431 (+43)	39049 (+588)	37663 (+541)	6816 (-328)
October	29087 (+18)	22244 (+320)	35599 (+1009)	34883 (+929)	5268 (-311)
November	17606 (+47)	14203 (+558)	25554 (+1513)	25351 (+1528)	3114 (-217)
December	10858 (-585)	7279 (-751)	13175 (-234)	12924 (-59)	975 (-156)



Note: Hydrological alteration categories (as per Table 2-2) – Low: <20% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; Medium: 20-50% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; High: >50% difference (+/-) from Base Case scenario conditions.

Figure 4-22 Percentage difference in mean monthly flows at key locations along Yanco and Colombo Creeks under the Cumulative Change scenario compared to the Base Case scenario.

4.3.3 Flow variability

4.3.3.1 Yanco and Colombo Creeks

Figure 4-23 shows modelled total annual flows for key reach locations in Yanco and Colombo Creeks under the Cumulative Change scenario. Consistent with modelled Base Case scenario, the total annual flow (GL/year) into the Upper Yanco Creek at Yanco Offtake can be seen to be highly variable under the Cumulative Change scenario. Although this may be due to a combination of factors, it is considered primarily associated with unregulated flows through Yanco Offtake passing through the system. Figure 4-24 presents a comparison (as percentage difference) of modelled under the Cumulative Change scenario annual flow volumes results compared to the Base Case scenario, which shows that the majority of change in annual flow volumes are low (-0.9% to +3.6%).

Based on these Cumulative Change case results, there appears to be no major changes to total annual flow volumes and variability within Yanco and Colombo Creeks when considering cumulative impacts of the proposal in the context of implementation of the Forest Creek Return Flows Project.

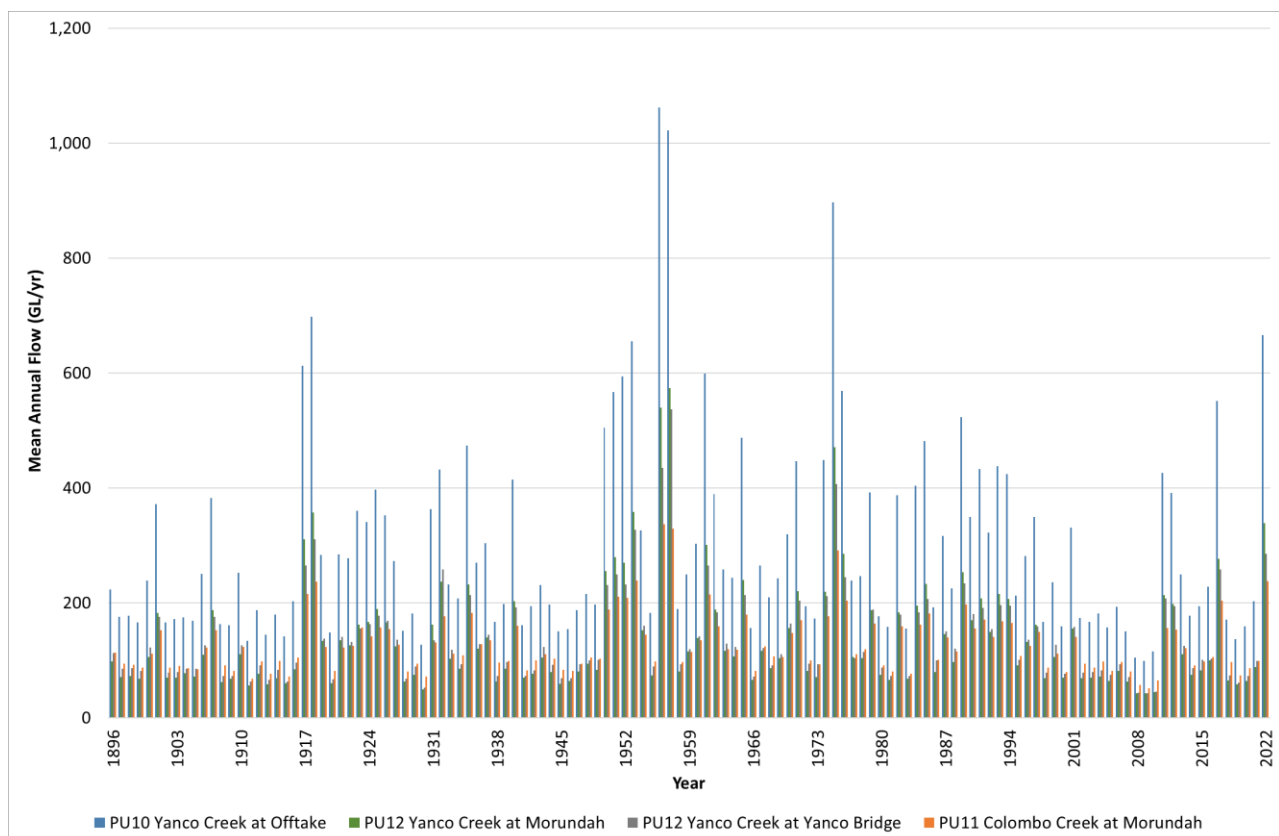
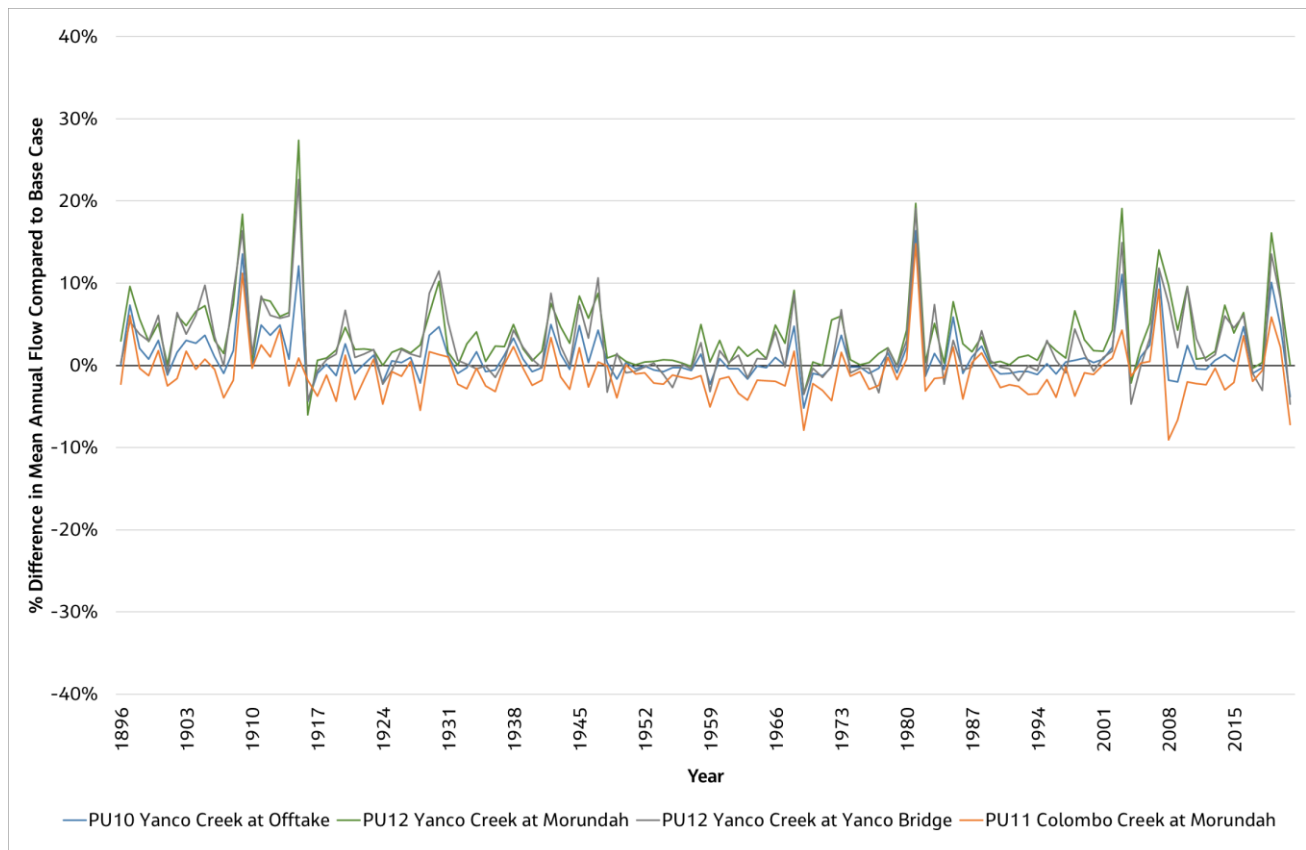


Figure 4-23 Total annual flows at key locations along Yanco and Colombo Creeks under the Cumulative Change scenario.



Note: Hydrological alteration categories (as per Table 2-2) – **Low:** <20% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; **Medium:** 20-50% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; **High:** >50% difference (+/-) from Base Case scenario conditions.

Figure 4-24 Percentage difference in total annual flows at key locations along Yanco and Colombo Creeks under the Cumulative Change scenario compared to the Base Case scenario.

Figure 4-25 present the modelled mean daily flows at key reach locations along Yanco and Colombo Creeks under the Cumulative Change scenario. These are compared to the Base Case scenario results in Figure 4-26, which shows that all changes in mean daily flows are low (-1.2% to +2.2%). When comparing the Cumulative Change scenario results to the Change Case results (see Section 4.2.3) there are very minimal (less than +/- 1%) differences in mean daily flows, which are considered the result of the inclusion of the new environmental flow provision for Forest Creek at Offtake of 10 ML/day for the Cumulative Change case model.

Based on these Cumulative Change case results, there appears to be no major changes to mean daily flow volumes and variability within Yanco and Colombo Creeks when considering cumulative impacts of the proposal in the context of implementation of the Forest Creek Return Flows Project.

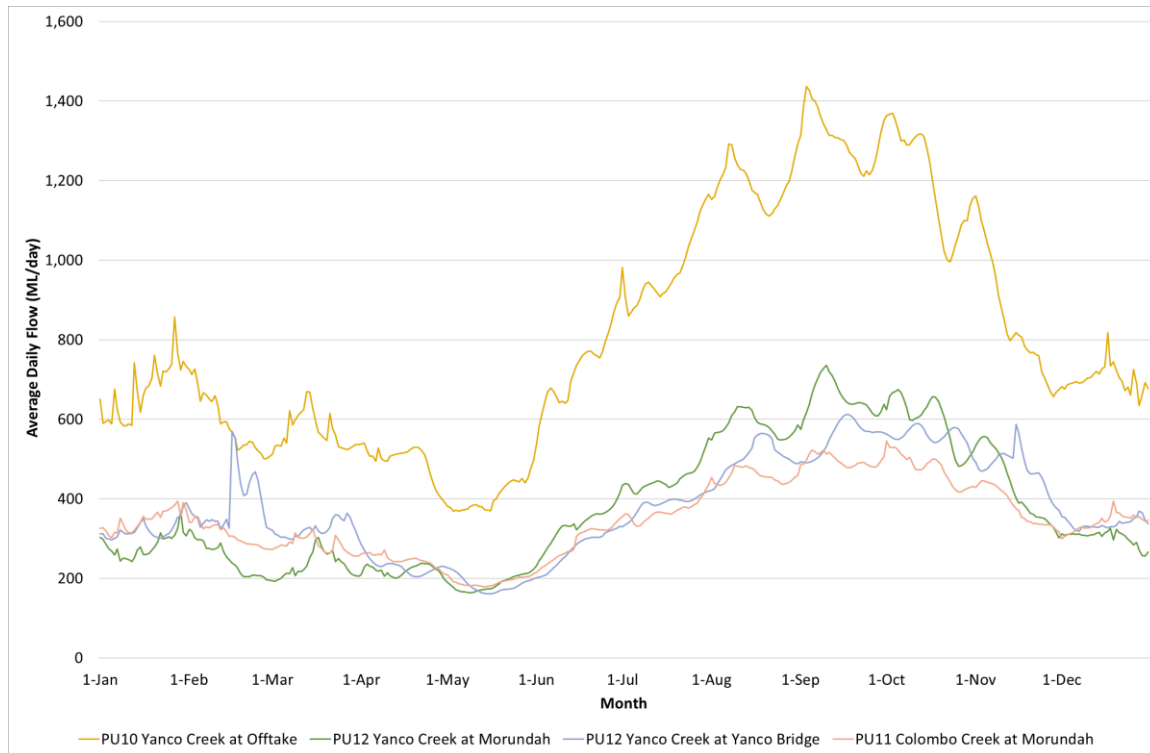


Figure 4-25 Mean daily flows at key locations along Yanco and Colombo Creeks under the Cumulative Change scenario.



Note that the green background represents changes within the low degree of hydrological change category as per Table 2-2.

Figure 4-26 Percentage difference in mean daily flows at key locations along Yanco and Colombo Creeks under the Cumulative Change scenario compared to the Base Case scenario.

4.3.3.2 Mid and lower Billabong Creek

Figure 4-27 shows modelled total annual flows for mid and lower Billabong Creek and Forest Creek under the Cumulative Change scenario. Consistent with modelled Base Case and Change Case scenarios, the total annual flow (GL/year) in mid and lower Billabong under the Cumulative Change scenario are highly variable at all locations and there is an absence of near no-flow years.

Figure 4-28 presents a comparison (as percentage difference) of modelled Cumulative Change scenario annual flow volumes results compared to the Base Case scenario, which shows that for mid and lower Billabong Creek the majority of change in annual flow volumes are low as average annual flow volume change ranges from -2.6% to +2.6% along Billabong Creek. For Forest Creek, the change in modelled annual flow volumes ranges from low to high, with an average change of -14.8% (low). This consistent reduction in modelled total annual flow volumes could be attributed to the new operational principle to divert unplanned flows down Piccaninny Creek to assist in preventing unplanned flows in Forest Creek downstream of Warriston Weir during normal regulated periods.

Based on these Cumulative Change case results, there appears to be no major changes to total annual flow volumes and variability within mid and lower Billabong Creek, except for Forest Creek at Warriston weir, when considering cumulative impacts of the proposal in the context of implementation of the Forest Creek Return Flows Project.

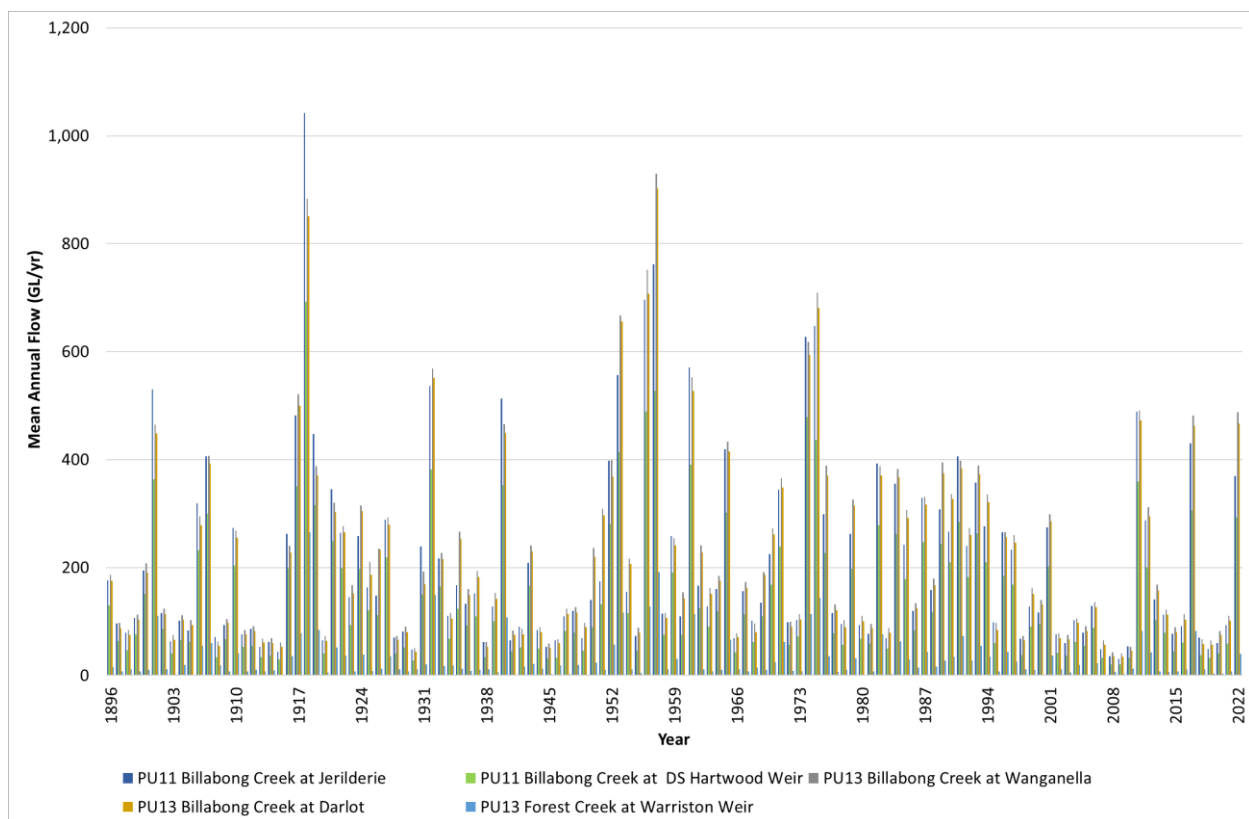
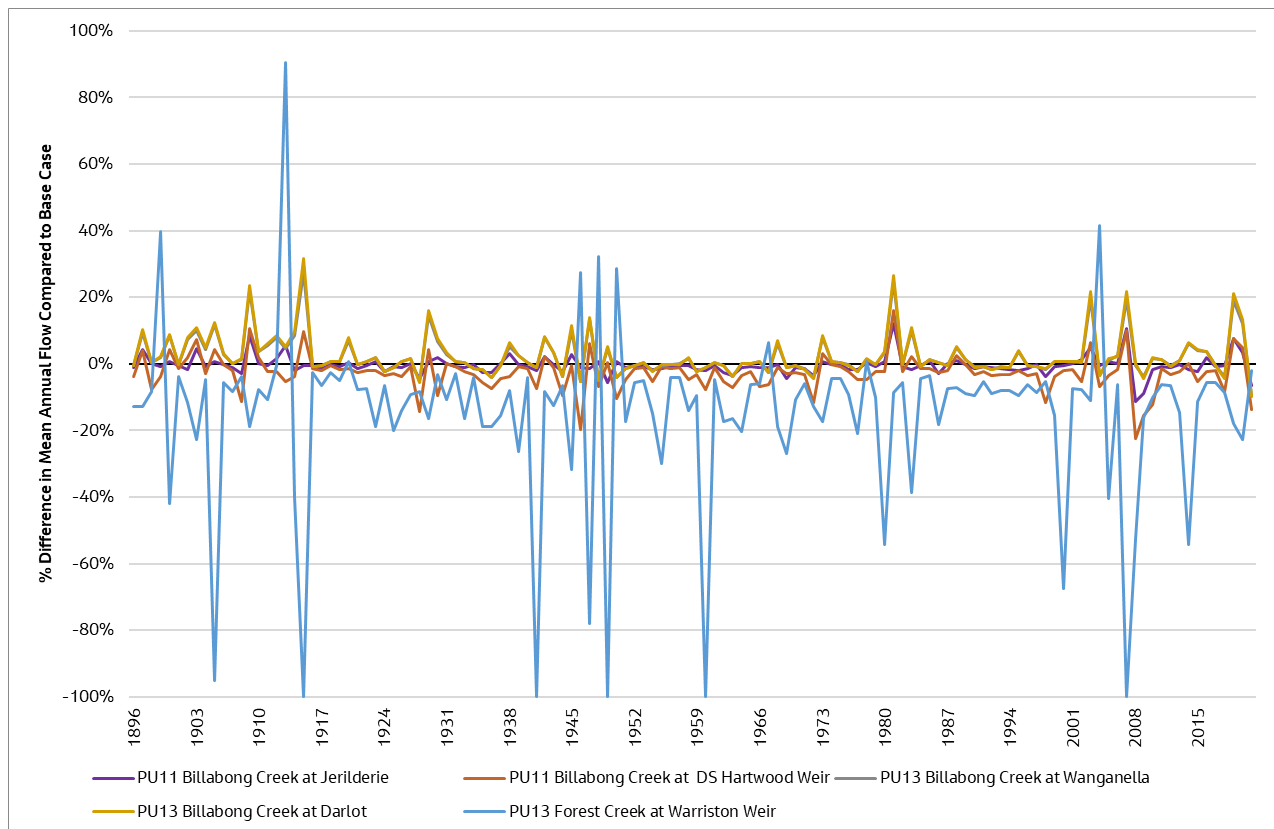


Figure 4-27 Total annual flows at key locations along Billabong and Forest Creeks under the Cumulative Change scenario.



Note: Hydrological alteration categories (as per Table 2-2) – **Low:** <20% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; **Medium:** 20–50% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; **High:** >50% difference (+/-) from Base Case scenario conditions.

Figure 4-28 Percentage difference in total annual flows at key locations along Billabong and Forest Creeks under the Cumulative Change scenario compared to the Base Case scenario.

Figure 4-29 presents the modelled mean daily flows for key reach locations within mid and lower Billabong Creek and Forest Creek under the Cumulative Change scenario. The percentage difference in modelled mean daily flows between Base Case and Cumulative Change scenarios for key reach locations within mid and lower Billabong Creek and Forest Creek is shown in Figure 4-30.

With the exception of Forest Creek at Warriston weir, the majority of differences in mean daily flows are low (averaged as -4.6% to -0.8%) between Base Case and Cumulative Change scenarios. For Forest Creek at Warriston Weir, the differences in mean daily flows range from low to high (ranging from -2.1 to -98%) compared to Base Case, with the largest reductions occurring during the summer-autumn period, particularly mid-Feb and mid-April. These reductions are attributable to the proposed operation of the Forest Creek Return Regulator that will enable the flow target downstream of Forest Creek @ Warriston Weir of 0 ML/day to be achieved for efficiently (NSW DCCEW 2023b).

As such, there appears to be no major changes to modelled mean daily flows and variability within mid and lower Billabong Creek, except for Forest Creek at Warriston Weir, when considering cumulative impacts of the proposal in the context of implementation of the Forest Creek Return Flows Project.

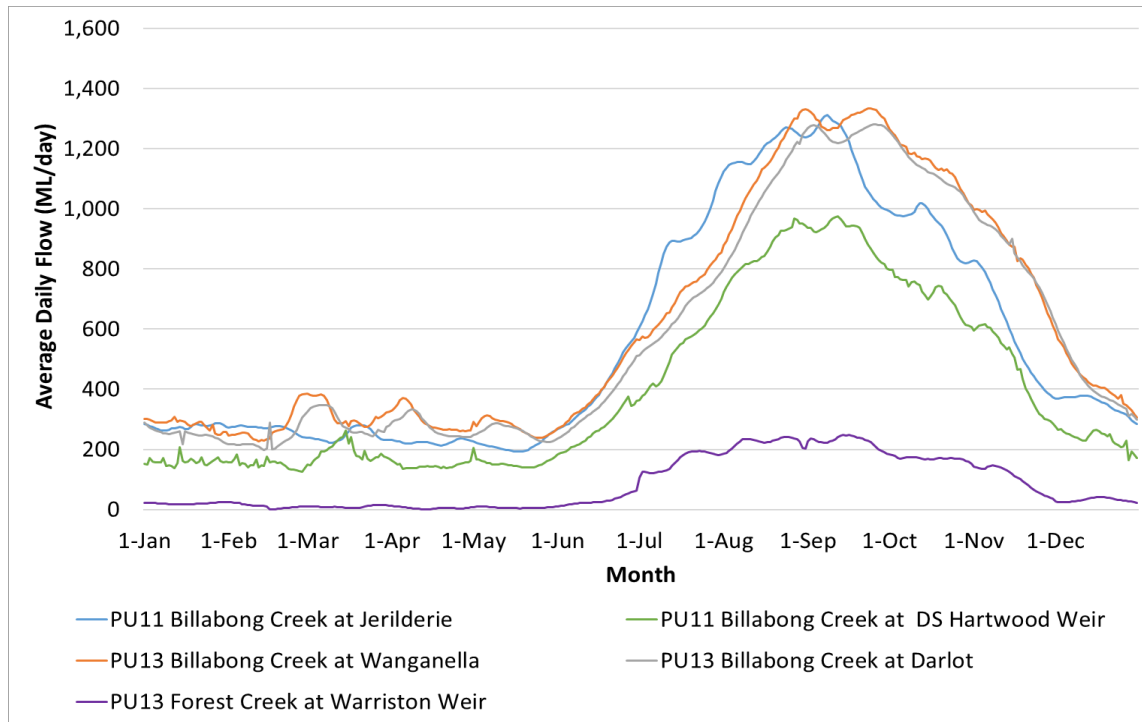
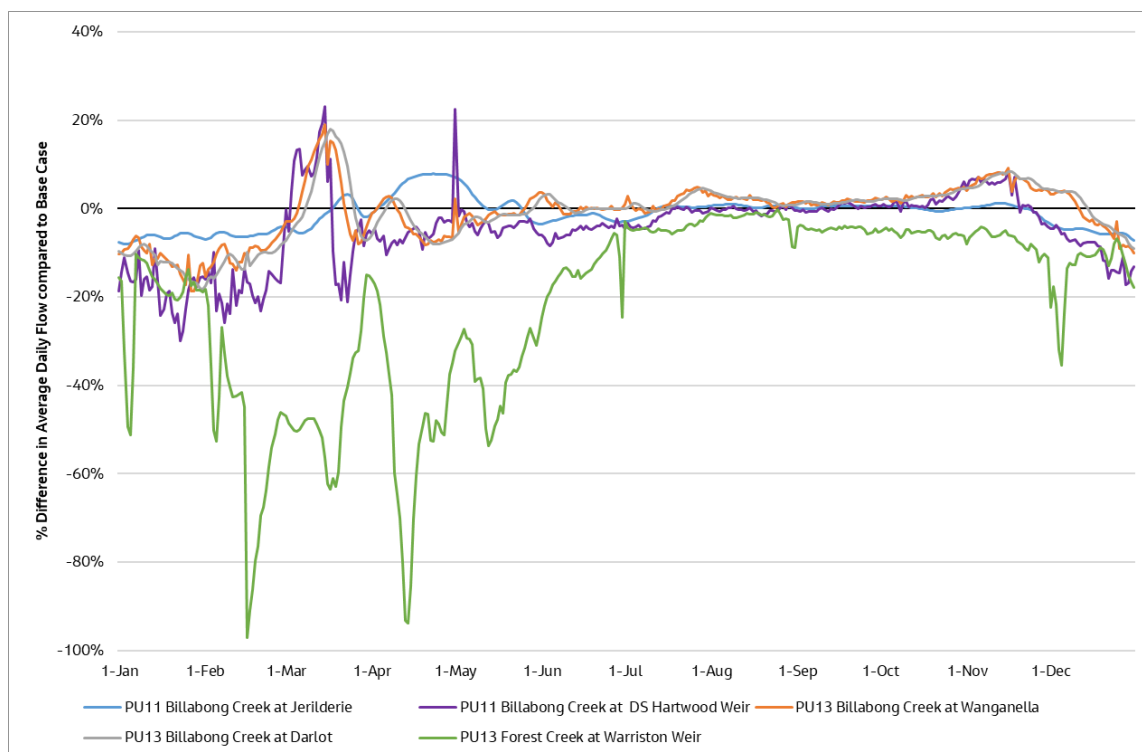


Figure 4-29 Mean daily flows at key locations along Billabong and Forest Creeks under the Cumulative Change scenario.



Note: Hydrological alteration categories (as per Table 2-2) – **Low:** <20% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; **Medium:** 20-50% difference (+/-) in key flow regime characteristics when compared to Base Case scenario conditions; **High:** >50% difference (+/-) from Base Case scenario conditions.

Figure 4-30 Percentage difference in mean daily flows at key locations along Billabong and Forest Creeks under the Cumulative Change scenario compared to the Base Case scenario.

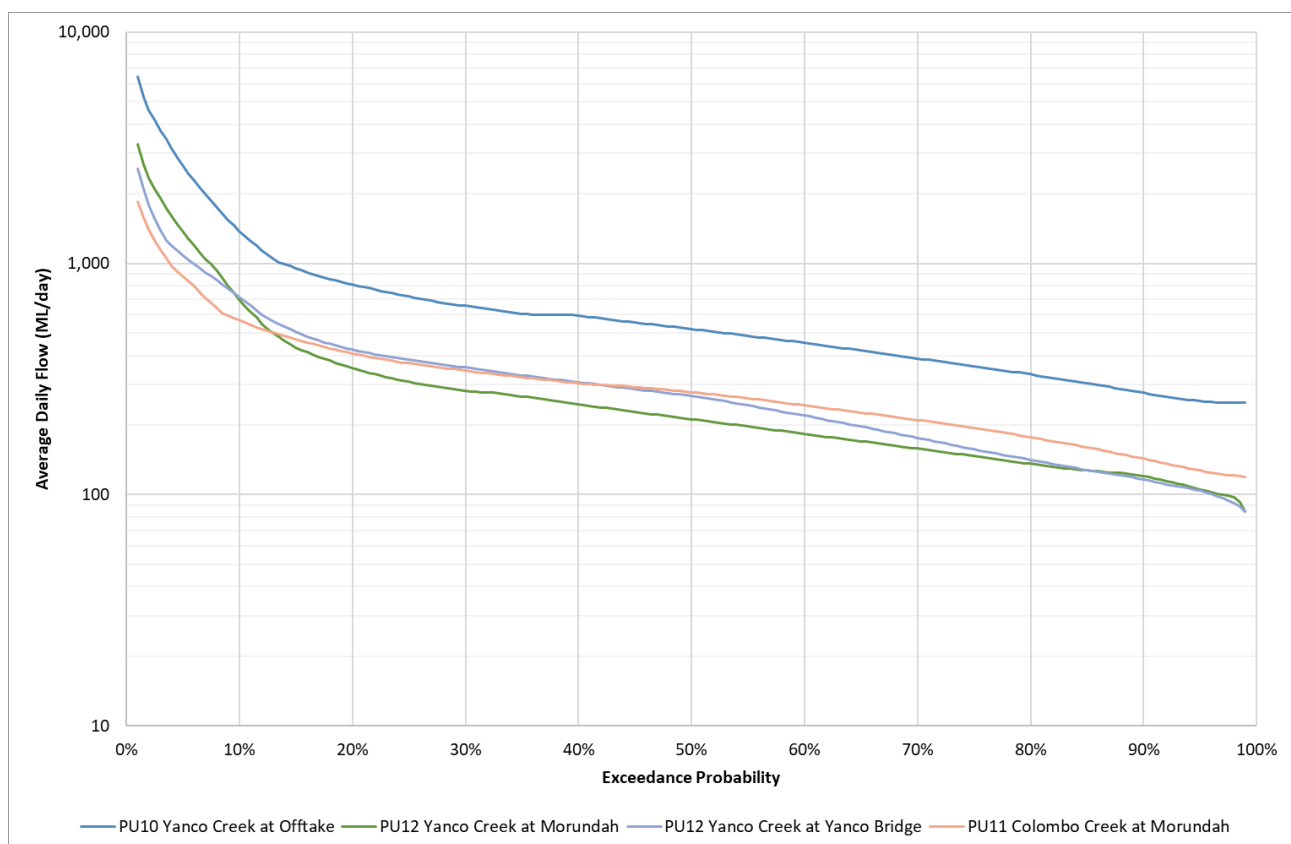
4.3.4 Flow sizes

4.3.4.1 Yanco and Colombo Creeks

When comparing the Cumulative Change scenario results (Table 4-16) to those for the Change Case scenario there are only minor ($\pm 5\%$) differences in the portion of daily flows which fall into different flow categories. In addition, there are very minor (less than $\pm 4\%$) differences in flow sizes for all percentiles reported. These very minor increases are considered the result of the inclusion of the Forest Creek Return Flows Project. As such, the proposal is not anticipated to have any major additional cumulative effects within Yanco and Colombo Creeks beyond those observed under the Change Case, when taking into consideration potential cumulative effects associated with the Forest Creek Return Flows Project.

Figure 4-31 and Table 4-16 present the flow size analysis results for modelled daily flows (ML/day) at key locations on Yanco and Colombo Creeks under the Cumulative Change Case scenario. Also shown in Table 4-7 are the flows (ML/day) and percentage differences compared to the Base Case results. When comparing the Cumulative Change scenario results to the Base Case results, the predicted differences in daily flow sizes ($+14.2$ to -3.2%) represent only a low degree of hydrological change. The same findings discussed in Section 4.2.1 are also relevant for the Cumulative Change Case, given that the Cumulative Change scenario results are generally consistent with the Change Case scenario results.

It should be noted that this is a high-level daily flow size analysis and does not take into account when these flows occur throughout the year and whether these flows satisfy the timing criteria of the environmental water requirements. This is addressed through the EWR analysis discussed in Section 4.2.6.



*Note that it has been chosen to exclude the 0% and 100% percentiles from this analysis (discussed further in Table 2-8).

Figure 4-31 Daily flow duration curves at key locations along Yanco and Colombo Creeks under the Cumulative Change scenario.

Table 4-16 Daily flow percentiles at key locations along Yanco and Colombo creeks under the Cumulative Change scenario, with comparison to Base Case.

Guide: 'Flow size ML/day' ('+/- flow size difference to Base Case scenario', 'percentage difference to Base Case scenario')

Percentile	PU10 Yanco Creek at Offtake	PU11 Colombo Creek at Morundah	PU12 Yanco Creek at Morundah	PU12 Yanco Creek at Yanco Bridge**
0%*				
5%	2639 (+18, +0.7%)	875 (+5, +0.5%)	1369 (+10, +0.8%)	1082 (+6, +0.6%)
10%	1380 (+9, +0.7%)	568 (-1, -0.2%)	696 (+3, +0.4%)	718 (+3, +0.5%)
15%	951 (-8, -0.9%)	470 (-10, -2.1%)	433 (+13, +3.0%)	506 (+6, +1.2%)
20%	810 (-13, -1.6%)	408 (-12, -3.0%)	353 (+5, +1.5%)	423 (+1, +0.3%)
25%	719 (-9, -1.3%)	370 (-9, -2.5%)	307 (+4, +1.3%)	383 (-1, -0.2%)
30%	655 (-3, -0.5%)	344 (-7, -2.1%)	281 (+3, +1.0%)	354 (+1, +0.4%)
35%	606 (0, +0.1%)	322 (-7, -2.2%)	266 (+6, +2.1%)	328 (+1, +0.4%)
40%	595 (-3, -0.5%)	303 (-7, -2.3%)	246 (+7, +2.9%)	306 (+4, +1.2%)
45%	555 (-2, -0.3%)	292 (-5, -1.7%)	228 (+7, +3.1%)	286 (+6, +2.1%)
50%	520 (0, +0.1%)	278 (-5, -1.7%)	212 (+6, +3.0%)	267 (+7, +2.6%)
55%	486 (+5, +1.0%)	261 (-4, -1.4%)	197 (+6, +2.9%)	243 (+7, +3.0%)
60%	453 (+8, +1.8%)	243 (-4, -1.8%)	183 (+6, +3.3%)	220 (+6, +2.9%)
65%	420 (+6, +1.5%)	226 (-5, -2.1%)	170 (+6, +3.8%)	197 (+5, +2.4%)
70%	388 (+6, +1.6%)	210 (-4, -1.9%)	158 (+7, +4.4%)	176 (+3, +1.5%)
75%	359 (+6, +1.8%)	194 (-3, -1.3%)	147 (+7, +4.6%)	157 (+2, +1.2%)
80%	331 (+5, +1.5%)	177 (-4, -2.5%)	136 (+8, +5.5%)	141 (+3, +2.2%)
85%	304 (+2, +0.6%)	160 (-5, -3.2%)	127 (+10, +8.2%)	128 (+5, +4.0%)
90%	275 (+2, +0.6%)	143 (-5, -3.2%)	120 (+15, +12.6%)	116 (+8, +7.2%)
95%	254 (+14, +5.6%)	127 (-2, -1.2%)	106 (+15, +14.2%)	104 (+13, +12.1%)
100%*				

*Note that it has been chosen to exclude the 0% and 100% percentiles from this analysis (discussed further in Table 2-8).

**Note that the following symbology has been used to distinguish between different flow categories. For Yanco Creek at Offtake, Colombo Creek at Morundah and Yanco Creek at Morundah, there are specific flow rate threshold estimates for different flow categories documented in Table 9 of Murrumbidgee Long Term Water Plan Part A: Murrumbidgee catchment (NSW DPIE 2020a). However, this does not exist for Yanco Creek at Yanco Bridge, and as such the flow categories for Yanco Creek at Morundah have been applied. Whilst there are additional inflows and outflows between Yanco Creek at Morundah and Yanco Bridge which may alter flow categorisation, for the purposes of this comparative assessment between scenarios, we believe this is an adequate approach.

Smaller than very low flows	Very low flows	Baseflows	Small freshes	Large freshes	Large freshes: wetland connection	Small overbank	Large overbank
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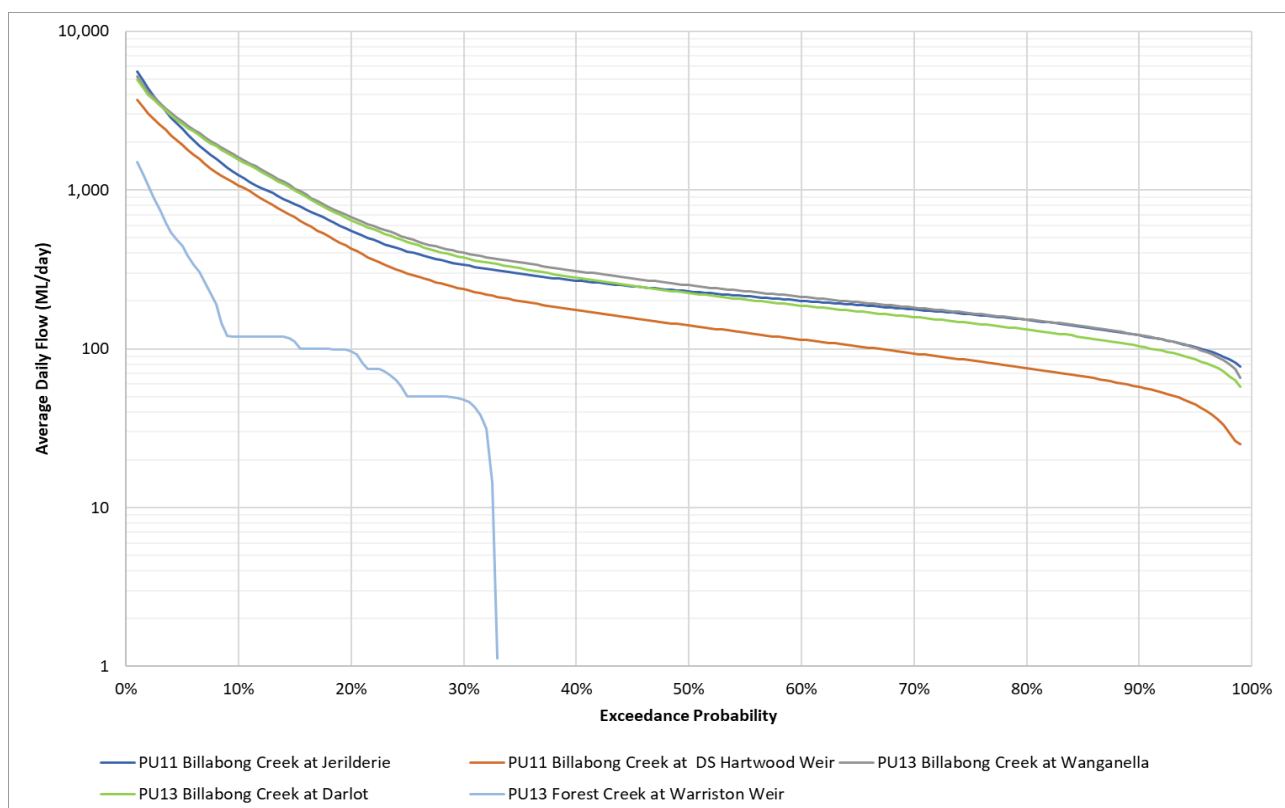
4.3.4.2 Mid and lower Billabong Creek

When comparing the Cumulative Change scenario results (Table 4-17) to those for the Change Case scenario there are only minor (+/-5%) differences in the portion of daily flows which fall into different flow categories for mid and lower Billabong Creek. In addition, there are very minor (-1% to +3%) differences in flow sizes for all percentiles reported. These very minor differences are considered the result of the inclusion of the Forest Creek Return Flows Project. As such, the proposal is not anticipated to have any major additional cumulative effects within mid and lower Billabong Creeks beyond those observed under the Change Case, when taking into consideration potential cumulative effects associated with the Forest Creek Return Flows Project.

Figure 4-32 and Table 4-17 present the flow size analysis results for modelled daily flows (ML/day) at key locations on mid and lower Billabong Creek, including the proposal study area, under the Cumulative Change Case scenario. Also shown in Table 4-17 are the flows (ML/day) and percentage differences compared to the Base Case results. The same findings discussed in Section 4.2.1 are also relevant for the Cumulative Change Case, given that the Cumulative Change scenario results are generally consistent with the Change Case scenario results along mid and lower Billabong Creek.

Figure 4-32 and Table 4-17 also present the flow duration curve and flow size results, respectively, for Forest Creek at Warriston Weir. The decrease in daily flow sizes are attributable to the proposed operation of the Forest Creek Return Regulator that will enable the flow target downstream of Forest Creek @ Warriston Weir of 0 ML/day to be achieved for efficiently (NSW DCCEEW 2023b).

It should be noted that this is a high-level daily flow size analysis and does not take into account when these flows occur throughout the year and whether these flows satisfy the timing criteria of the environmental water requirements. This is addressed through the EWR analysis discussed in Section 4.2.6.



*Note that it has been chosen to exclude the 0% and 100% percentiles from this analysis (discussed further in Table 2-8).

Figure 4-32 Daily flow duration curves at key locations along Billabong and Forest Creeks under the Cumulative Change scenario.

Table 4-17 Daily flow percentiles at key locations along Billabong and Forest Creeks under the Cumulative Change scenario, with comparison to Base Case.

Guide: 'Flow size ML/day' ('+/- flow size difference to Base Case scenario', 'percentage difference to Base Case scenario')

Percentile	PU10 Yanco Creek at Offtake	PU11 Colombo Creek at Morundah	PU12 Yanco Creek at Morundah	PU12 Yanco Creek at Yanco Bridge**
0%*				
5%	2639 (+18, +0.7%)	875 (+5, +0.5%)	1369 (+10, +0.8%)	1082 (+6, +0.6%)
10%	1380 (+9, +0.7%)	568 (-1, -0.2%)	696 (+3, +0.4%)	718 (+3, +0.5%)
15%	951 (-8, -0.9%)	470 (-10, -2.1%)	433 (+13, +3.0%)	506 (+6, +1.2%)
20%	810 (-13, -1.6%)	408 (-12, -3.0%)	353 (+5, +1.5%)	423 (+1, +0.3%)
25%	719 (-9, -1.3%)	370 (-9, -2.5%)	307 (+4, +1.3%)	383 (-1, -0.2%)
30%	655 (-3, -0.5%)	344 (-7, -2.1%)	281 (+3, +1.0%)	354 (+1, +0.4%)
35%	606 (0, +0.1%)	322 (-7, -2.2%)	266 (+6, +2.1%)	328 (+1, +0.4%)
40%	595 (-3, -0.5%)	303 (-7, -2.3%)	246 (+7, +2.9%)	306 (+4, +1.2%)
45%	555 (-2, -0.3%)	292 (-5, -1.7%)	228 (+7, +3.1%)	286 (+6, +2.1%)
50%	520 (0, +0.1%)	278 (-5, -1.7%)	212 (+6, +3.0%)	267 (+7, +2.6%)
55%	486 (+5, +1.0%)	261 (-4, -1.4%)	197 (+6, +2.9%)	243 (+7, +3.0%)
60%	453 (+8, +1.8%)	243 (-4, -1.8%)	183 (+6, +3.3%)	220 (+6, +2.9%)
65%	420 (+6, +1.5%)	226 (-5, -2.1%)	170 (+6, +3.8%)	197 (+5, +2.4%)
70%	388 (+6, +1.6%)	210 (-4, -1.9%)	158 (+7, +4.4%)	176 (+3, +1.5%)
75%	359 (+6, +1.8%)	194 (-3, -1.3%)	147 (+7, +4.6%)	157 (+2, +1.2%)
80%	331 (+5, +1.5%)	177 (-4, -2.5%)	136 (+8, +5.5%)	141 (+3, +2.2%)
85%	304 (+2, +0.6%)	160 (-5, -3.2%)	127 (+10, +8.2%)	128 (+5, +4.0%)
90%	275 (+2, +0.6%)	143 (-5, -3.2%)	120 (+15, +12.6%)	116 (+8, +7.2%)
95%	254 (+14, +5.6%)	127 (-2, -1.2%)	106 (+15, +14.2%)	104 (+13, +12.1%)
100%*				

*Note that it has been chosen to exclude the 0% and 100% percentiles from this analysis (discussed further in Table 2-8).

**Note that the following symbology has been used to distinguish between different flow categories. For Billabong Creek at Jerilderie and Billabong Creek at Darlot, there are specific flow rate threshold estimates for different flow categories documented in Table 9 of Murrumbidgee Long Term Water Plan Part A: Murrumbidgee catchment (NSW DPIE 2020a). However, this does not exist for Billabong Creek at DS Hartwood and Wanganella, and as such the flow categories for Billabong Creek at Jerilderie and Darlot have been applied respectively. There are no flow categories available for Forest Creek at Warriston Weir.

Smaller than very low flows	Very low flows	Baseflows	Small freshes	Large freshes	Large freshes: wetland connection	Small overbank	Large overbank
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4.3.5 Environmental water requirements

4.3.5.1 Yanco and Colombo creeks

The EWR results for Upper Yanco Creek (Table 4-18) indicate a +32% increase in the frequency with which Baseflow BF1_a ('typical year' minimum durations for baseflow) is predicted to be achieved, meaning that Baseflow BF1_a are predicted to be achieved in 100% of years. There are also predicted to be a 4-5% improvement in the frequency with which the Native Fish Nesting Support NestS1_mc (Murray Cod) and NestS1_tcmc (Trout Cod/Murray Cod) EWRs are achieved – this relates to avoiding rapid changes in water levels (rate of fall) during cod breeding season which is a priority in the Upper Yanco section where Trout Cod particularly are known to occur. There are also predicted improvements in the frequency (+1 to +6%) with which the Small freshes (SF1_P 'preferred seasonal timing' and SF1_S 'any time that is considered satisfactory') and Large fresh (LF1_P, LF1_S and LF2) EWRs are achieved, compared to Base Case scenario results (see Section 3.2.5). There is a modelled minor reduction (-1%) for wetland connecting flows W-LF, but this is likely an artifact of the limitations of the Source model, which are discussed in Table 2-8.

The EWR results for Lower Yanco Creek to Lower Billabong Creek (Table 4-18) indicate a +10% increase in the frequency with which Baseflow BF1_a ('typical year' minimum durations for baseflow) is predicted to be achieved, meaning that Baseflow BF1_a will be achieved in 42% of years. There are also predicted minor improvements in the frequency with which the Native Fish Nesting Support NestS1_mc (+5%) and NestS1_tcmc (+3%) EWRs are achieved. There are also predicted improvements in the frequency (+4 to +6%) with which the Small freshes (SF1_P, SF1_S and SF2) and Large fresh LF1_P (+4%) EWRs are achieved. There is a modelled minor reduction (-1%) for wetland connecting flows W-LF, but this is likely an artifact of the limitations of the Source model, which are discussed in Table 2-8. The EWR results (Table 4-18) for Colombo Creek at Morundah to Billabong Creek upstream of Jerilderie indicate a minor (-1%) reduction in the frequency with which the specific flow or inundation regime for Very low flow VF1_b ('dry year' minimum durations for very low flows) and Baseflow BF1_b ('dry or very dry year' minimum durations for baseflows) are achieved, compared to Base Case scenario results (see Section 3.2.5). However, the minimum flow targets as specified in the Yanco Creek System Operations for Colombo Creek @ Morundah is 100 ML/day when General Security allocations exceed 15%, which is larger than the required flow magnitudes for the VF1_b and BF1_b EWRs of 40 and 70 ML/day respectively. As such, these very minor reductions in very low flows and baseflows will not eventuate in reality. These reductions, in addition to the -4% reduction in the Large Floodplain Connection Flows OB-L1_P ('preferred seasonal timing') EWR, are likely artifacts of the limitations of the Source model, which are discussed in Table 2-8. The EWR results (Table 4-18) for Colombo Creek at Morundah to Billabong Creek upstream of Jerilderie also indicates there will be increases in the frequency (+2 to +9%) with which the specific flow or inundation regime for Small fresh (SF1_P, SF1_S and SF2) and Large fresh (LF1_P) EWRs are achieved. There is also a predicted improvement in the frequency with which the Native Fish Nesting Support NestS1_mc (+4%) and NestS1_tcmc (+7%) EWRs are achieved, which is a priority in the upper section of Colombo Creek where particularly Trout Cod are known to occur.

4.3.5.2 Mid and lower Billabong Creek

The EWR results for Billabong Creek at Jerilderie to downstream of Hartwood Weir (Table 4-18) indicate that with the exception of a minor (-1%) reduction in the frequency with which Cease-to-flow and Very low flow are achieved, there is no reduction in the frequency with which the specific flow or inundation regime for any EWR categories are achieved compared to Base Case scenario results (see Section 3.3.2.4). However, the minimum flow targets as specified in the Yanco Creek System Operations for Billabong Creek @ Jerilderie is 70 ML/day when General Security allocations are equal to or greater than 15%, which is larger than the required flow magnitudes for the CF1 and VF1_b EWRs of 0 and 50 ML/day respectively. As such, these modelled minor reductions in cease to flow and very low flows attainment will not eventuate in reality. These reductions are likely artifacts of the limitations of the Source model, which are discussed in Table 2-8.

The EWR results (Table 4-18) for Lower Billabong and Intersecting Streams downstream to Moulamein indicate a minor (-1%) reduction in the frequency with which Cease-to-flow and the specific flow or inundation regimes for small overbank floodplain connection flow (-2%) are achieved compared to Base Case scenario results (see Section 3.3.2.4). However, the minimum flow targets as specified in the Yanco Creek System Operations for Billabong Creek @ Darlot is 50 ML/day plus downstream orders, which is larger than the required flow magnitude for the CF1 EWR of 0 ML/day respectively. As such, this modelled reductions in cease to flow attainment will not eventuate in reality. These reductions are likely artifacts of the limitations of the Source model, which are discussed in Table 2-8.

Importantly, the EWR results (Table 4-9) for Lower Billabong and Intersecting Streams downstream to Moulamein indicate that there are increases in the frequency with which the specific flow or inundation regime for Large overbank floodplain connection OB-L1 (+4%), Wetland connection flow EWRs W-LF4_P ('preferred seasonal timing') and W-LF4_S ('any time that is considered satisfactory') (+1%), small freshes SF1 (+4 to +5%) and Native Fish Nesting Support NestS1 (+5 to +7%) are achieved.

Table 4-18 EWR adjusted frequency score results at key locations for PU reaches in the Yanco Creek System under the Cumulative Change scenario, with comparison to Base Case.

Note that the green, yellow and red shading represents high, medium and low degree of EWR attainment as per Table 2-2. In addition, +/- indicates an increase/decrease in EWR adjusted frequency score compared to the Base Case scenario.

Category	EWR	PU10 (Upper Yanco Creek)	PU12 (Lower Yanco Creek to Lower Billabong Creek)	PU11 (Colombo Creek at Morundah to Billabong Creek upstream of Jerilderie)	PU11 (Billabong Creek at Jerilderie to downstream of Hartwood Weir)	PU13 (Lower Billabong and Intersecting Streams)
Cease-to-flow (CtF)	CF1	100 (0)	100 (0)	100 (0)	100 (0)	99 (-1)
Very low flow (VLF)	VF1_a	100 (0)	100 (0)	100 (0)	100 (0)	100 (0)
	VF1_b	100 (0)	100 (0)	99 (-1)	99 (-1)	100 (0)
Baseflow (BF)	BF1_a	100 (+32)	42 (+10)	100 (0)	100 (0)	100 (0)
	BF1_b	100 (0)	97 (+1)	99 (-1)	99 (0)	100 (0)
Native Fish Nesting Support	NestS1_mc	52 (+5)	37 (+5)	65 (+4)		76 (+7)
	NestS1_tcmc	40 (+4)	29 (+3)	60 (+7)		65 (+8)
Small fresh (pulse) (SF)	SF1_P	79 (+7)	82 (+6)	86 (+9)		94 (+4)
	SF1_S	87 (+3)	90 (+5)	93 (+3)		96 (+4)
	SF2	100 (0)	59 (+4)	97 (+8)		100 (0)
Large fresh (pulse) (LF)	LF1_P	81 (+5)	81 (+4)	87 (+7)		85 (0)
	LF1_S	100 (+3)	100 (0)	100 (0)		100 (0)
	LF2	100 (+2)	100 (0)	100 (0)		100 (0)
Wetland connection flow (Wetland-LF)	W-LF4_P					68 (+1)
	W-LF4_S					72 (+2)
	W-LF5					98 (+2)
	W-LF6_P	100 (0)	100 (0)	100 (0)		100 (0)
	W-LF6_S	100 (0)	100 (0)	100 (0)		100 (0)
	W-LF7	89 (-1)	70 (-1)	73 (0)		87 (+1)
	W-LF8	100 (0)	100 (0)	100 (0)		100 (0)
Floodplain connection flow (OB)	OB-L1					96 (8)
	OB-L1_P	88 (0)	92 (0)	88 (-4)		
	OB-L1_S	100 (0)	100 (0)	100 (0)		
	OB-S1					70 (-2)
	OB-S2		90 (0)			98 (0)
	OB-S2_P	70 (0)		86 (0)		
	OB-S2_S	88 (0)		100 (0)		

4.3.6 Effective General Security Allocations

Effective General Security allocations have been modelled at on 3 key dates, opening allocation (1-July), summer planning decision dates (15-September and 1-October), and end the Year (30-June) (Table 4-19).

The Cumulative Change scenario model indicates no reductions to average Murrumbidgee General Security water availability (General Security Allocations plus carryover) across the water year. It can be seen from Table 4-19 that effective General Security Allocations are predicted to increase marginally under the Cumulative Change Case, compared to Base Case, for opening allocation and summer planning decision dates, but remain the same for end of the year. It can also be seen that minor increases in effective General Security Allocations for summer planning decision dates and end of the year are predicted when compared to Change Case scenario results. Therefore, no reduction in water availability to meet Water Access Licenses is predicted under the Cumulative Change Case scenario.

Table 4-19 Modelled General Security Effective Allocations (AWDs + Carryover)

Key date	Description	Base Case	Change Case	Cumulative Change Case
1-Jun	Opening allocation	48.2	48.4	48.4
15-Sep	Summer planning decision dates	57.5	57.7	57.8
1-Oct		58.8	58.9	59.0
30-Jun	End the Year	84.9	84.8	84.9

4.3.7 River Flow Objectives

An assessment of potential River Flow Objectives impacts for the Cumulative Change Case scenario, to the extent of project influence up and down stream, has been undertaken in Table 4-20.

Table 4-20 Potential impacts to River Flow Objectives under the Cumulative Impacts scenario

NSW river flow objective	Description	River Flow Objectives impacts under the Cumulative Impacts scenario
Protect natural low flows	Protect natural low flows	The flow variability and frequency and size analysis results for the Cumulative Change Case scenario (see Section 4.3) indicate no adverse impacts to low flows (i.e. unnatural prolonged drying) within the proposal study area and the broader Yanco Creek System, when taking into account operation of the proposal and the Forest Creek Return Flows Project ¹ . Very minor reductions are modelled in some instances, but these are likely modelling artifacts due to the limitations of the Source model.
Protect important rises in water levels	Protect or restore a proportion of moderate flows ('freshes') and high flows	The flow frequency and size analysis for the Cumulative Change Case scenario (see Section 4.3) indicate no material change in the proportion of moderate flows ('freshes') and high flows will occur within the study area when taking into account operation of the proposal and the Forest Creek Return Flows Project ¹ .
Maintain wetland and floodplain inundation	Maintain or restore the natural inundation patterns and distribution of floodwaters supporting natural wetland and floodplain ecosystems	The analysis of EWR (Environmental Water Requirements) attainments for the Cumulative Change Case scenario (see Section 4.3) indicate, with some exceptions, mostly no change or some minor improvements in the frequency in the expected frequency of over bank wetland connection or floodplain connection flows within the study area (i.e. mid and lower Billabong Creek) when taking into account operation of the proposal and the Forest Creek Return Flows Project ¹ . Very minor reductions in the frequency of small overbank floodplain connection flows (OB-L1_P and OB-S1) are modelled for the Colombo and mid Billabong Creeks and lower Billabong Creek reaches respectively, but this is likely a modelling artifact due to the limitations of the Source model.
Mimic natural drying in temporary waterways	Mimic the natural frequency, duration and seasonal nature of drying periods in naturally temporary waterways	The daily flow sizes results (see Section 4.3) indicate no major change in the natural frequency, duration and seasonal nature of drying periods for all key locations except for Forest Creek at Warriston Weir. This is a direct result of the new operational principle to divert unplanned flows down Piccaninny Creek to assist in preventing unplanned flows in Forest Creek downstream of Warriston Weir during normal regulated periods.

NSW river flow objective	Description	River Flow Objectives impacts under the Cumulative Impacts scenario
Maintain natural flow variability	Maintain or mimic natural flow variability in all streams	The flow variability analysis results (see Section 4.3) indicate no material change in the overall annual flow variability within the Yanco Creek System when taking into account operation of the proposal and the Forest Creek Return Flows Project ¹ . There is also no major impact to mean daily flow volumes within lower Billabong Creek, including the proposal study area under the Cumulative Change Case scenario.
Maintain natural rates of change in water levels	Maintain rates of rise and fall of river heights within natural bounds	No change to the expected improvements in the rates of change in water levels with operation of the proposal is anticipated for the Cumulative Change Case scenario when taking into account and the Forest Creek. The Yanco Creek System operations plan includes normal regulated flow operational limits for 'Pool Maximum Daily Rate of Rise' of 0.30m for Hartwood and Wanganella regulators. The Yanco Creek System operations plan also includes 'Native fish environmental flow provisions' of a maximum rate of fall of 9% (by volume) between the 14th September and 16th November inclusive for Yanco Creek at Yanco Offtake and Billabong Creek at Darlot, to better align with the EWR for fish nesting in the long-term watering plan.
Manage groundwater for ecosystems	Maintain groundwater within natural levels and variability, critical to surface flows and ecosystems	No potential cumulative impacts relevant to groundwater were identified.
Minimise effect of weirs and other structures	Minimise the impact of instream structures	For the Cumulative Change Case scenario when taking into account operation of the proposal and the Forest Creek Return Flows Project¹, no substantial adverse impact on the occurrence of high-quality flowing habitat or water quality are expected within the proposal study area. The design of the Hartwood and Wanganella regulators includes fishways that will allow an increase in river extent with unimpeded fish passage.

¹ Impacts directly associated with the Forest Creek Return Flows Project are being assessed via a different environmental approvals process.

5. Water surface levels and weir pool extents

5.1 Water surface levels

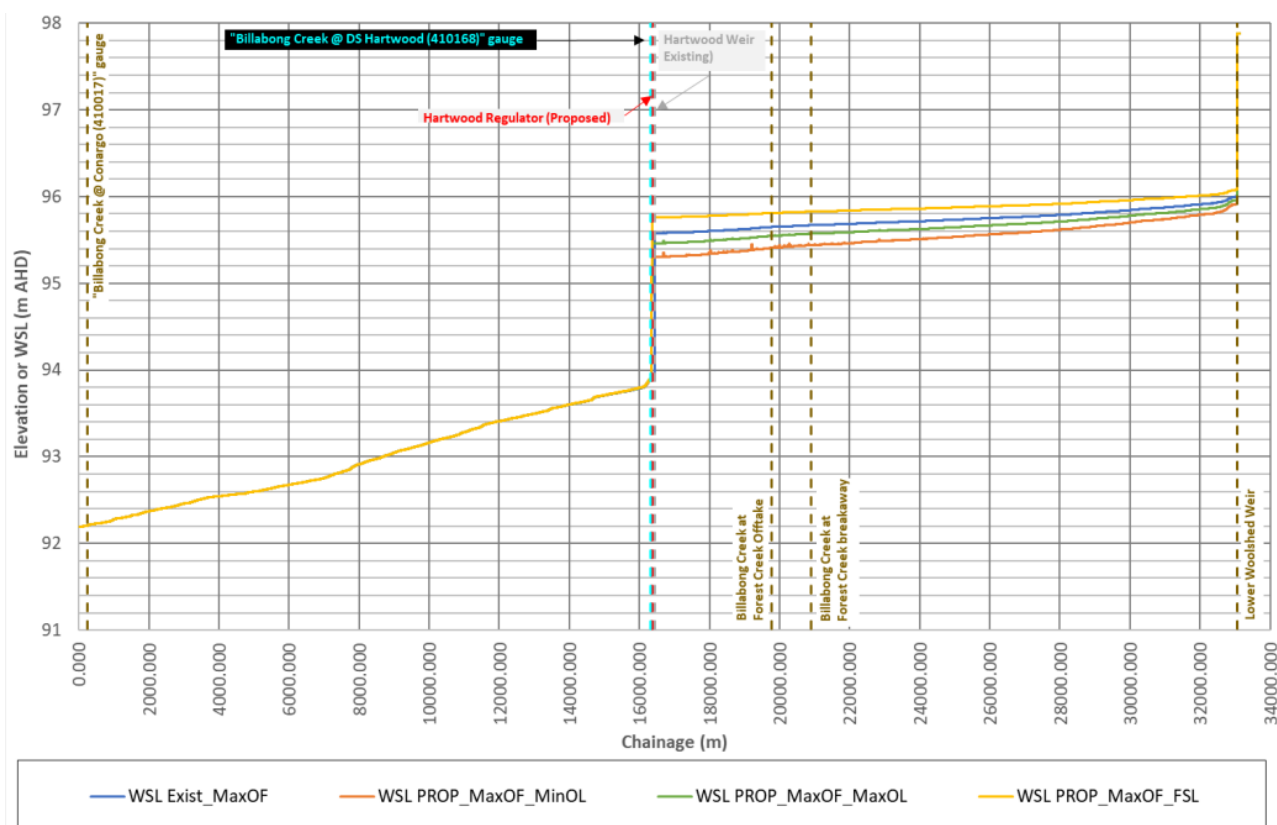
5.1.1 Hartwood Regulator

Modelled water surface levels (i.e. river running heights) within the weir pool extent and downstream of the proposed Hartwood regulator under existing condition and for regulator pool target levels proposed in the Yanco Creek System Operation Plan (NSW DCCEEW 2023b) are shown in Figure 5-1 for the Maximum Operating Flow (MaxOF) scenario and Figure 5-2 for the Minimum Operational Flow (MinOF) scenario.

Under the modelled Maximum Operating Flow scenario (500 ML/day passing flow), it can be seen from Figure 5-1 that modelled existing water surface levels within the weir pool for the current Hartwood weir range from approximately 95.58 mAHD at the existing Hartwood Weir to 96 mAHD at the modelled upstream extent of the weir pool. For the modelled Minimum Operating Flow (25 ML/day passing flow), Figure 5-2 indicates the modelled existing water surface levels within the weir pool for the current Hartwood weir is approximately 95.25 mAHD across the weir pool extent.

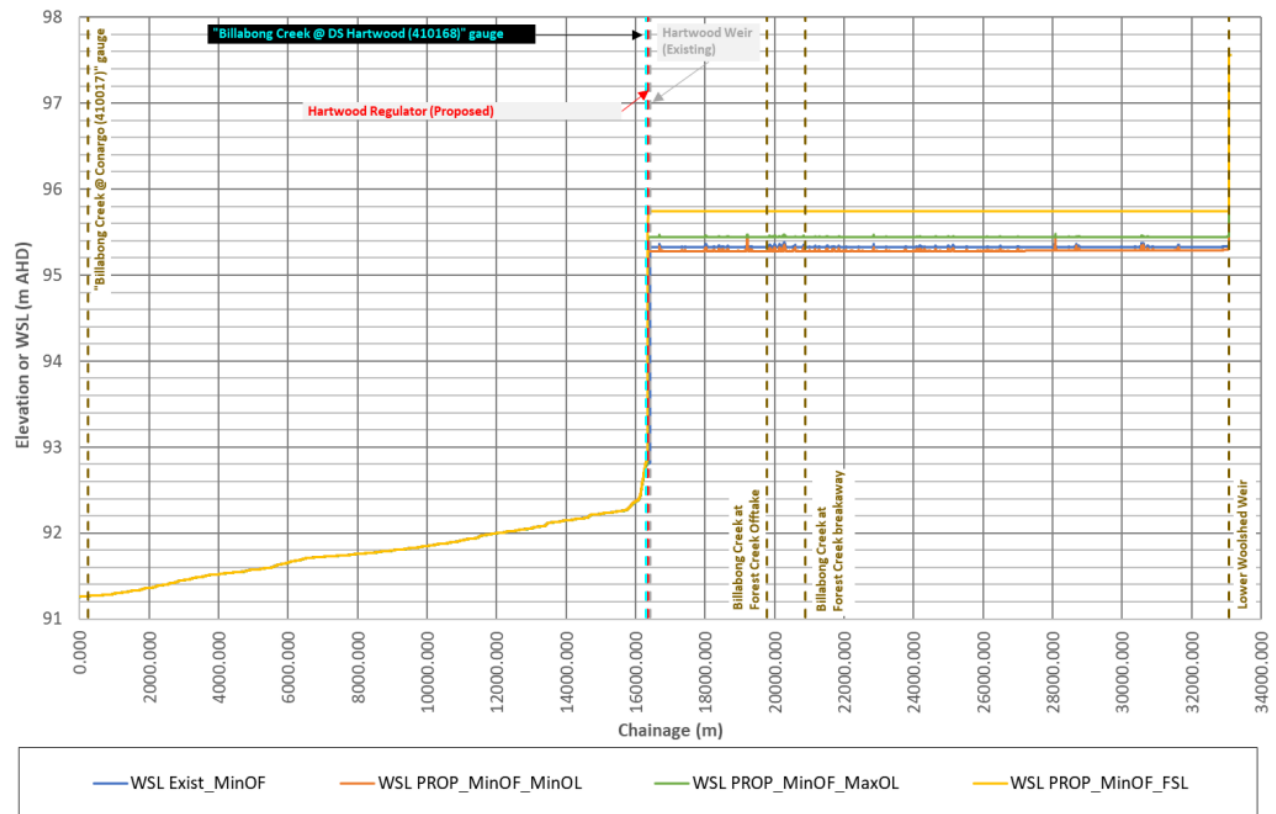
Figure 5-1 and Figure 5-2 show the water surface levels within the proposed Hartwood Regulator weir pool will vary as expected with the changes in the regulator pool target levels. With operation of the proposed Hartwood regulator at the Minimum Operating Level (MinOL) there is a predicted decrease in water surface levels of up to approximately 40 mm for the Minimum Operating Flow and 300 mm for the Maximum Operating Flow scenarios. For the Maximum Operating Level (MaxOL), there is a predicted increase in water surface levels of approximately 100 mm for the Minimum Operating Flow scenario and decrease of up to approximately 150 mm for the Maximum Operating Flow scenario. With operation of the proposed Hartwood regulator at the full supply level (FSL) there is a predicted increase in water surface levels of up to approximately 200 mm for the Maximum Operating Flow and approximately 400 mm for the Minimum Operating Flow scenarios.

Figure 5-1 and Figure 5-2 indicate there is no material change in water surface downstream of the proposed Hartwood Regulator for either the Maximum Operating Flow or Minimum Operational Flow scenarios. In particular, the township of Conargo does not experience any change outside of Billabong Creek and only changes of less than ± 10 mm within the channel - refer to Hydraulic Modelling Technical Report for Hartwood Weir (3Rivers 2024a).



Source: Yanco Creek Modernisation: Hydraulic Modelling Technical Report – Hartwood Weir to Piccaninny Weir Study Area

Figure 5-1 Modelled water levels along Hartwood weir pool extent at Maximum Operating Flow (500 ML/day passing flow).



Source: Yanco Creek Modernisation: Hydraulic Modelling Technical Report – Hartwood Weir to Piccaninny Weir Study Area

Figure 5-2 Modelled water levels along Hartwood weir pool extent at Minimum Operational Flow (25 ML/day passing flow).

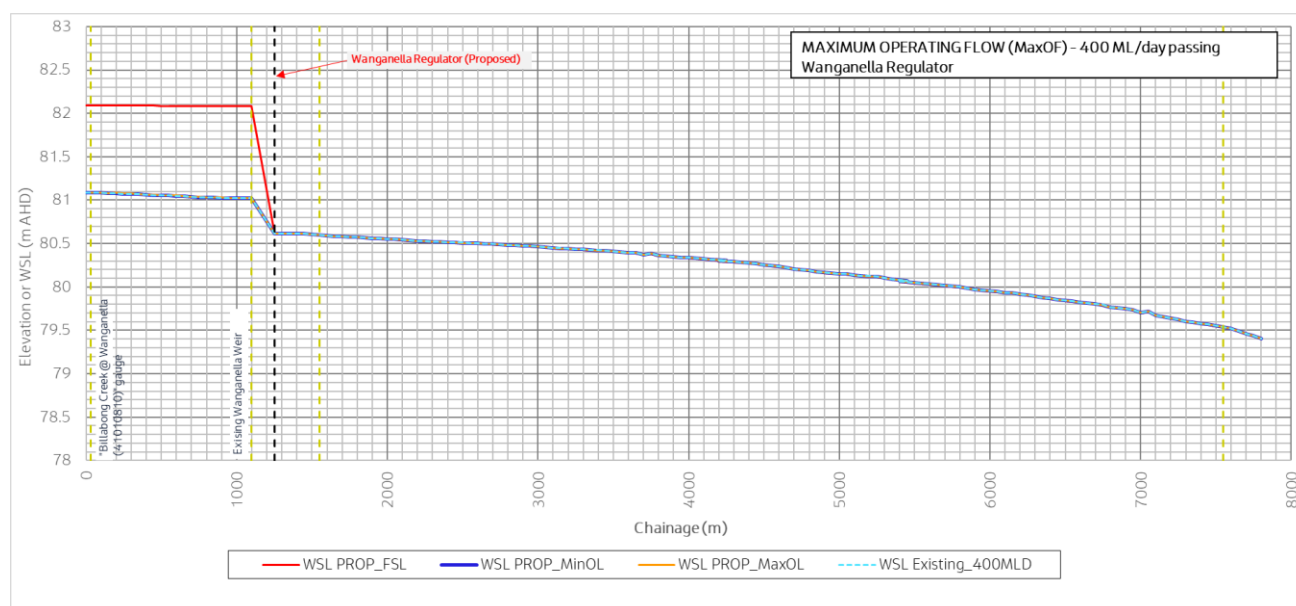
5.1.2 Wanganella Regulator

Modelled water surface levels within the weir pool extent and downstream of the proposed Wanganella Regulator under existing condition and for regulator pool target levels proposed in the Yanco Creek System Operation Plan (NSW DCCEEW 2023b) are shown in Figure 5-3 for the Maximum Operating Flow (MaxOF) scenario and Figure 5-4 for the Minimum Operational Flow (MinOF) scenario.

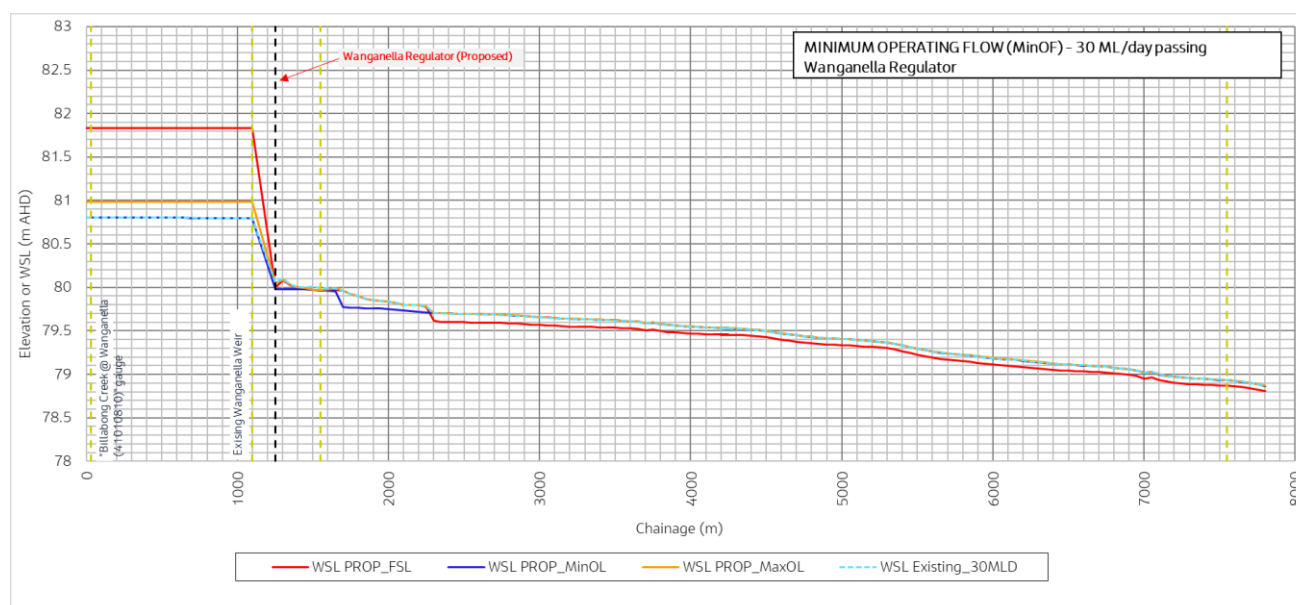
Under the modelled Maximum Operating Flow (400 ML/day passing flow), it can be seen from Figure 5-3 that modelled existing water surface levels within the current Wanganella Weir pool is approximately 82.1 mAHD across the weir pool extent. For the modelled Minimum Operational Flow (30 ML/day passing flow), Figure 5-4 indicates the modelled existing water surface levels within the current Wanganella Weir pool is approximately 81.82 mAHD across the weir pool extent. Figure 5-3 that modelled existing water surface levels within the current Wanganella Weir pool range from approximately 81 mAHD at the existing Wanganella Weir to 81.2 mAHD at the modelled upstream extent of the weir pool. For the modelled Minimum Operational Flow, Figure 5-4 indicates the modelled existing water surface levels within the current Wanganella Weir pool is approximately 80.8 mAHD across the weir pool extent.

Figure 5-3 and Figure 5-4 show the water surface levels within the proposed Wanganella Regulator weir pool will vary as expected with the changes in the regulator pool target levels. With operation of the proposed Wanganella Regulator at the Minimum Operating Level (MinOL) there is no predicted change of water surface levels upstream of the regulator under all flow scenarios (less than ± 10 mm). For the Maximum Operating Level (NormOL), there is a predicted increase in water surface levels of up to 190 mm upstream of the Wanganella Regulator under the Minimum Operational Flow scenario, while no material change of water surface levels (less than ± 10 mm) was identified under the Maximum Operating Flow scenario. With operation of the proposed Hartwood regulator at the full supply level (MaxOL) there is a predicted increase in water surface level of 1,280 mm upstream of the Wanganella Regulator under the Minimum Operational Flow scenario (Figure 5-3) and an increase in water surface level of 1,050 mm under Maximum Operational Flow scenario (Figure 5-4), respectively.

Figure 5-3 indicate there is no material change in water surface levels downstream of the proposed Wanganella Regulator for the Maximum Operating Flow and proposed operating level scenarios. For Minimum Operational Flow scenario, Figure 5-4 shows no change in downstream water surface levels at the Maximum Operating Level (NormOL). At the Minimum Operating Level (MinOL) there is a minor reduction in predicted water surface levels (approximately 5-20 mm) to approximately 600m downstream, from which in become consistent with existing conditions. For full supply level (MaxOL), a minor (approximately 10mm) reduction in downstream surface water levels is predicted from approximately 700m downstream of the proposed Wanganella Regulator.



Source: Yanco Creek Modernisation: Hydraulic Modelling Technical Report – Piccaninny Weir to Wanganella Weir Study Area
Figure 5-3 Modelled water levels along Wanganella weir pool extent at Maximum Operating Flow (400 ML/day passing flow).



Source: Yanco Creek Modernisation: Hydraulic Modelling Technical Report – Piccaninny Weir to Wanganella Weir Study Area
Figure 5-4 Modelled water levels along Wanganella weir pool extent at Minimum Operational Flow (30 ML/day passing flow).

5.1.3 Time series analysis

Figure 5-5 and Figure 5-6 show the long-term time series (for modelled data from 2000 to 2022) of predicted mean monthly water surface levels within Billabong Creek at the Hartwood Regulator and Wanganella Regulator respectively with operation of the regulator and for existing conditions. The calculated water levels under operation of the proposal are consistent with the specified operational weir pool targets in Table 1-1.

Figure 5-5 and Figure 5-6 show the predicted surface water levels at the proposed Hartwood and Wanganella regulators will cycle over time in line with the irrigation and non-irrigation season regulator pool target levels detailed in Table 1-1.

When comparing water surface levels at Hartwood Regulator under proposed (i.e. with operation of the regulator) versus existing conditions, the water surface level is on average 6 mm higher during the irrigation season (Nov-April) and outside of the irrigation season (May-October). However, these averages are skewed in the irrigation season by decreases in water surface level under high water level conditions, and in the non-irrigation season by increases in water surface level under high water level conditions. When comparing the median (50thile) water surface level at Hartwood Regulator under proposed versus existing conditions, the water surface level is 22 mm higher in the irrigation season and 3 mm lower in the non-irrigation season. These results align with the proposed higher weir pool target level during the irrigation season compared to the non-irrigation season.

When comparing water surface levels at Wanganella under proposed versus existing conditions, during the irrigation season (Nov-April) the water level is on average 80 mm higher, and outside of the irrigation season (May-October) the water level is on average 6 mm higher, with the water level being an average of 26 mm lower over May-July. When comparing the median (50thile) water surface level at Wanganella Regulator under proposed versus existing conditions, the water surface level is 65 mm higher in the irrigation season and 43 mm lower in the non-irrigation season. These results align with the proposed higher weir pool target level during the irrigation season compared to the non-irrigation season.

Also indicated by Figure 5-5 and Figure 5-6, is that for water surface levels that exceed the regulating capacity (i.e. full supply level) of the regulators for the proposal, there is little difference in water surface levels between existing conditions and with operation of the Hartwood and Wanganella regulators.

It should be noted that the accuracy of this analysis is limited due to limitations in the approach adopted to derive water levels over the long-term time series. This has been discussed in Section 2.2.7.

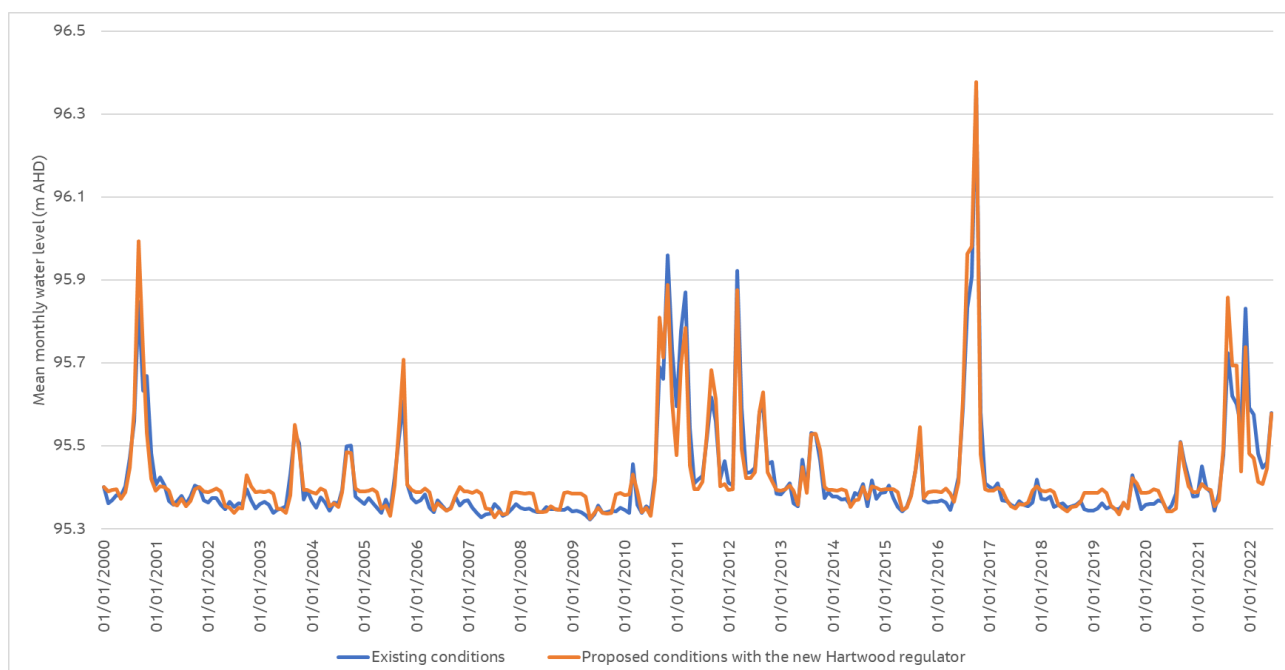


Figure 5-5 Calculated water levels under existing versus proposed conditions at Hartwood Regulator over a 22-year time period.

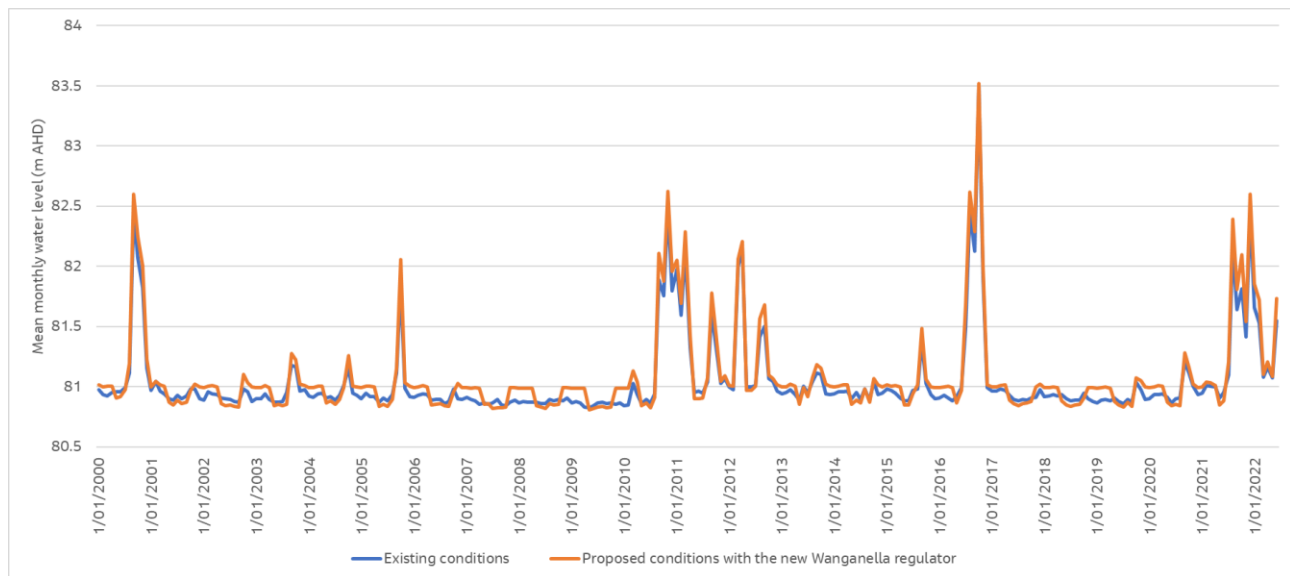


Figure 5-6 Calculated water levels under existing versus proposed conditions at Wanganella Regulator over a 22-year time period.

Duration results for water surface level exceedance of the existing weirs' full supply levels are presented in Table 5-1. For Hartwood Regulator, monthly average water surface levels are modelled to exceed the median (50th%ile) water surface level of the existing Hartwood weir (95.44 mAHD) in 58 months during the 22-year times series (270 months total) compared to 48 months for the existing Hartwood weir. The maximum number of consecutive months where water surface levels exceed the median (50th%ile) water surface level of the existing weir is predicted to be 12 months for Hartwood Regulator, compared to 8 consecutive months for the existing Hartwood weir. There is little or no change in the mean and minimum number of consecutive months where water surface levels exceed the median (50th%ile) water surface level of the existing weir between the proposed Hartwood Regulator and the existing weir.

For Wanganella Regulator, Table 5-1 shows monthly average water surface levels are modelled to exceed the median (50th%ile) water surface level of the existing Wanganella weir (80.99 mAHD) in 161 months compared to 71 months for the existing Wanganella weir. There is no change in the maximum number of consecutive months where water surface levels exceed the median (50th%ile) water surface level of the existing weir (12 months) for Wanganella Regulator compared to the existing Wanganella weir. The mean number of consecutive months where water surface levels exceed the median (50th%ile) water surface level of the existing weir is predicted to be 6 months for the Wanganella Regulator, compared to 4 consecutive months for the existing Wanganella weir. There is no change in the minimum number of consecutive months where water surface levels exceed the median (50th%ile) water surface level of the existing weir between the proposed Hartwood Regulator and the existing weir.

Table 5-1 Duration results for exceedance of existing median (50th%ile) water surface level

	Hartwood		Wanganella	
	Existing Hartwood weir	Proposed Hartwood regulator	Existing Wanganella weir	Proposed Wanganella regulator
Total number of months	48	58	71	161
Maximum consecutive months	12	8	12	12
Mean consecutive months	3.4	3	4	6
Minimum consecutive months	1	1	1	1
% of months	21%	18%	26%	60%

Figure 5-7 and Figure 5-8 show the modelled surface water level frequency curves under existing versus proposed conditions with operation of the proposed Hartwood and Wanganella regulators respectively, consistent with the specified operational weir pool targets in Table 1-1.

Figure 5-7 indicates that with operation of the proposed Hartwood Regulator, very minor increases in monthly average surface water levels (maximum of approximately +0.15 mAHD) are predicted over approximately 73% of the modelled time series. It can be seen from Figure 5-7 that under existing conditions modelled average monthly flows exceed the median (50th%ile) water surface level (95.44 mAHD) of the existing weir across 21% of the flow series, but with operation of the proposed Hartwood Regulator to achieve the target weir pool levels (see Table 1-1), monthly flows will exceed 95.44 mAHD (the median (50th%ile) water surface level of the existing weir) across 17.5% of the time series. These results indicate that operation of the Hartwood Regulator to achieve the proposed weir pool target levels will result in surface water levels within the weir pool of the regulator being higher than the median (50th%ile) water surface level of the existing weir (95.44 mAHD) less frequently (-3.5%) and will typically be marginally lower than occurs under existing conditions.

For the proposed Wanganella Regulator, Figure 5-8 indicates very minor increases in monthly average surface water levels (maximum of approximately +0.28 mAHD) are predicted over approximately 71% of the modelled time series. It can be seen from Figure 5-8 that under existing conditions modelled average monthly flows exceed the median (50th%ile) water surface level (80.99 mAHD) of the existing weir across 26% of the flow series, but with operation of the proposed Wanganella Regulator to achieve the target weir pool levels (see Table 1-1), monthly flows will exceed 80.99 mAHD (the median (50th%ile) water surface level of the existing weir) across 59.5% of the time series. These results indicate that operation of the Wanganella Regulator to achieve the proposed weir pool target levels will result in surface water levels within the weir pool of the regulator being higher than the median (50th%ile) water surface level of the existing weir (80.99 mAHD) approximately +33.5% more frequently and will typically be higher than occurs under existing conditions.

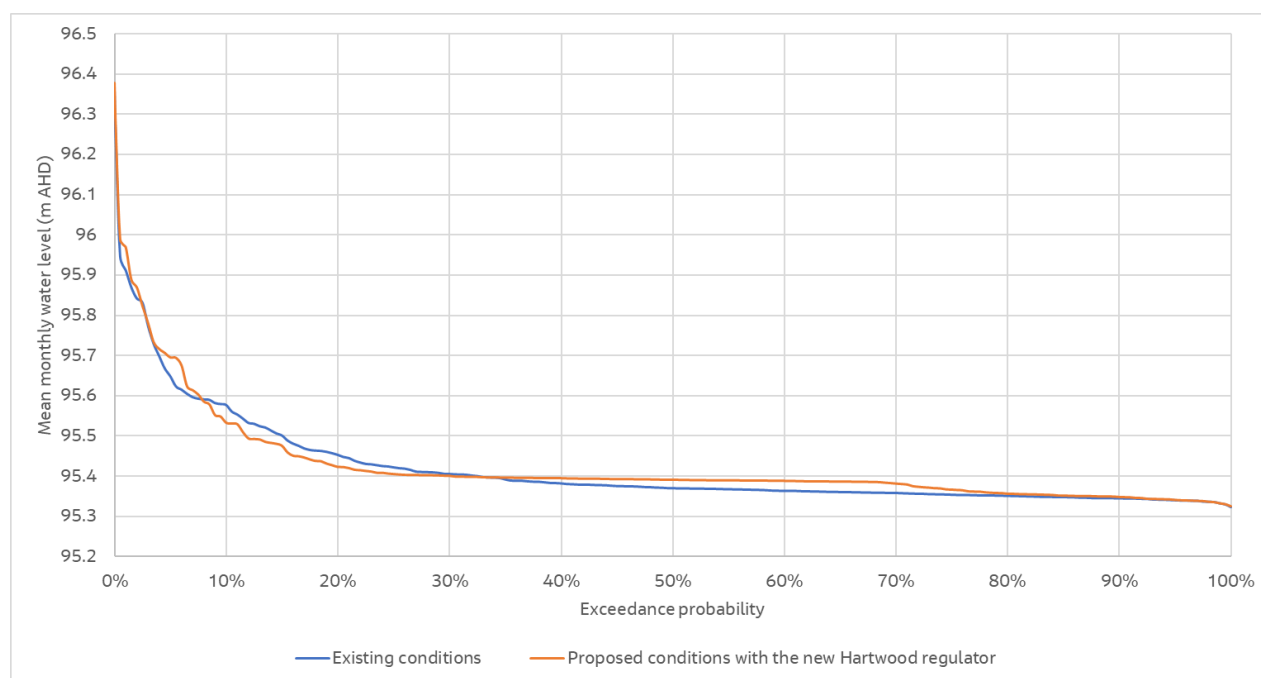


Figure 5-7 Water levels frequency curves under existing versus proposed conditions at Hartwood Regulator over a 22-year time period.

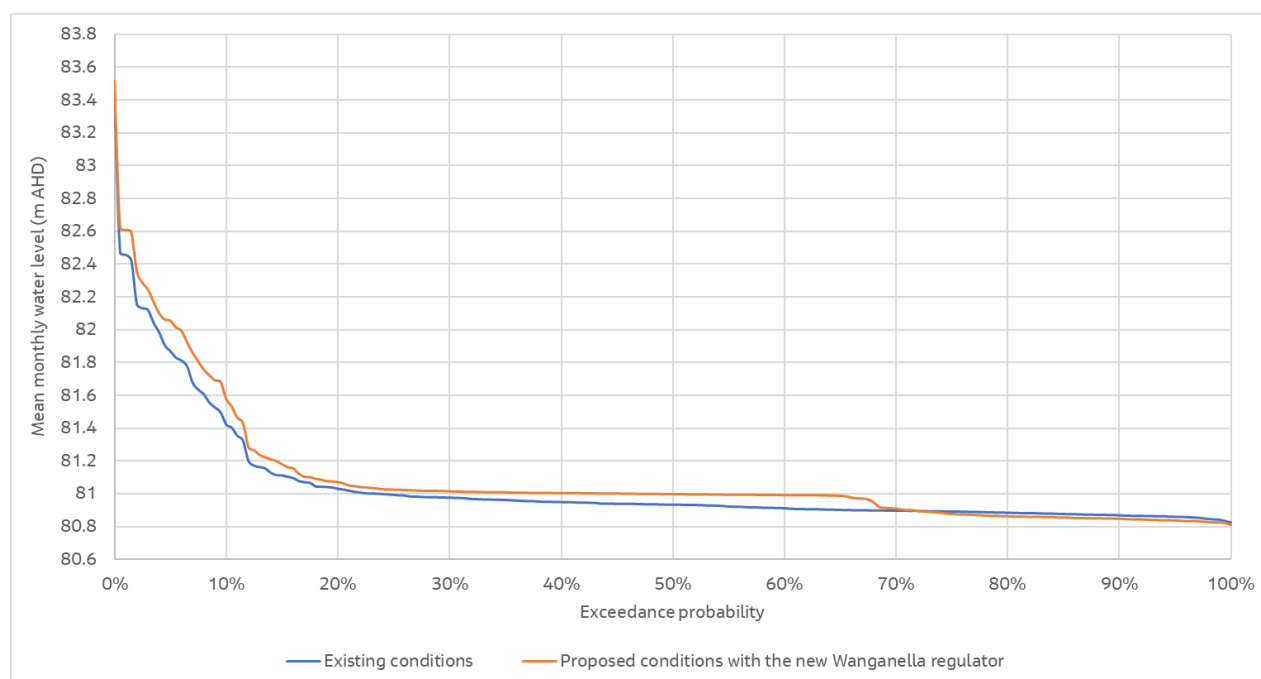
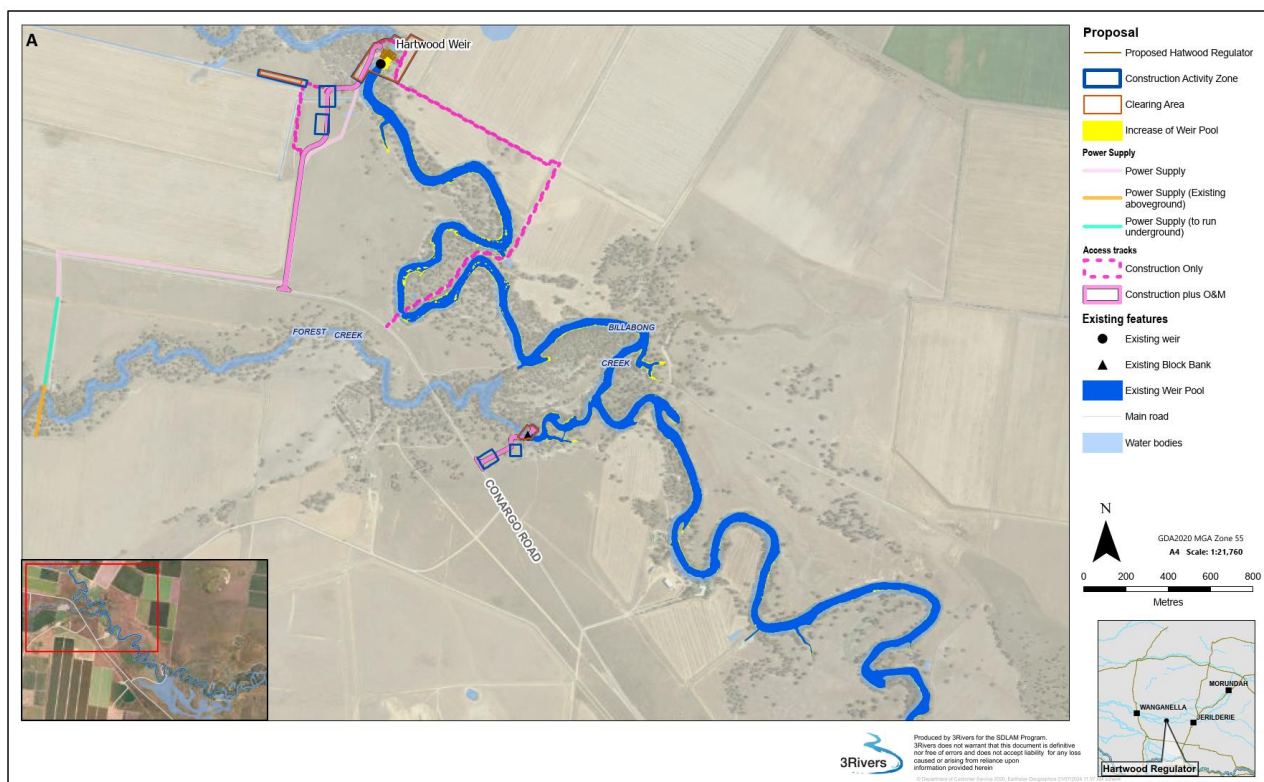


Figure 5-8 Water levels frequency curves under existing versus proposed conditions at Wanganella Regulator over a 22-year time period.

5.1.4 Weir pool extents

5.1.4.1 Hartwood Regulator

Figure 5-9 shows the modelled Hartwood weir pool extent when the weir pool is set to full supply level (FSL) under the Maximum Operating Flow scenario (500 ML/day) and under existing conditions. It is evident from Figure 5-9 that there is predicted to be an increase in lateral inundation within the creek channel and longitudinal inundation of the Hartwood weir pool extent. The weir pool is predicted to increase in longitudinal extent by 73 m, which includes an increase in downstream weir pool extent due to the proposed regulator being located approximately 70 m downstream of the existing structure. Compared to existing conditions, in total it is predicted the weir pool area for the Hartwood Regulator will increase by approximately 51,590 m² or 7.7% when the weir pool is set to full supply level (FSL) under the Maximum Operating Flow scenario (500 ML/day). However, it is not intended to operate the weir pool at full supply level for a substantial period of time, as this will only occur to capture a portion of unregulated flow events which are uncommon.



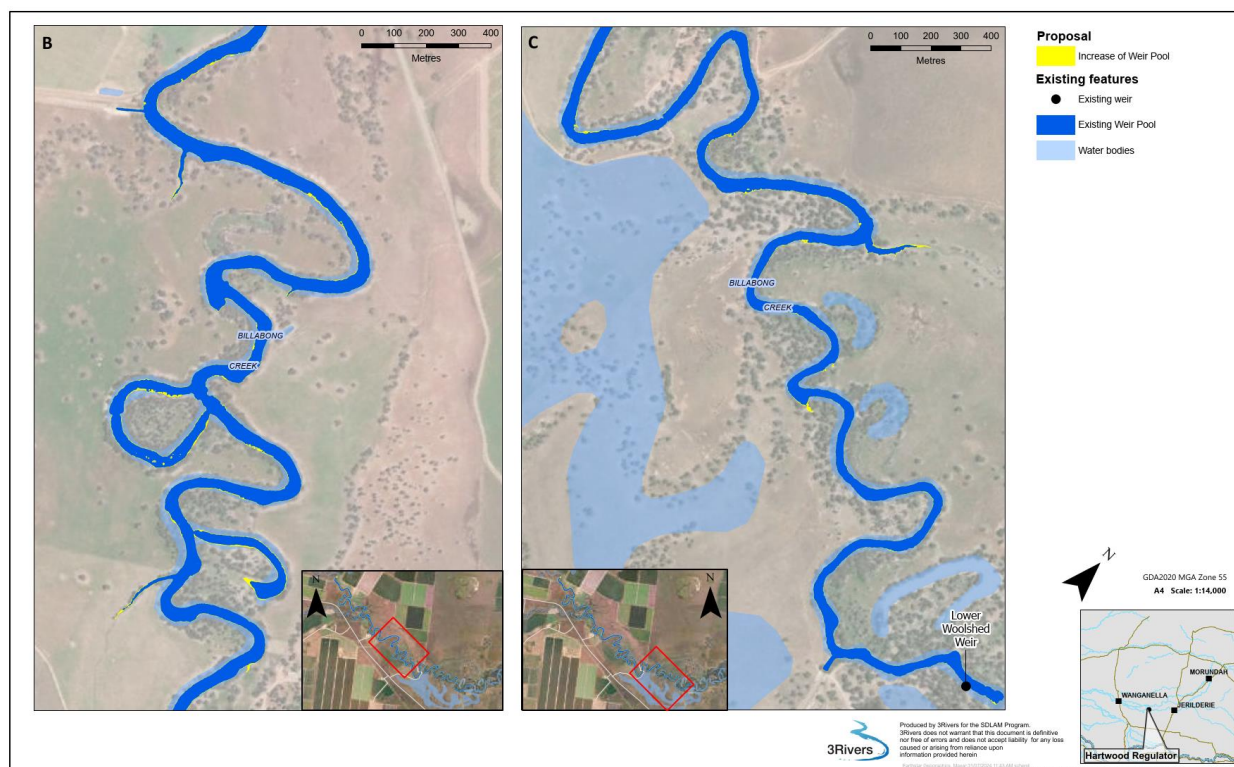


Figure 5-9 Modelled Hartwood weir pool extents at Maximum Operating Flow (500 ML/day passing flow) under existing conditions (blue) versus proposed conditions under full supply level (yellow).

5.1.4.2 Wanganella Regulator

Figure 5-10 shows the modelled Wanganella weir pool extent when the weir pool is set to full supply level (FSL) under the Maximum Operating Flow scenario (400 ML/day) and under existing conditions. It is evident from Figure 5-10 that there is predicted to be an increase in lateral inundation within the creek channel, but no change in upstream longitudinal inundation. There is a minor predicted increase in downstream weir pool extent due to the proposed regulator being located approximately 55 m downstream of the existing structure. Compared to existing conditions, in total it is predicted the weir pool area for the Wanganella Regulator will increase by approximately 110,350 m² or 30% when the weir pool is set to full supply level (FSL) under the Maximum Operating Flow scenario (400 ML/day). However, it is not intended to operate the weir pool at full supply level for a substantial period of time, as this will only occur to capture a portion of unregulated flow events which are uncommon.

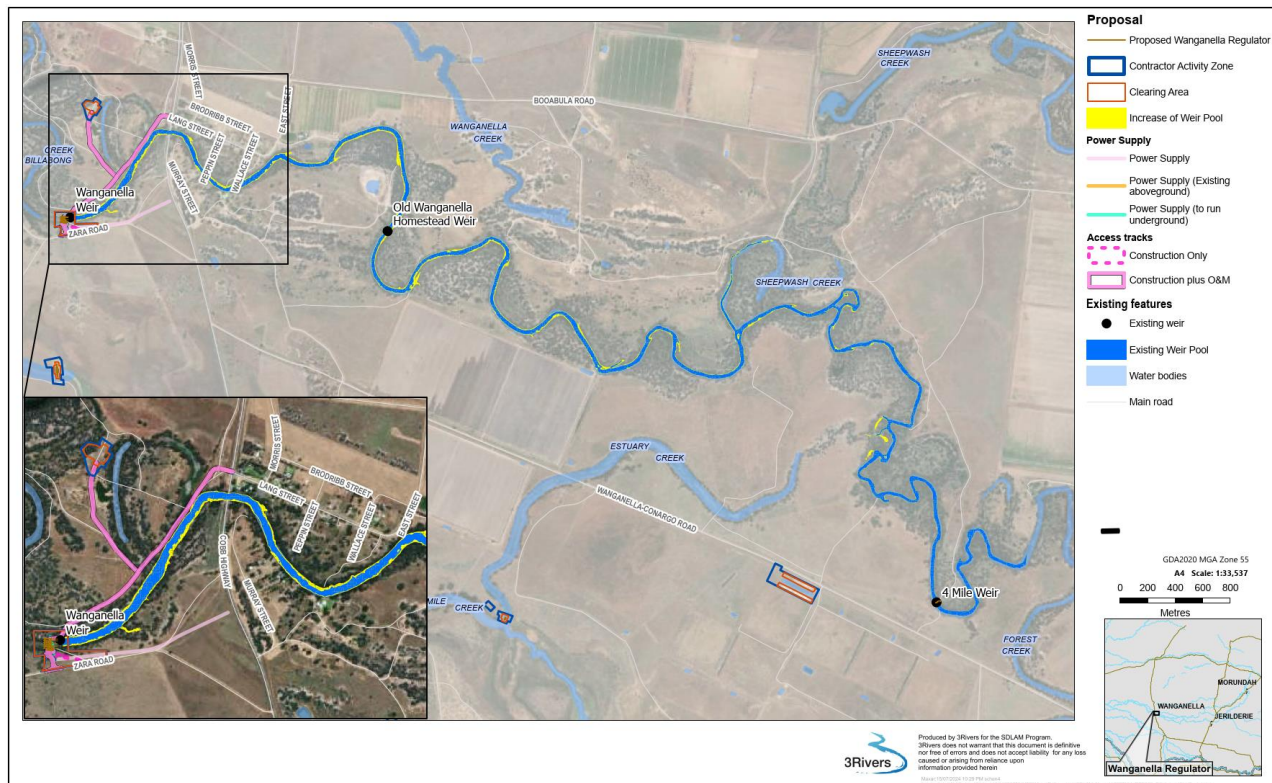


Figure 5-10 Modelled Wanganella weir pool extents at Maximum Operating Flow (400 ML/day passing flow) under existing conditions (blue) versus proposed conditions under maximum operating level (yellow).

6. Mitigation and management of impacts

Given the hydrological impacts identified in Section 4 are generally minor and consistent with those required and expected with the operation of the regulators for the proposal and broader system changes, there are no additional mitigation and management measures recommended beyond the operating principles and objectives specified in the Yanco Creek System Operations Plan (NSW DCCEEW 2023b).

The Yanco Creek System Operations Plan outlines the proposed general operating principles, targets and limits for the Hartwood and Wanganella regulators. The Yanco Creek System Operations Plan also outlines river operations principles that include, among others, adaptive management - adopting the lessons learnt from trialing new approaches and historic operational events that also includes adapting to seasonal conditions and variability. In addition, the objectives for the operating plan include, among others, to balance social, environmental, economic and cultural outcomes and ensure flexibility to assist river operators to respond to a broad range of circumstances and operational objectives that vary with time and water resource availability.

7. Key Findings and Conclusions

7.1 Summary of current hydrology

7.1.1 Overview

Prior to European settlement, Yanco Creek was a high-level gaining creek. Under current conditions, flows within the Yanco Creek System are highly variable at all locations and there is an absence of near no-flow years, to be a more consistently flowing system compared to pre-development. The hydrology of the Yanco Creek System, including the proposal study area, is highly altered from pre-development, with a loss or considerable alteration of key hydrological flow components and processes. As such the Yanco Creek System is characterised as being highly flow modified, which is consistent with previous historical analysis of the hydrology.

Flow within the Yanco system is regulated at key locations to manage water delivery. Weirs regulate the share of water between Colombo Creek and Yanco Creek (Tarabah Weir) and between Forest Creek and Billabong Creek (Hartwood Weir and Forest Creek Regulator). In addition, there are over 30 private licenced fixed crest weirs that have been constructed to provide a local store of water. As a result of regulation, flows through the Yanco Creek System are maintained at artificially high levels during high demand periods and as such the total annual flow volume is much higher than pre-development.

The current hydrology of Mid Billabong Creek from Jerilderie to downstream of Hartwood Weir (to where Lower Yanco Creek joins Billabong Creek) and Lower Billabong Creek and intersecting streams from downstream of Hartwood Weir to Moulamein (inclusive of Wanganella and Darlot) varies widely depending on rainfall, inflows, evaporation and demands including irrigation, industry, communities and the environment.

7.1.2 Modelled Base Case scenario conditions

The current hydrology was modelled in the Base Case scenario to define the baseline hydrological regime, against which the hydrology under the Change Case and Cumulative Change Case scenarios would be compared in order to assess the potential impacts of the proposal.

Under modelled Base Case scenario, the total annual flows (GL/year) throughout the Yanco Creek System can be seen to be highly variable, primarily associated with unregulated flows through Yanco Offtake and the unregulated upper Billabong Creek catchment passing through the system.

The modelled mean annual water balance results show that under the Base Case scenario flows within the Yanco Creek System are distributed between connected waterways, with some gains and losses in flow between these waterways attributed to consumptive extractions, irrigation escape inflows and evaporation losses. Mean monthly flows display a typical temperate seasonal pattern, with generally higher flows during winter-spring and lower flows during summer-autumn periods, which is generally consistent with pre-developed conditions. High variability in averaged daily flow volumes is particularly evident from December to April which is likely in response to modelled irrigation, consumptive and environmental demands during periods of lower flow.

The flow size analysis indicates overbank flows (small and large) occur infrequently under the Base Case scenario and that cease-to-flow and very low flows (Yanco and Colombo Creeks) no longer occur. The relative proportion of large and small freshes and baseflow is not considered to be substantially dissimilar between any of the reaches within the system. Overall, flows downstream of Hartwood Weir are lower than at other locations within mid and lower Billabong Creek, as a result of diversion of flows to Forest Creek through the Forest Creek Offtake. Correspondingly, baseflow occurs across a greater proportion (majority of flows) of modelled flows

downstream of Hartwood Weir. In contrast, small freshes occur across a greater proportion of the flow regime at Wanganella and Darlot due to additional flow contribution from Lower Yanco Creek which occurs upstream of Wanganella.

7.2 Key findings for construction of the proposal

During construction of the proposed new Hartwood and Wanganella regulators, the existing weirs will remain in place for the majority of the construction timeframe, only being demolished once the new regulator is fully installed and will therefore continue to have a similar influence on hydrology during the construction period compared to current conditions. In addition, partial cofferdamming of Billabong Creek within the construction timeframes for each respective regulator construction site will allow for passing flows to meet irrigation and consumptive demands and environmental water provisions.

Therefore, it is considered unlikely that construction of the proposal would have a material adverse effect on the hydrology of Billabong Creek, either upstream or downstream. If there were to be any potential changes in the hydrology of Billabong Creek, either upstream or downstream, it is considered they would be short-term (i.e. within the construction timeframes of the proposal) and would not adversely affect irrigation and consumptive demands and environmental water provisions.

Given the above findings, it is also considered unlikely that construction of the proposal would adversely impact the relevant River Flow Objectives applicable to the proposal study area (mid and lower Billabong Creek) during the proposal construction period.

7.3 Key findings for operation of the proposal (Change Case scenario)

7.3.1 Annual water balance

All changes in mean annual flows when comparing the Change and Base Case scenarios represent a low degree of hydrological change (-11.1% to +2.1%) from the Base Case scenario for key parameters and key locations within the Yanco Creek System assessed. The low degree of changes in mean annual flows within the Yanco Creek System are considered the product of the suite of differences between the Change Case and Base Case scenario, including:

- Environmental baseflow, native fish environmental flow and additional environmental provisions
- The ability of the new regulators to regulate flows within Billabong Creek itself to meet environmental and water supply demands
- New normal regulated flow operational limits on the use of irrigation escapes

However, due to the modelling approach taken, it is difficult to determine how much of these change can be attributed directly to the operation of the proposed regulators within the context of additional broader system changes. The specifics of these three categories of changes are detailed in Section 2.2.4.2.

7.3.2 Seasonality

All changes in mean monthly flows when comparing the Change and Base Case scenarios represent a low degree of hydrological change (-6.8% to +7.1% for Yanco and Colombo Creeks and -17.6% to +5.3% for mid and lower Billabong Creeks) from the Base Case scenario, and the typical temperate seasonal pattern of higher flows during winter-spring and lower flows during summer-autumn periods which was observed under the Base Case scenario has been retained in the Change Case scenario. The low degree of changes in mean monthly flows within the Yanco Creek System are considered the product of the suite of differences between the Change Case and Base Case scenario which are mentioned in the section above.

7.3.3 Flow Variability

The average change in annual flow volumes over the 127-year period when comparing the Change and Base Case scenarios represent a low degree of hydrological change (-1.1% to +3.5% for Yanco and Colombo Creeks and -2.0% to -0.9% for mid and lower Billabong Creeks) from the Base Case scenario. The changes in annual flow volumes within the Yanco Creek System are considered the product of the suite of differences between the Change Case and Base Case scenario which are mentioned in the section above.

The average change in mean daily flows when comparing the Change and Base Case scenarios represent a low degree of hydrological change (-1.3% to +2.2% for Yanco and Colombo Creeks and -3.9% to -1.3% for mid and lower Billabong Creeks) from the Base Case scenario. The changes in mean daily flows within the Yanco Creek System considered the product of the suite of differences between the Change Case and Base Case scenario which are mentioned in the section above.

7.3.4 Flow Sizes

Almost all changes in daily flow sizes when comparing the Change and Base Case scenarios represent a low degree of hydrological change (-3% to +18% for Yanco and Colombo Creeks and -25% to 3% for mid and lower Billabong Creeks) from the Base Case scenario. In addition, a comparison of Change Case to Base Case flow size results indicate no material change in the proportion of flow categories. The changes in daily flow sizes within the Yanco Creek System are considered the product of the suite of differences between the Change Case and Base Case scenario which are mentioned in the section above.

7.3.5 Environmental Water Requirements

The changes in EWR results within the Yanco Creek System are considered the product of the suite of differences between the Change Case and Base Case scenario which are mentioned in the section above.

The EWR results for Upper Yanco Creek and Lower Yanco to Lower Billabong Creek indicate no reductions in the frequency with which EWR categories are modelled to be achieved, compared to Base Case results, and that an increase in the frequency with which a number of specific EWRs are predicted to be achieved. This includes Baseflow, Native Fish Nesting Support, Small fresh and Large fresh EWRs.

The EWR results for Colombo Creek at Morundah to Billabong Creek upstream of Jerilderie indicate very minor reductions in the frequency with which Very low flow and Baseflows are achieved compared to Base Case results, but these contradict the new minimum flow targets, and therefore will not eventuate in reality. These reductions, in addition to the very minor reduction in Large Floodplain Connection Flows, are likely artifacts of the limitations of the Source model. The EWR results for Billabong Creek at Jerilderie to downstream of Hartwood Weir indicate a minor reduction in the frequency with which Cease-to-flow and Very low flow EWRs is predicted to be achieved compared to Base Case results, but these contradict the new minimum flow targets, and therefore will not eventuate in reality. Again, these reductions are likely artifacts of the limitations of the Source model. The EWR results for Lower Billabong and Intersecting Streams downstream to Moulamein indicate minor reduction in the frequency with which Cease-to-flow CF1 and the specific flow or inundation regimes for Small Overbank Floodplain Connection Flow EWRs are achieved, but these contradict the new minimum flow targets, and therefore will not eventuate in reality. Importantly, the EWR results for Lower Billabong and Intersecting Streams downstream to Moulamein indicate there are increases in the frequency with which the specific flow or inundation regime for Floodplain Connection Flow and Large Overbank, Small Freshes and Native Fish Nesting Support EWRs are achieved compared to Base Case results.

7.3.6 Effective General Security Allocations

Effective General Security Allocations are predicted to increase marginally under the Change Case scenario, compared to Base Case, for opening allocation and summer planning decision dates. A very minor decrease is

predicted for end of the year, which does not occur in the modelled cumulative change case. This minor decrease in end of the year Effective General Security Allocations is not modelled to occur under the Cumulative Change Case scenario.

7.3.7 Water extractions

No reduction in water availability to meet Water Access Licenses is predicted with the operations of the regulators for the proposal or broader system changes. Modelled consumptive extractions (Irrigation + Town Water Supply) results indicate that the predicted consumptive take can increase by 0.2 GL/year under the Change Case scenario compared to the Base Case scenario based on water availability in the Yanco Creek System.

7.3.8 River Flow Objectives

Under the Change Case scenario, no potential adverse impacts and some minor improvements to River Flow Objectives are predicted under the operation of the proposal alongside broader system changes specified in the Yanco Creek System Operations Plan.

With operation of the proposal alongside broader system changes, no adverse effects, and in some instances positive effects, are expected to low flows (i.e. unnatural prolonged drying), moderate flows ('fresches'), high flows and wetland and floodplain inundation flows. In addition, no material change is expected in the overall annual and daily flow variability within the Yanco Creek System with operation of the proposal. No adverse impacts are expected to groundwater dependent surface flows and ecosystems. An improvement in the rates of change in water levels is expected with implementation of operational limits for 'Pool Maximum Daily Rate of Rise' for Hartwood and Wanganella regulators and 'Native fish environmental flow provisions' for maximum rate of fall at Yanco Offtake and Billabong Creek at Darlot. Additionally, the design of the Hartwood and Wanganella regulators includes fishways that will allow an increase in river extent with unimpeded fish passage.

7.3.9 Water surface levels and weir pool extents

Compared to existing conditions, the water surface level in the Hartwood Regulator weir pool is predicted to be marginally higher (median 22 mm higher) in the irrigation season and median 3 mm lower in the non-irrigation season. Operation of the Hartwood Regulator to achieve the proposed weir pool target levels will result in surface water levels within the weir pool of the regulator being higher than the median (50th%ile) water surface level of the existing Hartwood weir less frequently (-3.5%). Under the full supply level (FSL) and Maximum Operating Flow scenario (500 ML/day), there is an approximate 51,590 m² or 7.7% increase in overall weir pool area compared to existing conditions, but no significant change in upstream longitudinal extent and a minor increase in downstream weir pool extent due to the proposed regulator being located approximately 70 m downstream of the existing structure. For the Wanganella Regulator, compared to existing conditions, the water surface level in the Wanganella Regulator weir pool is predicted to be median 65 mm higher in the irrigation season and median 43 mm lower in the non-irrigation season. Operation of the Wanganella Regulator to achieve the proposed weir pool target levels will result in surface water levels within the weir pool of the regulator being higher than the median (50th%ile) water surface level of the existing Wanganella weir +33.5% more frequently. Under the full supply level (FSL) and Maximum Operating Flow scenario (400 ML/day), there is an approximate 110,350 m² or 30% increase in overall weir pool area compared to existing conditions, but no significant change in upstream longitudinal extent and a minor increase in downstream weir pool extent due to the proposed regulator being located approximately 55 m downstream of the existing structure.

7.4 Key findings for cumulative impacts assessment (Cumulative Change scenario)

Given the general consistency of Cumulative Change Case mean annual flows, mean monthly flows, annual and daily flow variability, flow size, EWR results, Effective General Security Allocations and Water Extractions to those for the modelled Change Case scenario, there are not anticipated to be any major additional cumulative effects within Yanco and Colombo Creeks beyond those observed under the Change Case when assessing the proposal in the context of implementation of the Forest Creek Return Flows Project. Differences between Cumulative Change Case and Change Case scenarios are considered the result of the inclusion of the Forest Creek Return Flows Project.

Thus, in summary, the generally low degree of changes are considered the product of the following differences between the Cumulative Change and Base Case scenarios:

- New operational principle to divert unplanned flows down Piccaninny Creek to assist in preventing unplanned flows in Forest Creek downstream of Warriston Weir during normal regulated periods
- Environmental baseflow, native fish environmental flow and additional environmental provisions, including the new environmental flow provision for Forest Creek at Offtake of 10 ML/day
- The ability of the new regulators to regulate flows within Billabong Creek itself to meet environmental and water supply demands
- New normal regulated flow operational limits on the use of irrigation escapes

However, due to the modelling approach taken, it is difficult to determine how much of these changes can be attributed directly to the operation of the proposed regulators within the context of additional broader system changes.

7.5 Conclusions

Based on the findings of this assessment we are confident the eWater Source model developed by NSW DCCEE for the Murrumbidgee River has suitably characterised how the hydrology of Billabong Creek within the proposal study area, and the Yanco Creek System more broadly, will potentially be impacted by operation of the proposal within the context of broader system changes as outlined in the Yanco Creek System Operations Plan.

The proposed construction method, components and phasing for the proposal has taken into account the need to allow passing flow which will allow irrigation, consumption demands and environmental water provisions to be met during the construction timeframes. In addition, the existing weirs (i.e. Hartwood and Wanganella weirs) will remain in place for the majority of the construction timeframe to retain the water and not allow the creek to become unregulated. It is therefore concluded that construction of the proposal is unlikely to materially change the hydrology of the Yanco Creek System, including the proposal study area (Billabong Creek from Jerilderie to Darlot).

The Change Case scenario results indicate minor alterations in mean annual flows within the Yanco Creek System compared to the Base Case scenario. The typical temperate seasonal pattern of flows is maintained, with minimal impact on mean monthly flow volumes throughout the Yanco Creek System, including the proposal study area (Billabong Creek from Jerilderie to Darlot). The Change Case scenario results indicate the proposal does not substantially impact annual or daily flow volume variability and there are minimal impacts on daily flow sizes. Overall, the hydrological analysis suggests that while operation of the proposal will have some localised (within reach) effects on hydrology (i.e. water balance, seasonality, flow variability, and flow sizes) the impacts are generally low and consistent with those expected for as a result of implementing the proposal and broader system changes, and do not substantially alter the overall hydrological characteristics of Billabong Creek within the study area or the broader Yanco Billabong System.

The findings of the EWR analysis suggest that there are generally improvements in achieving EWRs with operation of the proposal (i.e. the Change Case scenario). Overall, there is predicted to be improvements in the frequency of achieving baseflows, Native Fish Nesting Support, small freshes and large fresh EWRs throughout the Yanco Creek System, including the proposal study area. Very minor modelled reductions in some very low flow and very high flow EWRs can be attributed to the limitations of the Source model. Therefore it is concluded that operation of the proposal will result in an overall improvement in the frequency of achieving EWRs for a number of EWR categories to support key ecological values of the system.

No reductions in Effective General Security Allocations or water availability to meet Water Access Licenses is predicted with the operations of the regulators for the proposal or broader system changes. Additionally, no potential adverse impacts, and some minor improvements, to River Flow Objectives are predicted with the operations of the regulators for the proposal or broader system changes.

When comparing the Cumulative Change scenario results to the Change Case scenario results, there are only minor differences in the hydrology (i.e. water balance, seasonality, flow variability, and flow sizes) and EWR frequency analyses, except for at Forest Creek at Warriston Weir. The reductions at Forest Creek at Warriston Weir can be directly attributed to the Forest Creek Return Flows Project, specifically, the proposed operation of the Forest Creek Return Regulator that will enable the flow target downstream of Forest Creek @ Warriston Weir of 0 ML/day to be achieved for efficiently (NSW DCCEEW 2023b). As such, the proposal is not anticipated to negatively impact key hydrological aspects of the Yanco Creek System, including the proposal study area, when taking into consideration potential cumulative effects associated with the Forest Creek Return Flows Project.

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Appendix A - Description of EWR code parameters

Summary of descriptions of EWR parameters adopted to define EWR codes in line with the LTWP's EWRs

EWR Parameter	Definition
StartMonth	Target timing window specified in the LTWP within which the EWRs must be achieved. Note that the timing window is seen as a hard edge, and events that fall partially outside the timing window are not counted as successful events.
EndMonth	
TargetFrequency	Target % of years with successful events to achieve full achievement against an EWR
TargetFrequencyMin	Minimum % of years with successful events to achieve full achievement against an EWR
TargetFrequencyMax	Maximum % of years with successful events to achieve full achievement against an EWR
EventsPerYear	Target number of successful events per year
Duration	The duration of flow above the threshold for the event (generally consecutive days depending on the minimum spell length and the within event-gap tolerance)
MinSpell	Minimum consecutive number of days that contribute to the event duration
FlowThresholdMin	Minimum flow threshold for a successful event in ML/day
FlowThresholdMax	Maximum flow threshold for a successful event in ML/day
MaxInter-event	Maximum inter-event length (time between events) from the LTWP. If the time between events is not less than this value, then a penalty is applied based on the maximum inter-event length.
WithinEventGapTolerance	Tolerance for dropping below the flow threshold for a certain number of days within a potential event
DrawdownRate	Maximum drawdown rate (in % per day rate of fall) during nesting period for trout cod and Murray cod where unnaturally rapid changes in water levels should be avoided to avoid the stranding or abandonment of nests. If the drawdown rate is exceeded, the nesting support EWRs will fail.
TriggerDay	The program will loop through the timeseries until it finds the trigger day, then it will check the EWR requirements. If not specified, the program will assume there is no trigger day.

Table A-1 The relevant EWR codes and the parameters adopted for PU10 Upper Yanco Creek - Yanco Creek at Offtake (410007)

Code	StartMonth	EndMonth	TargetFrequency (%)	TargetFrequencyMin (%)	TargetFrequencyMax	EventsPerYear	Duration (days)	MinSpell (days)	FlowThresholdMin	FlowThresholdMax	MaxInter-event	WithinEvent Gap Tolerant	DrawdownRate (%) per	TriggerDay	TriggerMonth
CF1	7	6	0			1	0	1	0	1	0	0			
VF1_a	7	6	50			1	365	1	80		4 days	0			
VF1_b	7	6	100			1	354	1	80		4 days	0			
BF1_a	7	6	50			1	360	1	250		58 days	0			
BF1_b	7	6	100			1	213	1	250		58 days	0			
NestS1_tcmc	9.15	11.15	75	50	100	1	60	60	250	1000	2 years	0	11	15	9
NestS1_mc	10.1	11.15	75	50	100	1	45	45	250	1000	2 years	0	11	1	10
SF1_S	7	6	100			2	10	10	450		1 year	0			
SF1_P	10	4	100			2	10	10	450		1 year	0			
SF2	9.15	5.1	75	50	100	1	14	14	450	1000	2 years	0			
LF1_P	7	9	75	50	100	1	5	5	1000		2 years	0			
LF1_S	9	2	75	50	100	1	5	5	1000		2 years	0			
LF2	10	4	65	60	70	1	5	5	1000		2 years	0			
W-LF6_S	7	6	25	20	30	1	5	5	1500		5 years	0			
W-LF6_P	7	6	25	20	30	1	5	5	1500		5 years	0			
W-LF7	7	2	70	60	80	1	5	3	1500		2 years	90			
W-LF8	7	6	30			1	5	5	1500		5 years	0			
OB-S2_S	7	6	50			1	8	4	2500		4 years	90			
OB-S2_P	8	2	50			1	8	4	2500		4 years	90			
OB-L1_S	7	6	25			1	8	4	4000		5 years	90			
OB-L1_P	9	3	25			1	8	4	4000		5 years	90			

Table A-2 The relevant EWR codes and the parameters adopted for PU11 Colombo & Billabong Creeks - Colombo Creek at Morundah (410014)

Code	StartMonth	EndMonth	TargetFrequency (%)	TargetFrequency Min (%)	TargetFrequency Max (%)	EventsPerYear	Duration (days)	MinSpell (days)	FlowThresholdMin (ML/day)	FlowThresholdMax (ML/day)	MaxInter-event	WithinEventGap Tolerance (days)	DrawdownRate (% per day)	TriggerDay	TriggerMonth
CF1	7	6	0			1	0	1	0	1	0	0			
VF1_a	7	6	50			1	365	1	40		1 day	0			
VF1_b	7	6	100			1	365	1	40		1 day	0			
BF1_a	7	6	50			1	365	1	70		10 days	0			
BF1_b	7	6	100			1	333	1	70		10 days	0			
NestS1_tcmc	9.15	11.15	75	50	100	1	60	60	70	400	2 years	0	14%	15	9
NestS1_mc	10.1	11.15	75	50	100	1	45	45	70	400	2 years	0	14%	1	10
SF1_S	7	6	100			2	10	10	250	Not available*	1 year	0			
SF1_P	10	4	100			2	10	10	250	Not available*	1 year	0			
SF2	9.15	5.1	75	50	100	1	14	14	250	400	2 years	0			
LF1_S	7	6	75	50	100	1	5	5	400	Not available*	2 years	0			
LF1_P	7	9	75	50	100	1	5	5	400	Not available*	2 years	0			
LF2	10	4	65	60	70	1	5	5	400	Not available*	2 years	0			
W-LF6_S	7	6	25	20	30	1	5	5	700	Not available*	5 years	0			
W-LF6_P	9	2	25	20	30	1	5	5	700	Not available*	5 years	0			
W-LF7	7	2	60			1	10	3	700	Not available*	2 years	90			
W-LF8	7	6	30			1	5	5	700	Not available*	5 years	0			
OB-S2_S	7	6	35	30	40	1	9	5	1000	Not available*	5 years	90			
OB-S2_P	8	2	35	30	40	1	9	5	1000	Not available*	5 years	90			
OB-L1_S	7	6	25			1	6	2	1400	Not available*	5 years	90			
OB-L1_P	9	3	25			1	6	2	1400	Not available*	5 years	90			

* The LTWP defines these values as "to be determined", thus these parameters have not been specified for use in the EWR Tool scenario runs to inform this hydrological impact assessment.

** Note that De-stratifying flow, which is required in Colombo Creek at Morundah to de-stratify refuge pools during periods of identified high risk, are Not applicable to hydrology in the EWR Tool as they are guidelines for complex event-based actions for water managers.

Table A-3 The relevant EWR codes and the parameters adopted for PU11 Colombo & Billabong Creeks - Billabong Creek at Jerilderie (410016)

Code	StartMonth	EndMonth	TargetFrequency (%)	TargetFrequency Min (%)	TargetFrequency Max (%)	EventsPerYear	Duration (days)	MinSpell (days)	FlowThresholdMin (ML/day)	FlowThresholdMax (ML/day)	MaxInter-event	WithinEventGap Tolerance (days)
CF1	7	6	0			1	0	1	0	1	0	0
VF1_a	7	6	50			1	365	1	50		20 days	0
VF1_b	7	6	100			1	308	1	50		20 days	0
BF1_a	7	6	50			1	365	1	70		29 days	0
BF1_b	7	6	100			1	271	1	70		29 days	0

Table A-4 The relevant EWR codes and the parameters adopted for PU12 Lower Yanco Creek to Lower Billabong Creek - Yanco Creek at Morundah (410015)

Code	StartMonth	EndMonth	TargetFrequency	TargetFrequency	TargetFrequency	EventsPerYear	Duration	MinSpell	FlowThresholdMin	FlowThresholdMax	MaxInter-event	WithinEvent	DrawdownR	TriggerDay	TriggerMonth
CF1	7	6	0			1	0	1	0	1	0	0			
VF1_a	7	6	50			1	365	1	40		14 days	0			
VF1_b	7	6	100			1	346	1	40		14 days	0			
BF1_a	7	6	50			1	339	1	130		65 days	0			
BF1_b	7	6	100			1	192	1	130		65 days	0			
DSF1	11	3	Not available*			1	2	2	Not available*	Not available*	0	0			
NestS1_tcm	9.15	11.15	75	50	100	1	60	60	130	400	2 years	0	9%	15	9
NestS1_mc	10.1	11.15	75	50	100	1	45	45	130	400	2 years	0	9%	1	10
SF1_S	7	6	100			2	10	10	250		1 years	0			
SF1_P	10	4	100			2	10	10	250		1 years	0			
SF2	9.15	5.1	75	50	100	1	14	14	250	400	2 years	0			
LF1_S	7	6	75	50	100	1	5	5	400		2 years	0			
LF1_P	7	9	75	50	100	1	5	5	400		2 years	0			
LF2	10	4	65	60	70	1	5	5	400		2 years	0			
W-LF6_S	7	6	25	20	30	1	5	5	800		5 years	0			
W-LF6_P	9	2	25	20	30	1	5	5	800		5 years	0			
W-LF7	7	2	70	60	80	1	10	3	800		2 years	90			
W-LF8	7	6	30			1	5	5	800		5 years	0			
OB-S2	8	2	50			1	8	4	1000		4 years	90			
OB-L1_S	7	6	25			1	8	5	2000		5 years	90			
OB-L1_P	9	3	25			1	8	5	2000		5 years	90			

* The LTWP defines these values as "to be determined", thus these parameters have not been specified for use in the EWR Tool scenario runs to inform this hydrological impact assessment.

Table A-5 The relevant EWR codes and the parameters adopted for PU13: Lower Billabong and Intersecting Streams - Billabong Creek at Darlot (410134)

Code	StartMonth	EndMonth	TargetFrequency	TargetFrequency	TargetFrequency	EventsPerYear	Duration	MinSpell	FlowThresholdMin	FlowThresholdMax	MaxInter-event	WithinEvent	DrawdownR	TriggerDay	TriggerMonth
CF1	7	6	0			1	0	1	0	1	0	0			

Code	StartMonth	EndMonth	TargetFrequency	TargetFrequency	TargetFrequency	EventsPerYear	Duration	MinSpell	FlowThresholdMin	FlowThresholdMax	MaxInter-event	WithinEvent	DrawdownR	TriggerDay	TriggerMonth
VF1_a	7	6	50			1	365	1	30	Not available*	18 days	0			
VF1_b	7	6	100			1	327	1	30	Not available*	18 days	0			
BF1_a	7	6	50			1	365	1	50	Not available*	32 days	0			
BF1_b	7	6	100			1	275	1	50	Not available*	32 days	0			
DSF1	11	3	Not available*			1	2	2	Not available*	Not available*	0	0			
NestS1_tcm	9.15	11.15	75	50	100	1	60	60	50	700	2 years	0	9%	15	9
NestS1_m	10.1	11.15	75	50	100	1	45	45	50	700	2 years	0	9%	1	10
SF1_S	7	6	100			2	10	10	200	Not available*	1 years	0			
SF1_P	10	4	100			2	10	10	200	Not available*	1 years	0			
SF2	9.15	5.1	75	50	100	1	14	14	200	700	2 years	0			
LF1_S	7	6	75	50	100	1	5	5	700	Not available*	2 years	0			
LF1_P	7	9	75	50	100	1	5	5	700	Not available*	2 years	0			
LF2	10	4	65	60	70	1	5	5	700	Not available*	2 years	0			
W-LF4_S	7	6	90	80	100	1	10	5	1000	Not available*	1.5 years	90			
W-LF4_P	7	2	90	80	100	1	10	5	1000	Not available*	1.5 years	90			
W-LF5	10	4	50			1	10	5	1000	Not available*	2 years	90			
W-LF6_S	7	6	25	20	30	1	5	5	1000	Not available*	5 years	0			
W-LF6_P	9	2	25	20	30	1	5	5	1000	Not available*	5 years	0			
W-LF7	7	2	70	60	80	1	10	5	1000	Not available*	2 years	90			
W-LF8	7	6	30			1	5	5	1000	Not available*	5 years	0			
OB-S1	10	4	50			1	10	5	1600	Not available*	4 years	90			
OB-S2	8	2	50			1	10	5	1600	Not available*	4 years	90			

Code	StartMonth	EndMonth	TargetFrequency	TargetFrequency	TargetFrequency	EventsPerYear	Duration	MinSpell	FlowThresholdMin	FlowThresholdMax	MaxInter-event	WithinEvent	DrawdownR	TriggerDay	TriggerMonth
OB-L1	9	3	25			1	10	5	3000	Not available*	5 years	90			

* The LTWP defines these values as “to be determined”, thus these parameters have not been specified for use in the EWR Tool scenario runs to inform this hydrological impact assessment.