Department of Climate Change, Energy, the Environment and Water

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Hydrologic analysis of options for the Murrumbidgee Regional Water Strategy

Regional Water Strategies Program

May 2024

Acknowledgement of Country

The NSW Government acknowledges First Nations people as the first Australian people and the traditional owners and custodians of the country's lands and water. First Nations people have lived in NSW for over 60,000 years and have formed significant spiritual, cultural, and economic connections with its lands and waters.

Today, they practise the oldest living culture on earth.

The NSW Government acknowledges the

First Nations people/Traditional Owners from the Murrumbidgee region as having an intrinsic connection with the lands and waters of the Murrumbidgee Regional Water Strategy area. The landscape and its waters provide the First Nations people with essential links to their history and help them maintain and practise their traditional culture and lifestyle.

We recognise Traditional Owners as the first managers of Country. Incorporating their culture and knowledge into management of water in the region is a significant step towards closing the gap.

Under this regional water strategy, we seek to establish meaningful and collaborative relationships with First Nations people. We seek to shift our focus to a Country-centred approach; respecting, recognising and empowering cultural and traditional Aboriginal knowledge in water management processes at a strategic level.

We show our respect for Elders past and present through thoughtful and collaborative approaches to our work, seeking to demonstrate our ongoing commitment to providing places where First Nations people are included socially, culturally, and economically.

As we refine and implement the regional water strategy, we commit to helping support the health and wellbeing of waterways and Country by valuing, respecting and being guided by First Nations people, who know that if we care for Country, it will care for us.

We acknowledge that further work is required under this regional water strategy to inform how we care for Country and ensure First Nations people hold a strong voice in shaping the future for all communities.

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Contents

Executive summary

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

The draft Murrumbidgee Regional Water Strategy (DPIE 2022a) and a long list of options were released in April 2022 (DPIE 2022b).

This report presents the outcomes of hydrological assessment undertaken to understand the impact of selected options on existing water supply risks to catchment water users, and feed into economic and ecological assessments of the options.

We assessed water security and changes in flow regimes in the Murrumbidgee River system for 3 plausible climate scenarios:

- an instrumental historical climate (hereafter referred to as 'historical climate'). This is based on observed meteorological recordings and simulated flow at headwater gauges and mainstream residual catchments from 1890–2020. We obtained the simulated flow at those gauges from calibrated rainfall runoff models, which are used to extend and replicate observed data.
- a long-term historical climate. This scenario assumes our future climate will be similar to what science indicates our long-term paleoclimate was like and is based on a 10,000-year data set.
- a dry future climate. This assumes a future worst-case dry climate change scenario. The dry future climate scenario was developed by adjusting the long-term historical climate scenario rainfall, temperature, and evapotranspiration data according to regionally downscaled factors generated from the Dry future 1.0 project.

We modelled a base case and 8 options. Four options were assessed by modelling several variations. All hydrologic and water supply assessment modelling was done using the Murrumbidgee River system model, which was built using the eWater Source modelling platform. This model was developed as a tool to plan and evaluate water resource management policies at a river-system scale. It can be applied to regulated and unregulated streams and can address water quality and environmental issues as well as water quantity issues (Welsh et al, 2012).

Glossary

AHD (Australian Height Datum) is the first and only national height reference in Australia.

ASV (active storage volume) is the volume of storage that can be regulated from a dam, or the volume of water that is stored above dead storage volume.

airspace is a volume in a water storage that is kept empty for the purpose of flood mitigation or in the case of Blowering Dam to allow Snowy Hydro Limited to make releases from Jounama reservoir such that it would not spill from Blowering Dam or cause channel constraints to be exceeded.

allocations are given though an announcement that specifies the volume of water allocated to water access entitlements. An announcement could increase, decrease, or leave unchanged the quantity of water allocated.

annual permitted take has the same meaning as it has in section 6.10 of the Basin Plan which is the maximum quantity of water for a water accounting period permitted to be taken by each form of take for consumptive use from the SDL resource unit using a specific methodology set out in the Murrumbidgee River water resource plan.

available water means the water that is available in that area or water source in accordance with an available water determination that is in force.

available water determination is an order in writing that is a determination:

- to the availability of water for one or more categories or subcategories of access licences in relation to one or more specified water management areas or water sources and/or
- while an order is in force during severe water shortages (suspension of WSP) or suspension of Basin management plans during extreme events as to the availability of water for one or more individual access licences in relation to one or more specified water management areas or water sources.

Basin Plan means the Basin Plan 2012 made under section 44 (3) (b) (i) of the Water Act 2007 of the Commonwealth.

BDL (baseline diversion limit) means the baseline limit of take from an SDL resource unit. This baseline limit for a surface water SDL resource unit, which for the regulated Murrumbidgee River is the quantity of water calculated in accordance with item 14, column 2 of the table in Schedule 2 of the 2012 Basin Plan.

Blowering Dam water storage has the same meaning as it has in the Murrumbidgee River Water Management Area Regulated River Order (Government Gazette No 110 of 1 July 2004), as set out in item 21 (3) of Schedule 12 of the Act.

Blowering Dam local inflows are the inflows into Blowering Dam between Jounama Dam and Blowering Dam wall.

Blowering Power Station is the power station at Blowering Dam.

Burrinjuck Dam water storage has the same meaning as it has in the Murrumbidgee River Water Management Area Regulated River Order (Government Gazette No 110 of 1 July 2004), as set out in item 21 (2) of Schedule 12 of the Act.

Cap is the average annual volume of water extraction for consumptive purposes corresponding to river system infrastructure, and user infrastructure and behaviour, at 1993/94. This is an upper bound on diversions for valleys in the Murray-Darling system.

Carryover is an arrangement that allows a water access licence holder to retain water allocations not taken in a water accounting period for possible take in the next water accounting period. It gives the water entitlement holder a right to a share of space in storage dams and the right to retain any unused water for use in a later year. There are several carryover arrangements in the Murrumbidgee River water sharing plan:

- EWA1: 50,000 ML limit
- EWA 2: no limit, but not carried over in the following year.
- general security, regulated river conveyance, Murrumbidgee Irrigation conveyance and Coleambally Irrigation conveyance: 0.3 ML/unit share, subject to available water determinations not exceeding 1 ML/unit share.

CIC (Coleambally Irrigation conveyance) is an access licence type in the regulated Murrumbidgee River system. It is described in section 26 and 43 of the *Water Sharing Plan for the Murrumbidgee Regulated River Water Source 2020.*

Domestic and stock is an access licence type in the regulated Murrumbidgee River system. It is described in section 20 and 38 of the *Water Sharing Plan for the Murrumbidgee Regulated River Water Source 2020.*

DSV (dead storage volume) is water storage that is stored below the level of the lowest outlet (the minimum supply level). This water cannot be accessed under normal operating conditions.

EWA (environmental water allowance) is comprised of 3 allowances which can be credited, debited, and carried over with specific rules of operation set out in the *Water Sharing Plan for the Murrumbidgee Regulated River Water Source 2020.*

environmental flows are regulated water supplied for specific environmental outcomes at identified locations in the Murrumbidgee River system.

environmental water refers to a portfolio of water access licences used to achieve environmental outcomes. In the Murrumbidgee River regulated system this includes general security, regulated river conveyance, high security, Murrumbidgee Irrigation conveyance, Coleambally Irrigation conveyance, supplementary access licences, and environmental water allowance accounts.

flow regimes mean (collectively) the magnitude, duration, frequency, and pattern of flows that characterise a river or water source.

FSV (full storage volume) is the maximum volume of water that can be held in a storage with an ungated spillway without an uncontrolled spill, or for a storage with a gated spillway, the volume at designated maximum operating level.

general security effective allocation is the sum of available water determinations made for regulated river (general security) access licences in the water year and the water carried over in the regulated river (general security) access licence water allocation account from the previous water year, divided by total regulated river (general security) access licences unit shares.

GL means gigalitres (10^9 litres, or 1,000 megalitres).

GS (general security) is a type of access licence in the regulated Murrumbidgee River system. It is described in section 23 and 41 of the *Water Sharing Plan for the Murrumbidgee Regulated River Water Source 2020.*

HEW (held environmental water) is generally taken or permitted to be taken under a licence. It can be high security or general security or committed under an adapted environmental water condition. Related water accounts include PHS, HS GS CIA, MIA, EWA1, EWA 2 and EWA 3.

HS (high security) is a type of access licence in the regulated Murrumbidgee River system. It is described in section 22 and 40 of the *Water Sharing Plan for the Murrumbidgee Regulated River Water Source 2020.*

hydrological modelling is the characterisation of hydrologic features and systems as described by mathematical analogues and computer simulations. It simplifies real-world systems to support our understanding, predictions, and management of water resources.

inflows are water flowing into a storage (dam, reservoir, or lake) or river system. Inflows can result from natural catchment rain or snow that runs off into tributary creeks and rivers or regulated (where releases from storages or other infrastructure such as pipes or power stations upstream of or outside the system or storage influence or control arriving flow). Inflows are measured by gauges deployed just upstream of their junction point or connection into the system or storage. Inflows to storages can also be estimated using a mass balance – considering change in storage volume, evaporation, and releases.

IPO (Interdecadal Pacific Oscillation) is a large-scale, long-period oscillation that influences climate variability over the Pacific Basin. The IPO is multi-decadal, with phases lasting around 20–30 years.

IVT (Murrumbidgee inter-valley transfer) is an account of the net trade from the Murrumbidgee River system. The Murray-Darling Basin Authority draws water from the Murrumbidgee when required for Murray River system operations, and the IVT account is debited accordingly. The maximum balance of the IVT account is 100 GL. For modelling purposes there is a node below Balranald that orders IVT to be transferred to the Murray River system.

LTAAEL (long-term average annual extractive limit) is a limit on average annual extractions from a water source over a defined assessment period. In water sharing plans for inland regulated river surface water, LTAAELs are the lesser of long-term annual extractions under Cap conditions (which generally reflect irrigation development, operation, and management rules in 1993/94, or irrigation development, and management rules in the early 2000s). Each type of water source — regulated, unregulated and groundwater — has its own LTAAEL.

Lowbidgee water event is a period water can be taken under a Lowbidgee supplementary access from a specific part of the water source. These events are effectively surplus flow that cannot be captured or 're-regulated' into storage.

LWU (local water utility) is a water supply authority (usually a local government council or county council) that supplies water under Division 2 of Part 3 of Chapter 6 of the *Local Government Act 1993,* or a licensed network operator within the meaning of the *Water Industry Competition Act 2006*. LWU is a type of access licence in the regulated Murrumbidgee River system and is described in sections 21 and 39 of the *Water Sharing Plan for the Murrumbidgee Regulated River Water Source 2020.*

MIC (Murrumbidgee Irrigation conveyance) is a type of access licence in the regulated Murrumbidgee River system. It is described in sections 25 and 42 of the *Water Sharing Plan for the Murrumbidgee Regulated River Water Source 2020.*

ML means megalitres (10^6 litres, or 1,000,000 litres).

Murrumbidgee River water sharing plan is the *Water Sharing Plan for Murrumbidgee Regulated River Water Source 2020 (*https://legislation.nsw.gov.au/view/pdf/asmade/sl-2016-367).

PCR (pre-release compensation reserve) refers to an account maintained in the Snowy scheme by the Ministerial Corporation under clause 8.1 of the Blowering Airspace Deed.

PEW (planned environmental water) is water committed by management plans for fundamental ecosystem health or other specified environmental purposes, either generally, at a specified time, or in specified circumstances, and which cannot (to the extent committed) be taken or used for any other purpose. Note the PEW reported in this report is the sum of the 3 EWA accounts, it does not include Blowering Dam transparent releases, nor Burrinjuck Dam transparent and translucent releases.

PHS (premium high security) is a subset of regulated Murrumbidgee River high-security access licences, which is provided water before other high-security access licences. It is described in section 40(1) of the *Water Sharing Plan for the Murrumbidgee Regulated River Water Source 2020.*

physical constraint means a natural formation or a physical structure (for example, a pipe, bridge, or channel) that limits the volume of water that can pass a given location.

RAR (required annual release) is a volume of water that must be released by SHL each Snowy water year. It is described in section 12.2 of the *Snowy Water Licence, amended 18 November 2020.*

RWS (regional water strategies) are part of DCCEEW's program of work to identify the critical challenges we must address over the coming decades and outline how we will respond to these challenges.

regulated river is a river that has been declared (in accordance with the *Water Management Act 2000* and by the Minister, by order published in the Gazette) to be a regulated river. Generally, it is a gazetted length of a watercourse containing water delivered by the operator of a state-owned storage. For the purposes of the Basin Plan, the river must have been declared regulated before the Basin Plan commenced.

regulated system means a surface water system in which water in a watercourse can be stored, or flow levels controlled, through the use of structures such as dams, weirs, and diversion infrastructure.

return flows are water returned to the river from floodplains and wetlands and (for diverted surface water) water trickling back into the river through channels, drains and creeks.

reliability refers to the frequency with which water allocated under a water access entitlement is able to be supplied.

river system is the larger network of streams, storages, rivers, and water users that are part of a larger river's network of water use, infrastructure, tributaries, and distributaries.

river system model is a computer software tool that simulates the flow and behaviour of water in a river system, and how water moves through and controlled in the river channel and associated floodplains, wetlands, and anabranches. Models consider extraction from the river, and losses and gains as water moves through the landscape.

SCS (Southern Connected System) is a network of rivers that feed into the Murray River. The network includes outflows from the Snowy scheme, the Kiewa, Ovens, Goulburn, Campaspe, and Loddon rivers in Victoria, and the Murrumbidgee River, Edward-Wakool rivers, and Darling River below Menindee.

SDL (sustainable diversion limit) is a limit on the amount of water that can be used by Basin towns, communities, farmers, and industries long term, while leaving enough water in the river system to sustain natural ecosystems. SDLs are set at catchment level.

SDL compliance is assessed at the end of every water year. Assessment involves calculating the maximum volume of water expected to be taken in that year if the system is compliant with the SDL over the long term, and the volume actually taken, each year. The difference between these 2 volumes is recorded in a register of take as a credit or debit, depending on whether actual take is less than or greater than permitted take. A cumulative balance is established that varies according to each year's credit or debit. An SDL resource unit is considered to be noncompliant when the cumulative balance is in debit by any amount equal to or greater than 20% of the SDL for that unit.

security refers to how often water under a water entitlement is able to be allocated in full.

SHD (Snowy Height Datum) is the height datum used for the Snowy scheme and is 1.12 m higher than AHD.

Sleepers are completely inactive entitlement licences — that is, they do not consume or take water. Where less water is taken than the entitlement allows, we refer to them as 'dozers.

Snowy scheme (the) is the Snowy Mountains Scheme.

Stochastic refers to a statistical method of creating artificial data records with the same characteristics as the original historical record, but with different sequences and durations of events such as droughts and floods. Stochastic data are useful for testing system performance against possible future climate as likely to occur as the past climate, but with different sequences. They also allow better estimates of economic impacts of climate (including current climate).

Supplementary water event means a period during which the taking of water under supplementary water access licences or supplementary (Lowbidgee) access licence is permitted in all or part of the water source. These are effectively surplus flows that cannot be captured or 're-regulated' into storage. These were previously known as off-allocation events.

Supplementary water access licence is an access licence type that entitles its holder to shares of water from a regulated river after an event has been declared. It is described in section 27 and 44 of the *Water Sharing Plan for the Murrumbidgee Regulated River Water Source 2020.* There is an exclusive component of supplementary for Lowbidgee described in clauses 28 and 44(2).

SWIOID is the Snowy Water Inquiry Outcomes Implementation Deed.

underutilisation occurs when a water entitlement or allocation is not completely used. It is often cited as an issue arising from complicated trading rules. Historically, irrigators in the Murray-Darling Basin have only used around 70% of their water allocations. Increased utilisation of permanent water entitlements leads to both less water in storages and rivers and has an impact on future water allocations, which can be a significant driver of water market demand. It also has implications for SDL compliance.

water allocation is the right to access a volume of water in a water year (1 July to 30 June). It is the water to which the holder of an access licence is entitled from time to time under the licence as recorded in the water allocation account for the licence and is the percentage of a water entitlement that can be taken from the river that year. Under some types of licence allocations can be used, traded, or carried over. Allocations change depending on how much water is available.

water allocation account is an account against which water is credited when it is made available under an available water determination, traded from an access licence, transferred from interstate, or credited from water return flows.

water entitlement is an ongoing right to receive up to a certain volume or share of available river system water in a year, up to a maximum amount. Entitlements can be bought or sold permanently or temporarily. Once sold, the seller loses their right to that water.

water storage is a dam, weir, or other structure which stores water and can be used to regulate and manage river flows.

1. Introduction

This report outlines hydrologic modelling done to understand supply risks posed to water users by Murrumbidgee regulated river system infrastructure options, using the Murrumbidgee eWater Source River System Model.

Hydrological modelling is a key input to development of the Murrumbidgee Regional Water Strategy (RWS). The results of the modelling offer evidence toward the inclusion of options on the proposed shortlist of actions identified in the Draft Regional Water Strategy Murrumbidgee: Short-listed actions - Consultation Paper (DCCEEW, 2024).

We modelled a base case and 8 options. We present modelling results for each option (and for several variations of some options) in sections 4 to 12 of this report.

Section 13 summarises results of our modelling of the impact of long-term climate and climate change on the base case and selected options.

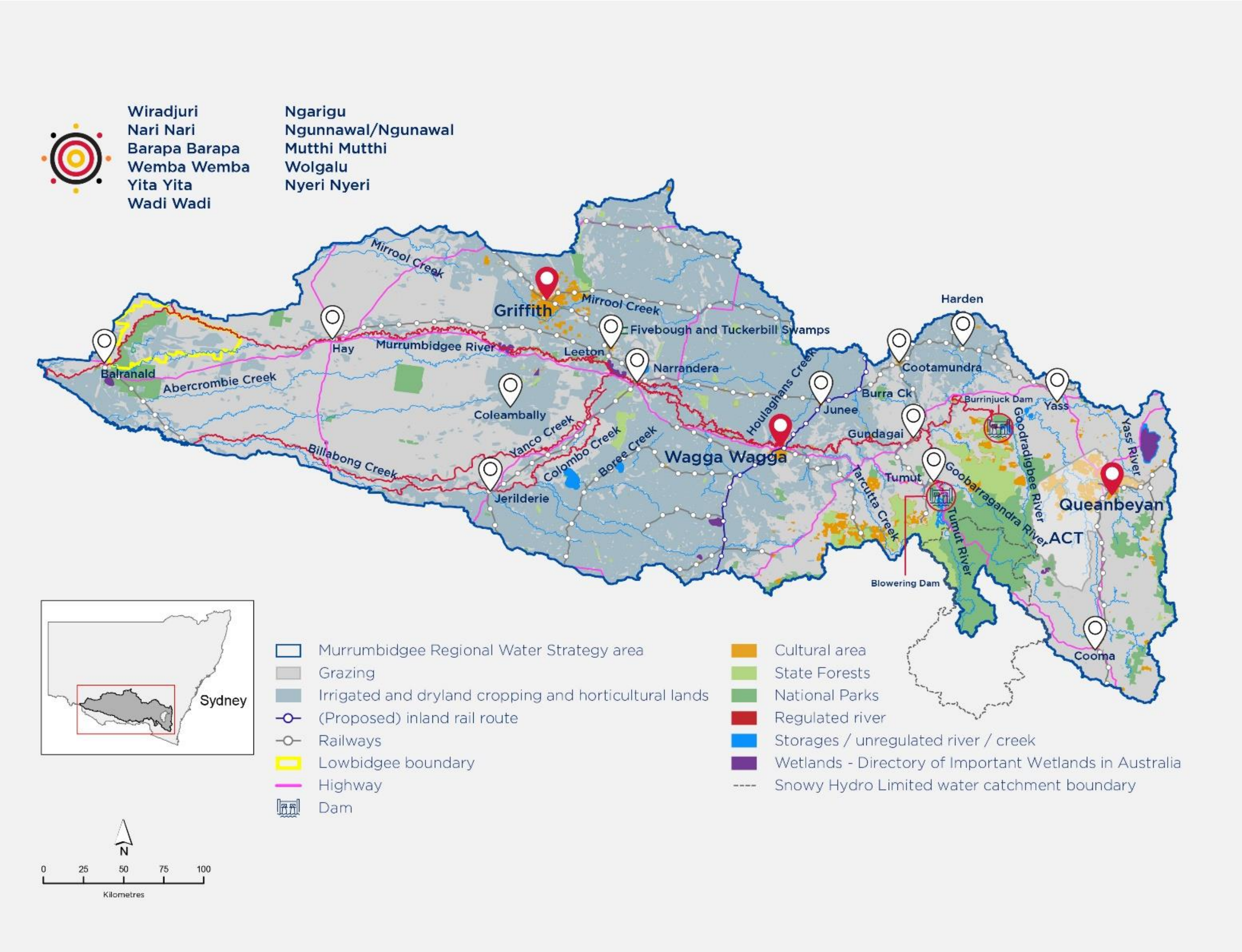
2. Background

Murrumbidgee region

The Murrumbidgee region (Figure 1) lies west of the Great Dividing Range, in southern NSW. Its terrain varies from mountainous in the east to open plains in the west. Extending across more than 84,000 km^2, the region is home to almost a third of the Murray–Darling Basin's population. Key regional centres include Wagga Wagga, Griffith, and Queanbeyan, as well as smaller regional towns such as Cooma, Yass, Cootamundra, Gundagai, Hay, Leeton, and Balranald. The Australian Capital Territory (ACT), situated within the upper Murrumbidgee River catchment, is a separate jurisdiction.

Water management in the Murrumbidgee region is complex. The region is part of the Southern Connected System (SCS), and specific rules govern water management arrangements between the ACT, the Snowy scheme, and the Murray and Murrumbidgee River systems.

Figure 1: Map of the Murrumbidgee region



The upper Murrumbidgee River system consists of many unregulated rivers and creeks that are vital water sources for communities, industries, and the environment. Water availability in the upper Murrumbidgee River is linked to rainfall variability and is susceptible to short intense droughts. This variability poses risks to water users in the upper Murrumbidgee River, particularly those who rely solely on unregulated rivers for their water supply like Batlow, Tumbarumba, Yass, and those in the Queanbeyan–Palerang area.

From Burrinjuck and Blowering dams to Darlington Point, the mid-Murrumbidgee consists of extensive alluvial plains, with a few major tributaries and several anabranches. Downstream of Narrandera the Yanco Creek system links the Murrumbidgee and Murray rivers through 800 km of interconnected waterways, including Colombo Creek, Billabong Creek, and Forest Creek. Towns and industry in the mid-Murrumbidgee rely on both regulated river and groundwater sources. The lower reaches of the Murrumbidgee River expand into a broad floodplain and a complex area of effluent channels, wetlands and swamps known as the Lowbidgee.

The Murrumbidgee region has 2 main water storages, Burrinjuck Dam and Blowering Dam, with a combined storage capacity of 2,654 GL. Burrinjuck Dam, constructed during the First World War, was NSW's first major irrigation dam, and enabled development of the Murrumbidgee Irrigation Area (MIA). The Snowy scheme, constructed between 1951 and 1974, was originally designed to capture and move water from east to west, releasing water into the Murrumbidgee and Murray rivers to support industries and communities in NSW, Victoria, and South Australia, and generate electricity as a by-product. Blowering Dam, one of the largest dams in NSW, was built in the 1960s to store water released from the Snowy scheme for use in the Murrumbidgee region. The Snowy scheme significantly regulates inflows from the Tumut River into the Murrumbidgee and diverts water to the Murrumbidgee from the Tooma River and Snowy River catchments. Since construction, the function of the region's major storages has expanded to include providing water to communities and other users in the Murrumbidgee region.

Rainfall and climate vary greatly across the catchment, with high rainfall in the mountainous terrain to the east and less in the very flat, semi-arid plains to the west. Winter and spring rainfall, and additional spring snowmelt in elevated areas of the east, are critically important for inflows to the region's main storages. Most catchment inflow occurs across the Great Dividing Range between June and October. This reliance on winter–spring rainfall contrasts with the summer-dominated rainfall and storms of northern NSW.

Rainfall in the Murrumbidgee region varies year to year and shows distinct dry and wet periods in observed historical records, some spanning 10–20 years. Although recent droughts have been less severe in the Murrumbidgee region than in northern NSW, the 24 months from January 2018 to February 2020 saw well below average rainfall and the lowest 2 years of inflow on record for Burrinjuck Dam. However, in 2020 and early 2021, above average rainfall and dam inflows increased the region's storages with both Burrinjuck and Blowering dams spilling in mid-2021. This pattern of extended drought followed by intense wet conditions is common in the region.

The Murrumbidgee River is highly regulated downstream of Blowering and Burrinjuck dams, with 8 major weirs along the river that regulate flows to town water supplies, the main irrigation areas, environmental assets, and effluent streams. Balancing water supply from the region's 2 main storages and meeting the water demands from regional towns and communities, industries and the environment can be complex and challenging, particularly during spring and summer periods when physical constraints limit the river's capacity to convey water.

Groundwater is also an important regional water source. During droughts, reliance on groundwater increases significantly to support regional industries and supplement town water needs. Some of the region has been affected by intensive groundwater extraction, with declining groundwater levels and increasing salinity posing a risk to future groundwater access.

The Murrumbidgee is NSW's most diverse agricultural region, producing citrus, wine, almonds, cotton, rice, vegetables, winter cereals, as well as annual pastures for beef, sheep, and dairy. Recent growth in permanent plantings that require water year-round and the expansion of cotton plantings (which compete for water with other annual crops such as rice) are changing water use and demand. Future climate variability and climate change may further test the resilience of the region's base industry.

The development of water resources and extensive river system regulation have altered flow regimes and affected the region's key environmental assets. For example, around 58% of the original Lowbidgee floodplain wetlands has been lost, and those that remain are degraded. More effective watering of this floodplain, through the shared management of Gayini Nimmie-Caira, the Nimmie-Caira Infrastructure Modification and the Yanga National Park project, will improve environmental and cultural outcomes in the Lowbidgee. The Bitterns in Rice project (which, with the assistance of local rice growers and conservation groups, sees a large breeding population of bitterns supported by Riverina rice crops) is another successful example of how land and water can be managed collaboratively for both food production and the environment.

There are many licensed environmental water entitlements in the Murrumbidgee region. These entitlements are managed to benefit the environment by delivering water to specific sites including culturally and nationally significant environmental assets (such as the Fivebough and Tuckerbil swamps, the mid-Murrumbidgee wetlands and the Lowbidgee floodplain) and to support ecosystem functions and native species (such as the Murray cod, southern bell frog, and Australasian bittern). Planned environmental water in the Murrumbidgee region is equally important to the environment and is managed through several rules in the water sharing plan. Effective delivery of environmental water is a challenge due to factors including physical constraints, barriers and associated flow management within the regulated river, and the balancing of water demand and delivery timing for many users — including agriculture — with environmental needs.

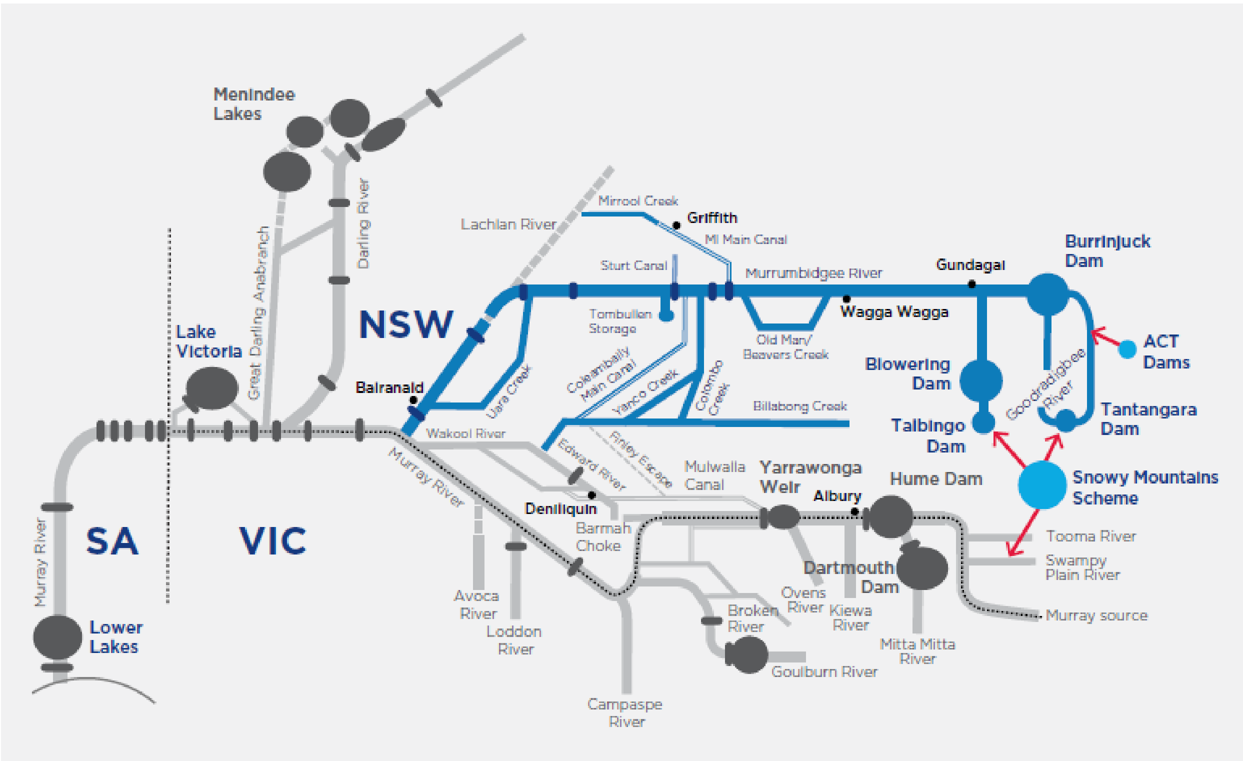
Aboriginal people in the region rely on water for their health, wellbeing, and connection to Country. Aboriginal people consider that current water access licence arrangements are unable to meet the full spectrum of their spiritual, cultural, environmental, social, and economic needs, as defined by the 2007 Murray Lower Darling Rivers Indigenous Nations (MLDRIN) *Echuca Declaration*. They also seek more opportunities to manage water using their cultural knowledge and improved economic opportunities as either licence holders or decision-making partners.

Managing water in the Murrumbidgee region

The Murrumbidgee region is part of the SCS (Figure 2), a network of rivers that feed into the Murray River between Hume Dam and the South Australian border. Interstate agreements and rules govern how water in the Murray River catchment is shared between NSW, Victoria, and South Australia. Interaction with water managers in the ACT, and the Snowy scheme, is governed by other relevant rules.

There is a long history of collaboration between state and federal agencies to manage the SCS. However, cross-border water management at such a large scale can be challenging. Changes to the *Murray-Darling Basin Agreement* (the Agreement; MDBA, 2006) must be agreed to by the Murray–Darling Basin Ministerial Council, which comprises members from all Basin states (New South Wales, Victoria, South Australia, Queensland, and the Australian Capital Territory) and the Commonwealth.

Figure 2: The Murrumbidgee region as part of the Southern Connected System



The Agreement is part of the *Federal Water Act 2007* (Parliament of Australia, 2007) and embodies the longstanding agreement between NSW, Victoria, and South Australia to share the water of the Murray River and the rivers that flow into it. Schedule 1 of the *Water Act 2007* sets out rules by which the Basin states agree to share water in Basin rivers. The agreement addresses the sharing of:

- NSW tributary inflows into the Murray River downstream of Albury, including the Murrumbidgee River and Billabong Creek

- inflows to the Menindee Lakes
- inflows to the Murray upstream of Albury.

The Agreement also provides:

- a definition of water available from the Snowy scheme to the Murrumbidgee River system (i.e., water from the Eucumbene, Tooma, upper Murrumbidgee, and upper Tumut rivers)
- rules for interstate water trading between in the southern connected system
- requirements for implementing the *Basin Salinity Management Strategy 2030* (BSMS2030), including end-of-valley salinity targets for each valley in the southern connected system.

The Agreement's broad water-sharing arrangements have remained the same since the original agreement was established in 1914. Other than changes made in 2011 to address issues identified during the Millennium drought, the last substantive change occurred in 1970 after 10 years of negotiations and led to the construction of Dartmouth Dam and an increase to South Australia's water entitlement.

In preparation for corporatisation in 2002 the Snowy scheme operator, Snowy Hydro Limited (SHL), was issued with a package of agreements, licences, and other regulatory instruments including the:

- *Snowy Water Inquiry outcomes implementation deed* (SWIOID; NSW Government, 2002)
- Snowy water licence (NSW Government, 2020)
- Snowy Compensation Deed
- *Blowering airspace deed* (NSW Government, 2002)
- bilateral deed.

The Snowy water licence was initially issued on 30 May 2002 under the *Snowy Hydro Corporatisation Act 1997* (NSW) and updated in 2010 and 2020. The licence defines SHL's water rights and obligations and strikes a balance between competing demands for water for hydroelectricity generation, consumptive use, and the environment. The licence allows SHL to collect, divert, store, and release water by and from Snowy scheme works for the 75-year term of the licence. The licence also defines the rules for releases into the Murray and Murrumbidgee rivers and imposes environmental flow release obligations on SHL for the benefit of the Snowy River and other rivers in the Snowy Mountains.

The *Blowering airspace deed* sets rules for managing airspace in Blowering Reservoir to reduce constraints on hydroelectricity generation from Tumut 1, Tumut 2, Tumut 3 and Blowering power stations. Releases from Blowering surplus to water supply requirements may be made at the request of SHL, subject to Tumut River channel capacity. SHL maintain a compensation reserve in the Scheme (e.g., Lake Eucumbene) to compensate for loss of regulated water. The reserve may be called out in severe drought. The compensation reserve is limited to the volume of pre-release, and the minimum volume of airspace.

Water in NSW is managed and shared under the *Water Management Act 2000* (the Act), with specific water sharing rules set out in water sharing plans. The Act sets out how we prioritise water sharing during normal operations. The highest priority is the environment, followed by basic landholder rights.

During extreme events, such as prolonged droughts, these priorities change. Basic landholder rights and essential town water services (authorised by an access licence) become the highest priority in the Basin, followed by the environment. Priority changes are triggered when a water sharing plan (or part of a plan) is suspended. The aim is to operate within plan rules for as long as possible, as they provide clarity for all users of the water sources.

Water sharing plans currently in operation in NSW for the Murrumbidgee Valley are:

- Murrumbidgee Regulated River Water Source (2016)
- Murrumbidgee Unregulated River Water Sources (2012)
- Murrumbidgee Alluvial Groundwater Sources (2020)
- NSW Murray-Darling Basin Porous Rock Groundwater Sources (2020)
- NSW Murray-Darling Basin Fractured Rock Groundwater Sources (2020).

The *Basin Plan 2012* establishes sustainable diversion limits (SDLs) which set how much water can be taken, on average, by towns, communities, and industries from Murray-Darling Basin water sources, thus leaving enough water to sustain natural ecosystems. SDLs were set for 29 surface water and 80 groundwater areas across the Murray–Darling Basin, informed by the best climate, past water use, water infrastructure and trade pattern information available at the time.

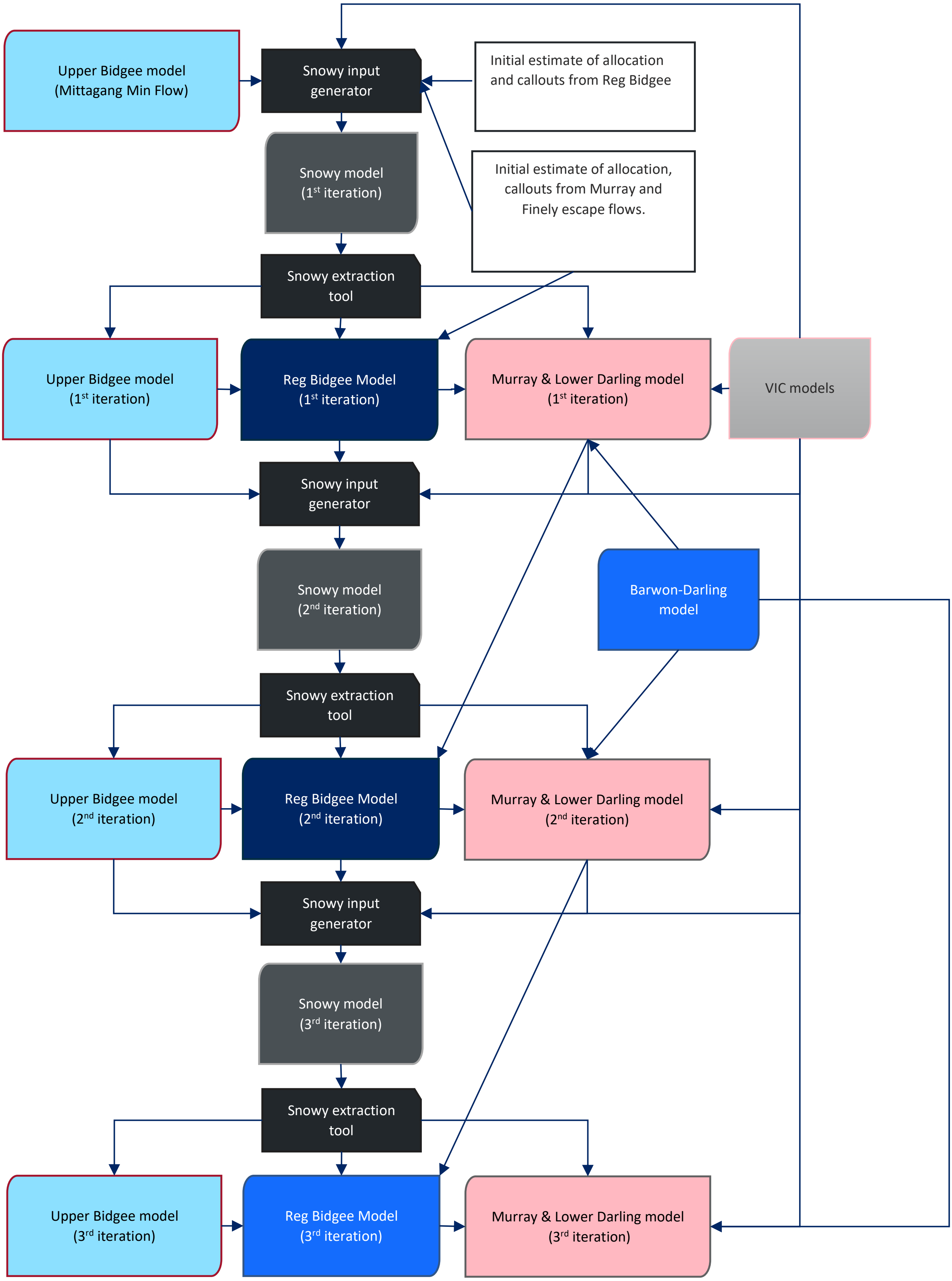
Current SDL estimates for the Murrumbidgee valley are 2,048.9 GL for surface water and 355.3 GL for groundwater, excluding fractured and porous rock groundwater sources. Extractions in the region are managed so that they remain within these limits, irrespective of licensed entitlement volumes. SDLs also ensure that, where a new regional water strategy option involves creating additional storage, and thus the potential to harvest and use more water, rules will apply to keep water use within limits. Modelling for each option addressed in this report accounts for the need to keep overall water use within SDLs.

The Basin Plan includes a Sustainable Diversion Limit Adjustment Mechanism (SDLAM) that allows SDLs to be increased by a maximum of 5% by implementing a suite of supply and efficiency measures.

Modelling the Southern Connected System

The SCS is represented by a suite of models including models of the Snowy Scheme and the upper Murrumbidgee, Murrumbidgee, Goulburn-Broken-Campaspe-Coliban-Loddon, Ovens, Kiewa, and Barwon-Darling river systems (DPIE, 2023). These models run on a range of modelling platforms and at different time steps (daily, weekly, and monthly). There are multiple points of feedback between the Snowy scheme, Upper Murrumbidgee, Murrumbidgee, and Murray models. The models are run through 3 iterations to address this feedback and ensure convergence is reached. Convergence is assessed as less than a 1% change in flows from the Snowy System. Figure 3 shows how information flows between the models for each of the iterations.

Figure 3: Modelling the Southern Connected system.



3. Assessment framework

Modelled options.

Chapter 4 of the *Draft regional water strategy: Murrumbidgee* (DPIE, 2022) lists 53 options to be considered. A subset of 8 of these options (detailed in Table 2) were modelled. These options have quantifiable impacts on hydrology, as well as quantifiable costs and benefits, and therefore were deemed suitable for modelled assessment.

Option 36a is a combination of options 35 and 36 and is not detailed in the draft strategy; this means 13 scenarios were modelled including the base case scenario.

Each of the options in Table 1 were modelled using historical climate datasets. Those that passed the rapid cost-benefit analysis were hydrologically assessed using the long-term (stochastic) and dry future climate change (NARCliM) datasets.

Table 1: Options assessed using hydrologic modelling for the draft Murrumbidgee regional water strategy.

Category	Description
Base case	Current conditions as codified in the 2020 Water Sharing Plan (1/7/1891–30/6/2020), infrastructure and policy settings, with Held Environmental Water (HEW) and Planned Environmental Water (PEW) represented as environmental use
Option 13: investigate water access licence conversion	Test the potential risks and benefits of allowing voluntary conversion from general security (GS) to high security (HS) water access licences in the Murrumbidgee regulated river, for the following 2 variations: i)10% of GS entitlement converted to HS entitlement ii)50% of GS entitlement converted to HS entitlement

Category	Description
Option 33a, b, and c: investigate alternatives for increased storage capacity	The storage's primary purpose is to address the Tumut River's lack of capacity downstream of Blowering Dam to carry additional flow diverted by the Snowy Scheme. This will assist in overcoming out of balance issues between Burrinjuck and Blowering reservoirs and will also allow the Tumut River to be run at capacity less of the time, helping to reduce erosion in the river. 33a: An on-river storage of 47 GL capacity on the Tumut River near the Murrumbidgee River confluence 33b: An on-river dam of 20 GL capacity on the Murrumbidgee River near Gundagai 33c: An on-river dam of 1,000 GL capacity on the Murrumbidgee River near Gundagai
Option 35: Install gravity pipeline along Tumut River	Investigate the feasibility of installing a 2,000 ML/day gravity pipeline along the Tumut River to address channel capacity constraint by enabling release of higher flows downstream of Blowering Dam
Option 36: enlarged Blowering Dam	Investigate the water-supply impacts of increasing the active storage of Blowering Dam by 200 GL to 1,831 GL. Alternatives to be considered include raising the dam by 4 m to increase active storage in the Murrumbidgee region by 200 GL; with a corresponding increase in the dam capacity of 12% with 2 different volumes of pre-release compensation airspace: i) 100 GL airspace reserved for Snowy Hydro Limited releases ii) 200 GL airspace reserved for Snowy Hydro Limited releases
Option 36a: enlarged Blowering Dam and Tumut gravity pipeline	Combination of option 35 and 36 with 2 different volumes of pre-release compensation airspace: i) 100 GL of pre-release compensation airspace ii) 200 GL of pre-release compensation airspace
Option 37: enlarged Burrinjuck storage reservoir	Investigate the feasibility of increasing the storage capacity of Burrinjuck Dam by 672 GL to 1,700 GL, increasing the region's active storage to increase reliability and security of supply

Category	Description
Option 38: enlarged Bundidgerry off-river storage and a new transfer canal	Investigate enlarging the existing Bundidgerry storage in the mid-Murrumbidgee region to 5,490 ML to address delivery issues such as supply shortfalls in the summer months, and improve the system's efficiency
Option 39: augment Tombullen storage and modify operational changes	Investigate potential operational changes for Tombullen storage to mitigate water quality issues

Climate datasets

To support the development of the draft NSW Murray and Murrumbidgee regional water strategies, this document presents the results of climate and baseline hydrological modelling of 3 plausible climate scenarios, and their respective implications for regional water resources. The 3 climate scenarios are:

- the historical climate as reflected in instrumental observations (hereafter referred to as historical climate),
- the long-term historical climate
- a dry future climate.

Historical climate

The historical climate scenario is based on more than 130 years of recorded daily rainfall, temperature, and evaporation data (1889–2020). This climate scenario helps us understand how climate challenges and proposed regional water strategy options would respond if future climate repeats recorded climate conditions.

Long-term historical climate

The long-term historical climate scenario is derived stochastically from historical daily climate data and paleoclimate information including:

- 500 years of climate pattern data detected in paleorecords such as tree rings, river sediments, cave deposits, ice cores and so on. This data shows us that both longer and deeper droughts and stronger wet periods (as compared with recorded climate) occurred before climate observations began.
- records and scientific knowledge of major southern Murray-Darling Basin climate drivers, including the Interdecadal Pacific Oscillation (IPO).

This climate scenario helps us understand how proposed regional water strategy options would respond to climate challenges under the extremes of droughts and wet periods indicated by the 500 years of paleorecords of climate data.

Dry future climate

The dry future climate scenario was developed by adjusting long-term historical climate scenario rainfall, temperature, and evapotranspiration data using regionally downscaled factors generated from the NSW and Australian Regional Climate Modelling (NARCliM) 1.0 project.

The dry future climate scenario adopted is *Special Report on Emissions Scenarios* (SRES) A2 (a high carbon emissions scenario), and thus results in higher projected climate change impacts on the region in 2060–2079. We selected this emissions scenario for the NSW regional water strategy program to understand how a drying climate would impact regional water resources, and how different regional water strategy options would perform. The scenario is not a climate change forecast, but rather one of the possible future outcomes our long-term water strategy must recognise.

Outputs for option assessment

We interpreted each option's performance using the metrics presented in Table 2. Third-party impacts on different licence classes were assessed using mean annual diversions. The SDL assessment period and mean annual diversions are aligned over the period 1/7/1895–30/6/2010. Allocations were used to assess changes to allocation reliability. We used storage information to assess impacts on harmony operations between Blowering and Burrinjuck storages and associated spilling changes, and supply reliability. Streamflow locations were selected to represent alterations in the flow regime at key locations throughout the regulated Murrumbidgee River system. Changes to end-of-system flows have subsequent impacts for the Lower-Darling and Murray river system.

Blowering Dam's full storage volume (FSV) is 1,631.41 GL, and its dead storage volume (DSV) is 23.99 GL (approximately 1.5% of FSV). Burrinjuck Dam's FSV is 1,028 GL; its DSV is 3.25 GL or approximately 0.3% of FSV. Values shown in the storage behaviour tables for percentage of time below FSV are based on these current storage volumes. Some options consider increasing storage capacity by increasing FSV.

Water NSW aims to maintain specified airspace in Blowering Dam to support Snowy scheme hydroelectricity generation. A pre-release compensation reserve (PCR) is maintained in the Snowy scheme to compensate for this.

Airspace provision is declared by SHL, and as such can vary. We agreed with SHL to fix airspace at 100 GL for the options modelling. We examined this parameter's sensitivity by considering a 200 GL airspace for options that proposed increasing storage volumes (while recognising SHL could increase variable airspace, and thereby influence any increased storage capacity). We considered metrics for assessing percentage of time below the target airspace. The PCR can be called out from the Snowy scheme when Blowering Dam is forecast to go below 160 GL (or approximately 10% of FSV included in the metrics for measuring PCR callout sensitivity).

Under base case harmony operations, water orders are directed to Burrinjuck Dam when it is above 80% of FSV. Consequently, this has been included in the output metrics.

The regulated river supplementary entitlement use metric only considers consumptive use and does not consider environmental use as this is accounted separately. The Lowbidgee supplementary use represents water diverted from the river for environmental purposes. Data on diversions for consumptive use is obtained at Redbank North and for environmental use of supplementary entitlements from diversions at Nimmie-Caira, Yanga, Glen Dee, Bill's Pipe, Patto's Pipe, LF3 river pump and the Western Lakes. Separate entitlement caps of 201,382 ML and 545,618 ML are associated with the respective consumptive and environment use.

Murrumbidgee inter-valley transfers (IVT) are represented by a non-consumptive demand node below Balranald and are the average IVT transfer from the Murrumbidgee to the Murray River.

Table 2: Performance metrics

Category	Component
Mean annual diversions	General security (GS)
	High security (HS)
	Murrumbidgee Irrigation conveyance (MIC): river diversion does not consider returns
	Coleambally Irrigation conveyance (CIC): river diversion does not consider returns
	Premium high security (PHS)
	Domestic and Stock
	Local water utilities (total of towns)
	Regulated river supplementary (excluding environment)
	Lowbidgee consumptive supplementary

Category	Component
	Inter-Valley Transfer to Murray (IVT)
	Held environmental water (HEW)
	Lowbidgee environment supplementary
	Planned environmental water (PEW)
Average allocations	General security average effective allocation 1 July
	General security average effective allocation 30 September
	General security average effective allocation 30 June
	General security average allocation 1 July
	General security average allocation 30 September
	General security average allocation 30 June
	High security average allocation 1 July
	High security average allocation 30 September
	High security average allocation 30 June
	Coleambally irrigation conveyance average allocation 1 July
	Coleambally irrigation conveyance average allocation 30 September
	Coleambally irrigation conveyance average allocation 30 June
	Murrumbidgee irrigation conveyance average allocation 1 July
	Murrumbidgee irrigation conveyance average allocation 30 September
	Murrumbidgee irrigation conveyance average allocation 30 June
Storage behaviour:	Spills

Category	Component
• Blowering Dam • Burrinjuck Dam	% of time below enlarged FSV
	% of time below enlarged FSV-airspace (100 GL; Blowering Dam only)
	% of time below FSV
	% of time below FSV airspace (100 GL; Blowering Dam only)
	% of time below 80%
	% of time below 50%
	% of time below 25%
	% of time below 10%
	% of time below 5%
Mean annual streamflow	Murrumbidgee River at Gundagai (410004)
	Murrumbidgee River at Gundagai (410001)
	Billabong Creek at Darlot (410134)
	Murrumbidgee River at Balranald (410130)

Modelling analysis

The river system models were run across different time periods and replicates, to allow for the different models of different organisations.

To assess the portfolio of options overall, we used the period of historical record (1/7/1891-30/6/2020; see sections 4–12).

Long-term climate impacts were evaluated using the 10,000-year stochastic and NARCliM dry future climate data sets (see section 13).

To assess economic impacts 1,000 replicates of 40 years were used; these were subsampled from the stochastic data set.

Our ecological analysis is based on the stochastic and NARCliM dry future climate data sets.

Economic analysis

Each of the thousand 40-year replicates used in economic assessment was initialised with the same storage volumes. These were:

- for Blowering Dam, 1,360,363 ML
- for Burrinjuck Dam, 828,761 ML

These values were based on storage volumes at 1/1/2020. Results are presented in a separate report.

Post-processed estimates of high security and local water utility shortfalls were input to the economic analysis models, which was necessary because the river system models do not take demand restrictions related to forecast resources into account. Moreover, short-term delivery shortfalls in the model do not represent real restrictions.

The forecast resource is calculated as the sum of:

- combined Burrinjuck and Blowering active storage volume (ASV),
- the minimum expected inflow from the current month to the end of the water year (Table 3),
- the minimum expected inflow for the second water year (Jul-Jun Table 3),

the remaining required annual release (RAR) to be delivered by SHL; and

- the forecast RAR for the next water year.

Table 3: Minimum expected inflow into Murrumbidgee River system

Month	Minimum inflow (GL)
January-June	41.6
February-June	28.4
March-June	24.6
April-June	19.2
May-June	12.7
June	2.2

Month	Minimum inflow (GL)
July-June	272.9
August-June	234.2
September-June	160.6
October-June	107.8
November-June	87.4
December-June	66.6

The restrictions applied based on the daily forecast resource are shown in Table 4.

Table 4: Local water utility and high security restrictions

Forecast resource (GL)	Local water utility restriction (%)	High security restriction (%)
0	0	0
100	15%	6%
200	29%	12%
300	44%	18%
400	58%	23%
500	73%	29%
600	88%	35%
700	100%	41%
800	100%	49%
900	100%	56%
1,000	100%	67%
1,100	100%	82%

Forecast resource (GL)	Local water utility restriction (%)	High security restriction (%)
1,200	100%	98%

High security shortfall processing

The Murrumbidgee model does not separate crops that rely on general security water from crops that rely on high security water. Instead, the entire reach and/or state share is lumped into one crop demand node with a portfolio of licenses.

This makes it difficult to determine where there are shortfalls for high-security watered crops because the high security licence is prioritised over the general security licence, so all high security allocations are exhausted early in the water year.

Daily unrestricted crop demand is generated via a Python script that emulates the crop water demands in the model if they had unlimited access to irrigation water. This demand is aggregated to a cumulative time series use pattern over the water year for respective nodes. Assuming all high security entitlement is demanded every year, we compared this pattern to the restricted entitlement to determine the shortfall. For example, restricting high security demand by 50% restriction for the first 2 months of the water year and allowing 100% of the allocation thereafter will not trigger a shortfall, since high security demand did not exceed 50% of the entitlement in the first 2 months. If a shortfall is triggered, its volume is based on the difference between unrestricted cumulative demand for the water year, and the entitlement multiplied by the restriction.

Local water utility shortfall processing

Unrestricted LWU demands are calculated using a Python script and accumulated from the start for the water year, with perfect knowledge of future net evaporation. Where the projected accumulated demand to the end of the water year is less than the entitlement multiplied by the restriction, a restriction is assumed to have occurred. This accounts for restrictions that can be applied early in the water year, and then removed if inflows occur that increase the allocation.

Ecological analysis

The ecological assessment compares the portfolio of options against the base case for the long-term climate data sets of 10,000 years without and with NARCliM dry future climate projections. Flows at a range of sites are processed through different metrics that describe flow-based ecological regime differences. Flow sites and associated metrics are addressed in more detail in the ecological assessment report.

Murrumbidgee Irrigation Area loss rates

The Murrumbidgee model was calibrated to accommodate 2 distinct Murrumbidgee Irrigation Area (MIA) supply escape loss rates:

- 26% (before 2012)
- 16% (from 2012 onward).

Most analyses were conducted assuming the pre-2012 rate, although the rate from 2012 onward would better reflect future behaviour. Subsequent work should utilise the 2012 onward rate.

We ran the models again to assess whether altering the loss rates would impact the conclusions drawn from option-versus-baseline comparisons. The comparisons revealed negligible differences.

4. Option 13: Investigate water access licence conversion (general security to high security)

Option description

This option involves evaluating the impacts of allowing consumptive general security (GS) entitlements to be voluntarily converted to high security (HS) entitlements. To ensure SDL compliance, we derived a conversion factor for the converted entitlements and increased the storage reserve by the additional high security entitlements.

To bookend the amount of water that could be converted, we considered 2 conversion options:

- conversion of 10% of general security entitlement to high security
- conversion of 50% of general security entitlement to high security.

Held environmental water entitlements were not converted (see the section on assumptions below).

Model configuration and assumptions

The model is structured with lumped irrigation water use on a reach basis. Each water user in a reach has a portfolio of entitlements, including general and high security entitlements (Table 5). These entitlements are used to irrigate crops including annual pasture, barley, canola, corn, cotton, fruit trees, rice, soya beans, summer cereal, vegetables, vines, winter cereals, pasture, and wheat.

Area for annual crops is based on total available water at time of planting.

Table 5: Consumptive use of Murrumbidgee high and general security licenced water

Water user group	High security (unit share)	General security (unit share)
MIA	285,432.2	601,206.3
CIA	8,825.9	357,369.0

Water user group	High security (unit share)	General security (unit share)
Blowering to Brungle	1,783.5	4,311.5
Burrinjuck to Gundagai	1,985.0	4,713.0
Gundagai to Wagga	887.0	12,399.5
Wagga to Beavers Creek Offtake	300.0	4,298.0
Beavers Creek Offtake to Currawarna	5.0	728.0
Currawarna to Berembed	28.0	4,540.0
Bundidgerry Creek	50.0	2,991.0
Berembed to Old Man Creek Return	0.0	2,832.0
Old Man Creek System	0.0	11,352.0
Old Man Creek to Narrandera	1,635.0	7,706.6
Narrandera to Yanco Weir	50.0	2,860.0
Yanco Weir to Coleambally main offtake	193.5	2,578.0
Coleambally main offtake to Gogeldrie	450.0	609.0
Gogeldrie Weir to Darlington Point	2,441.3	27,522.9
Darlington Point gauge to Carrathool	3,945.3	38,312.2
Carrathool to Hay Weir	7,839.1	96,744.2
Hay Weir to Maude	6,728.8	62,120.4
Maude to Redbank	5,797.9	3,889.0
Redbank to Balranald	0.0	8,801.4
Balranald to Murray	0.0	2,580.0

Water user group	High security (unit share)	General security (unit share)
Yanco offtake to Morundah	28.0	4,395.0
Colombo Creek	500.0	9,472.8
Innes Bridge to Jerilderie	392.0	5,371.2
Jerilderie to Forest Creek offtake	383.0	25,480.8
Forest Creek	302.0	6,761.8
Morundah to Yanco Bridge	0.0	9,157.0
Yanco Bridge to Conargo	173.7	20,357.3
Conargo to Wanganella	0.0	15,140.9
Wanganella to Darlot	40.0	4,001.3
Downstream of Darlot gauge	123.5	9,027.0
Inactive	17,893	47,468.9
Total	348,212.7	1,417,098.0

A pattern-demand water user node and associated supply point was inserted upstream of Gogeldrie Weir gauge. The pattern demand is normalised and based on the monthly average irrigation demand (1/7/1891–30/6/2020) for high security water use at MIA for citrus, other fruit trees and vines (Table 6).

Daily demand is calculated by multiplying monthly pattern demand by entitlement share at the node, the high security allocation then dividing by the number of days in the month. This ensures the year's high security allocation is consumed. In the base case we force the demand to zero, to ensure there is no diversion at this node, and remove its entitlement from the resource allocation system.

Table 6: Normalised monthly demand pattern.

Month	Pattern
January	0.225733
February	0.155548
March	0.120993
April	0.062159
May	0.017548
June	0.005368
July	0.002728
August	0.0061
September	0.018302
October	0.046956
November	0.123627
December	0.214939

We configured the high security reserve using a Source reserve function, which was modified to include an additional reserve for entitlements converted to high security.

- For the base case, the value of entitlements converted to high security was set to zero.
- For general security to high security conversion options, we set the value of entitlements converted to high security to the additional high security entitlement.

We recorded diversions for all system entitlements (*consumptive usage*). Diversion types included:

- supplementary
- premium high security
- high security

- domestic and stock
- local water utilities
- Murrumbidgee Irrigation conveyance
- Coleambally Irrigation conveyance.

We also configured the model with a scenario input set (*GSHSConversion*), which points to a local *conversion_inputset.txt* file that reloads on run. This file contains variables to set the general and high security entitlements.

We ran the model iteratively until total average annual diversions were within 0.1% of the base case result to ensure sustainable diversion limits were not exceeded. This iterative process used a modified binary search algorithm to find the solution. The program solves for a conversion factor that meets the convergence objective. The basic process is:

1. read setup information, including entitlements and proportion of general security entitlement to be converted (0.1 or 0.5)
2. read base case results.
3. start with an initial conversion factor of 0, then apply a conversion factor of 1, and then apply interpolated conversion factors.
4. based on the amount of conversion and the conversion factor, write the *conversion_inputset.txt* file
5. write the batch file to run the Murrumbidgee Source model from the command line.
6. run the batch file.
7. read, summarise (GL/y for licence type from 1/7/1895-30/6/2010), and write out results.
8. check that the solution lies within upper and lower bound conversion factor of 0 and 1. If so, interpolate a new conversion factor; if not, exit
9. if less than 8 iterations and the absolute difference in total demand is greater than 0.1%, go to Step 3.

Assumptions

Licences were converted on a *pro rata* basis and most general security entitlements (including 'sleeper', or unused, licences) were decreased by the same proportion (0.1 or 0.5).

Converted general security licences were summed, then multiplied by a conversion factor, which becomes the high security entitlement at the high security conversion node. No other high security entitlements were modified.

This approach assumed that the total general security licence pool will change proportionally and that converted high security licences will be fully utilised at Gogeldrie Weir. In practice the full allocation is unlikely to be used each year, and diversions would still comply with sustainable diversion limits. We located the node within the system where there is substantial high security crop demand, but in practice water could be diverted under this licence from anywhere in the system. This may affect delivery efficiency and losses.

In the model, planting behaviour functions and crop mix are fixed at the nodes; in practice both are likely to change. Moreover, different crop types will have different water requirements which will also affect planting decisions.

We explicitly modelled environmental flows of held environmental water entitlements for a range of basin environmental asset demands. The distribution of water to these assets is controlled by an environmental flow manager that holds a portfolio of entitlements including general and high security. General and high security environmental entitlements are, respectively, 401,376 ML and 10,199 ML. Because we do not know how environmental water licences will be converted, we did not consider the conversion of these entitlements in this assessment.

We did not consider entitlements associated with Snowy water savings. Snowy water savings general and high security entitlements are, respectively, 76,489 ML and 1,885 ML. These are used for environmental flow releases outside the regulated Murrumbidgee River system, so it is not clear if they could be converted.

We assumed that, if there were no changes to overall licenced water use and water security in the regulated Murrumbidgee River, there would be no feedback to either the Snowy or Murray river system models. We ran this model independently of other models for this reason.

Total diversion for the base case and each of the conversion options matched (within 0.1%), so we assumed SDL compliance. Diversions were assessed across a period consistent with the SDL assessment period of 1/7/1895 to 30/6/2010. However, the model used for the base case is not the official SDL accounting scenario (the BDL model); so, we have instead assumed the base case is SDL compliant and that, by matching base case total diversions, the conversion options would be compliant. This may not be the case.

Moreover, compliance is not limited to total diversions; existing entitlements must also continue to be reliable. We assumed that, if the reliability of other entitlements remains within 3%, the result would comply with the requirements of the *Water Management Act 2000*. This may not be so, however, because entitlements might be unreliable even if averages remain the same — particularly, and possibly most significantly, in dry conditions.

Modelling results

This section presents the results of modelling a 10% and 50% conversion of general security entitlements to high security. Conversion factors for the 10% and 50% conversions are 0.42 and 0.48, respectively.

The 50% conversion factor is larger than the 10% conversion factor in part because a considerably larger reserve was set aside for high security users in modelling this option than was set aside in base case modelling.

In modelling this option, we increased the reserve only by the additional high security entitlement. If more entitlements are converted the reserve decreases, and high security entitlements may be less reliable.

Water diversion changes

Table 7 shows average annual diversions (from 1/7/1895 to 30/6/2010) for base case consumptive use, and values for 2 different percentages of general to high security conversions. It shows that for a 10% and 50% reduction in general security entitlements, there is:

- a corresponding diversions reduction of 8% and 47%, respectively
- a corresponding increase in high security diversions.

Reducing general security diversions by 56.8 GL and 315.9 GL increases high security diversions by 58.1 GL and 326.4 GL, respectively. There are only minor impacts on other entitlements with a 10% conversion.

Overall, total system diversions remain the same for both options. However, Murrumbidgee Irrigation conveyance and inter-valley transfers are reduced by 8% and 9%, respectively, with a 50% conversion. This might not be acceptable in terms of sustainable diversion limits. Converting fewer high security licences may reduce this impact.

Table 7: Mean annual water diversions for the base case and Option 13 ((i) 10% and (ii) 20% conversion of general to high security entitlement)

Water diversions (GL/y)	Base Case	Option 13(i)	Change (%)	Option 13(ii)	Change (%)
General Security	674.8	618.0	-8%	358.9	-47%
High Security	294.1	352.1	20%	620.5	111%
Murrumbidgee Irrigation Conveyance	161.6	163.0	1%	148.5	-8%
Coleambally Irrigation Conveyance	103.8	103.7	0%	103.8	0%

Water diversions (GL/y)	Base Case	Option 13(i)	Change (%)	Option 13(ii)	Change (%)
Premium High Security	18.1	18.0	-1%	17.9	-1%
Stock and Domestic	19.4	19.4	0%	19.5	1%
Local Water Utility	10.1	10.1	0%	10.1	0%
Supplementary	116.0	115.8	0%	116.8	1%
Lowbidgee consumptive	48.6	48.8	0%	50.2	3%
Inter-valley transfer	105.5	104.2	-1%	96.2	-9%
Total diversions	1,552.0	1,553.1	0%	1,542.4	-1%

Annual distribution of total general and high security diversions from 1/7/1891–30/6/2020 are shown in Figure 4 and Figure 5 respectively. These show a reduction in general security use in line with the general security licence transfer. The 50% transfer option is approximately 47% of general supply diversions — that is, an average 315.9 GL reduction in general security sees a 326.4 GL average increase in high security diversions.

Figure 4: Total general security annual diversions for the base case and Option 13 ((i) 10% and (ii) 20% conversion of general to high security entitlement)

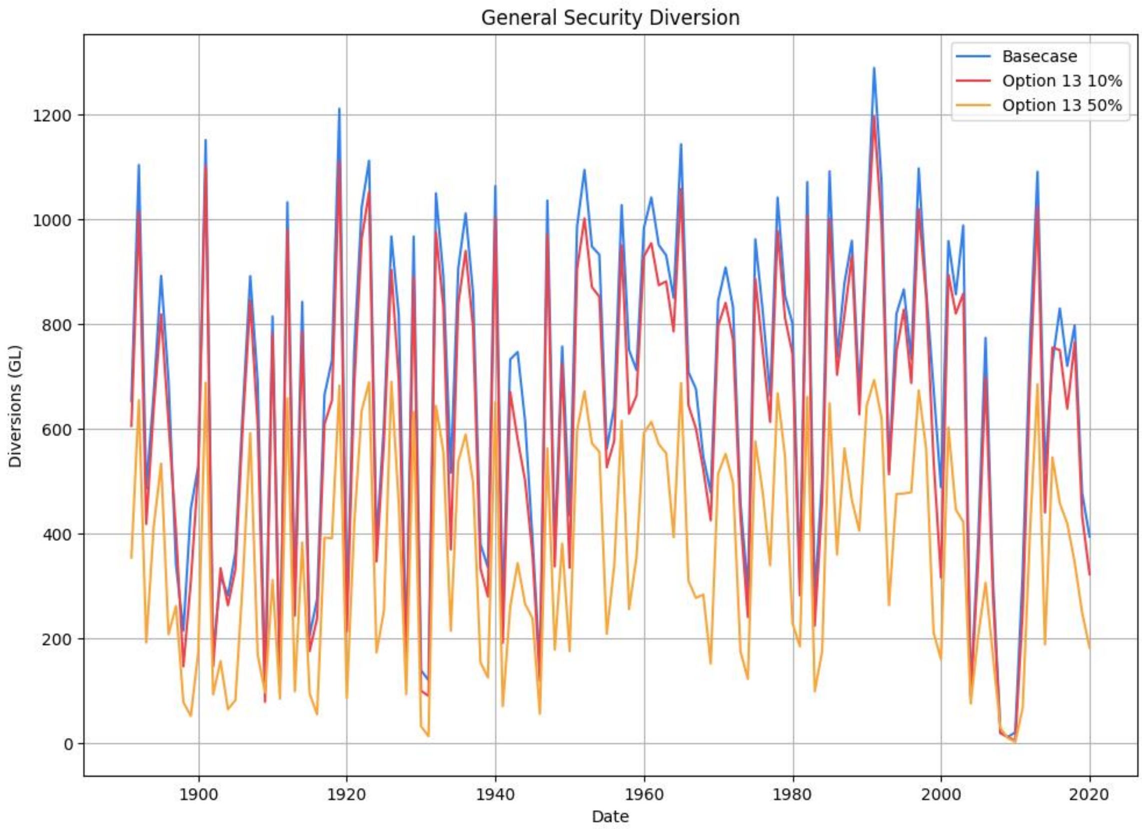
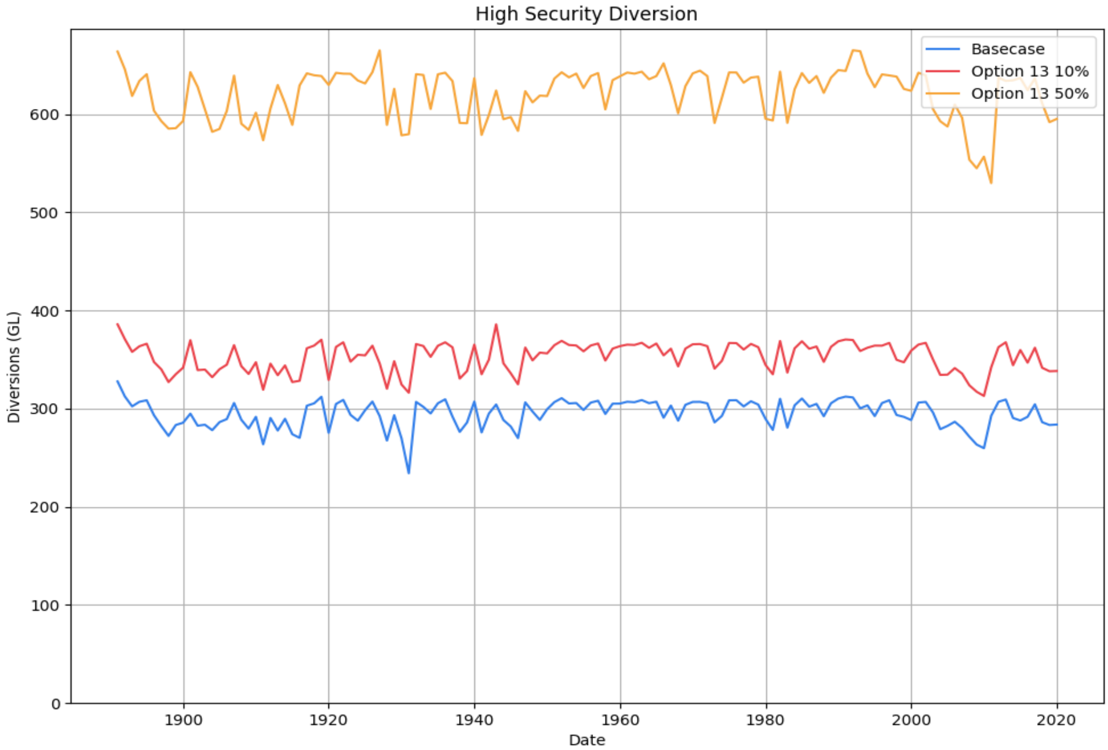


Figure 5: Total high security annual diversions for the base case and Option 13 ((i) 10% and (ii) 20% conversion of general to high security entitlement)



Environmental water delivery changes

Table 8 shows average annual held water, and Lowbidgee supplementary and planned environmental water deliveries, from 1/7/1895 to 30/6/2010 under the base case and both conversion options. When 10% and 50% of licences are converted, overall environmental water is increased by 2% and 5%, respectively. This is mostly due to increased HEW allocations, which in turn are due to more reliable general security entitlements (particularly at the start of the water year). Lowbidgee supplementary access impacts are small with a 10% conversion but increase with a 50% conversion. The increase is due to less frequent 5,000 ML/day flows at Balranald, which allow supplementary water to be diverted for longer periods.

Table 8: Mean annual environmental water delivery for the base case and Option 13 ((i) 10% and (ii) 20% conversion of general to high security entitlement)

Water delivery (GL/y)	Base Case	Option 13(i)	Change (%)	Option 13(ii)	Change (%)
Held environmental water	144.6	151.6	5%	158.8	10%
Lowbidgee environment	70.0	69.3	-1%	72.3	3%
Planned environmental water	133.4	132.7	-1%	133.1	0%
Total environmental water	**348.0**	**353.6**	**2%**	**364.2**	**5%**

Alterations in allocation reliability

Start, end and September 30 water year allocations from 1/7/1891 to 30/7/2020 for the base case and conversion of general to high security entitlements options are shown in Table 9.

The results show there are only small impacts on existing licence security for the 10% option. However, general security allocations improve for the 50% option because the available resource is divided by a smaller entitlement share. By the end of the water year this impact is largely resolved, as the difference between forecast and observed resource is reconciled.

Table 9: Allocations for the base case and Option 13 ((i) 10% and (ii) 20% conversion of general to high security entitlement)

Average allocations (%)	Base Case	Option 13(i)	Difference (%)	Option 13(ii)	Difference (%)
General security effective allocation on 1 July	39%	41%	2%	51%	12%
General security effective allocation on 30 September	61%	62%	1%	67%	6%
General Security effective allocation on 30 June	80%	81%	1%	81%	1%
General security allocation on 1 July	31%	34%	3%	45%	14%
General security allocation 30 September	53%	55%	2%	62%	9%
General Security allocation on 30 June	72%	74%	2%	75%	3%
High security allocation on 1 July	93%	93%	0%	92%	-1%
High security allocation 30 September	96%	96%	0%	96%	0%
High security allocation on 30 June	98%	98%	0%	98%	0%
Coleambally Irrigation conveyance allocation on 1 July	88%	88%	0%	91%	3%
Coleambally Irrigation conveyance allocation 30 September	92%	92%	0%	93%	1%
Coleambally Irrigation conveyance allocation on 30 June	95%	95%	0%	96%	1%
Murrumbidgee Irrigation conveyance allocation on 1 July	76%	77%	1%	81%	5%
Murrumbidgee Irrigation conveyance allocation 30 September	85%	86%	1%	87%	2%

Average allocations (%)	Base Case	Option 13(i)	Difference (%)	Option 13(ii)	Difference (%)
Murrumbidgee Irrigation conveyance allocation on 30 June	92%	92%	0%	92%	0%

Effective general security reliability on 30 September, and at the end of the water year, are shown in Figure 6 and Figure 7, respectively. These show a September increase in effective general security reliability in both cases, largely due to a similar resource being divided among a smaller number of shares. This improvement decreases by the end of water year, particularly for the 50% conversion.

Figure 6: Effective general security allocation reliability on 30 September for the base case and Option 13 ((i) 10% and (ii) 20% conversion of general to high security entitlement)

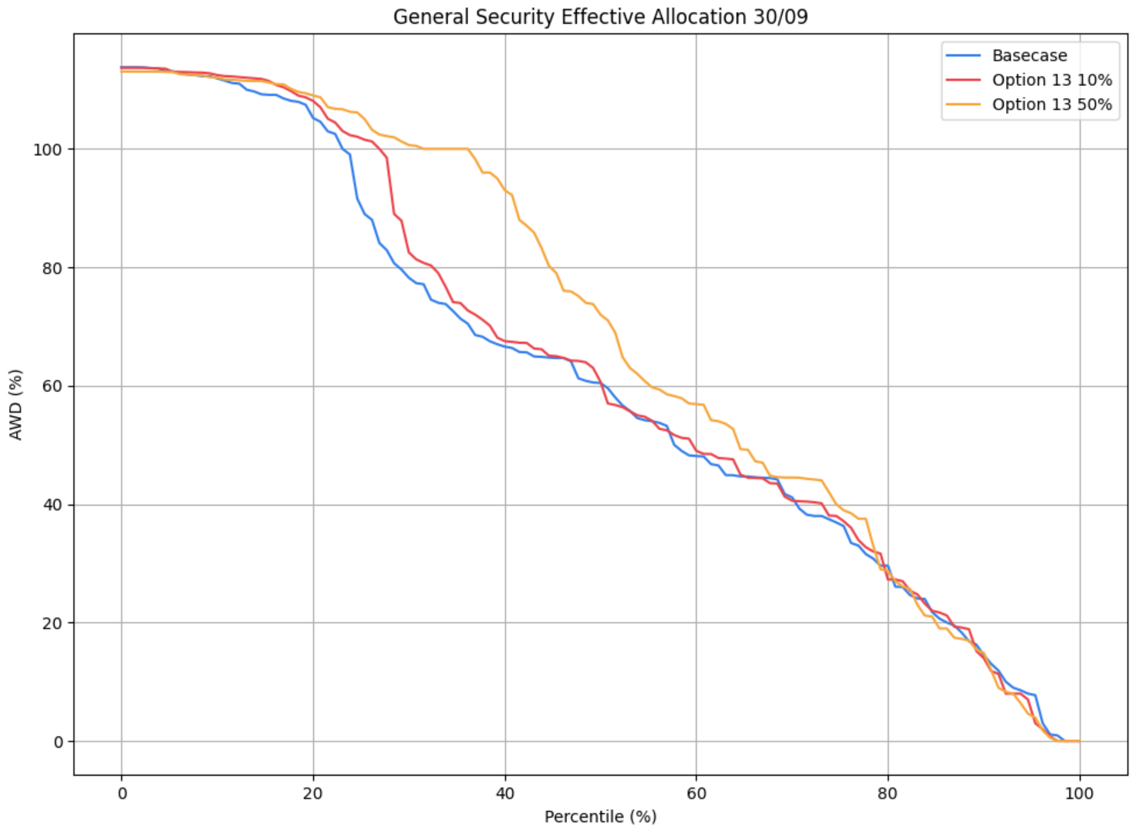
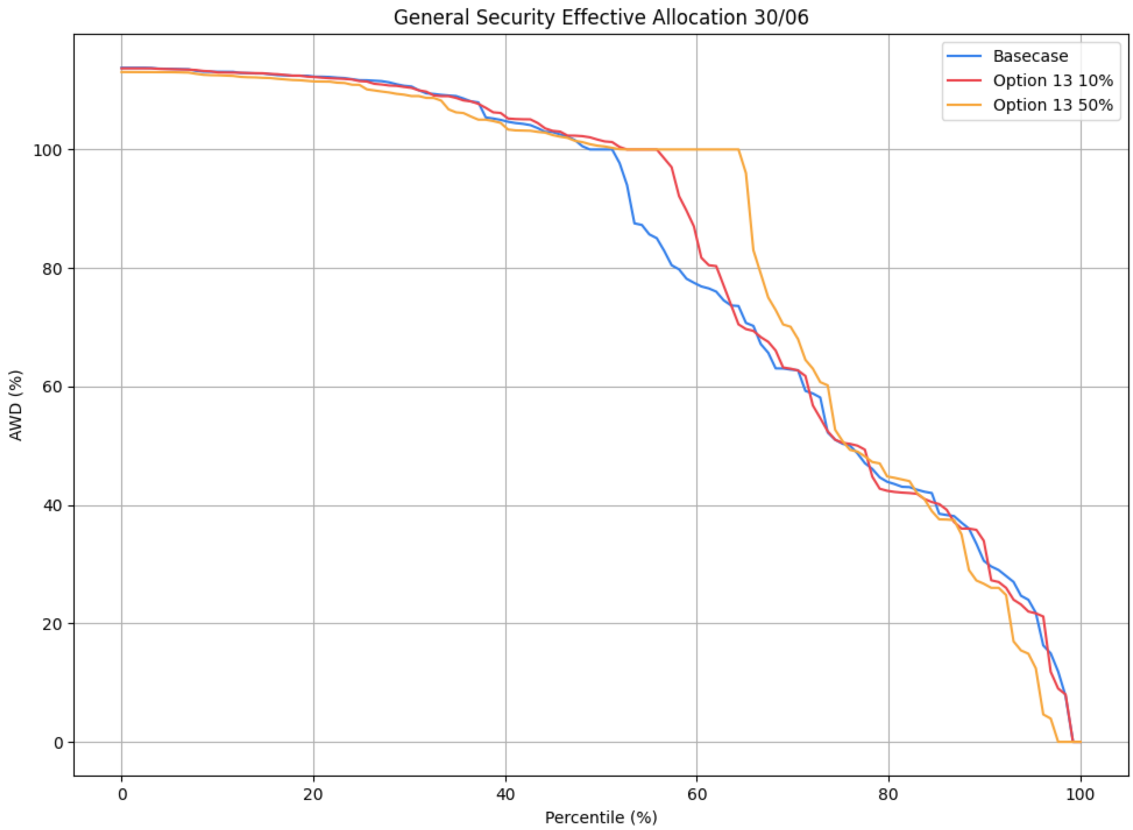


Figure 7. End of water year (30/6) effective general security allocation reliability for general security for the base case and Option 13 ((i) 10% and (ii) 20% conversion of general to high security entitlement)



High security reliability on 30 September and at the end of the water year are shown in Figure 8 and Figure 9, respectively. These show an improvement in high security reliability for both cases, with substantial improvement for the 50% conversion due to the extra reserve set aside for the additional high security entitlement.

Figure 8. 30 September high security allocation reliability for the base case and Option 13 ((i) 10% and (ii) 20% conversion of general to high security entitlement)

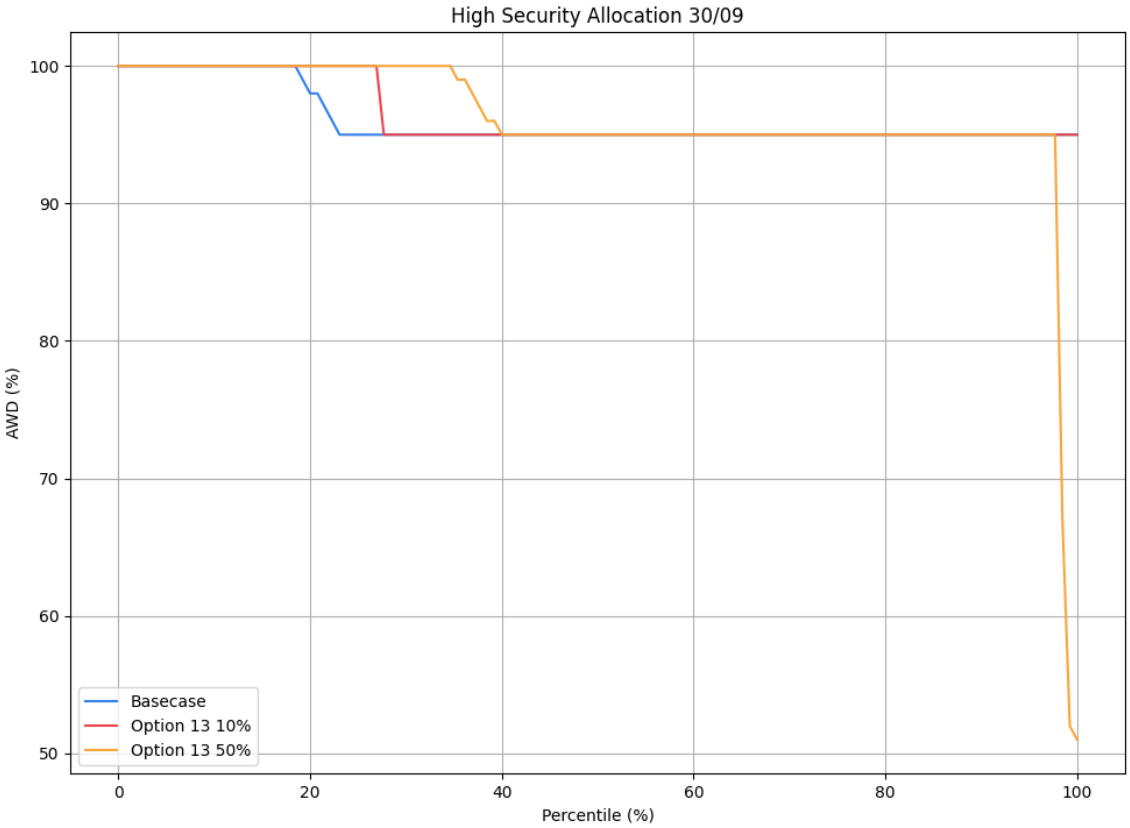
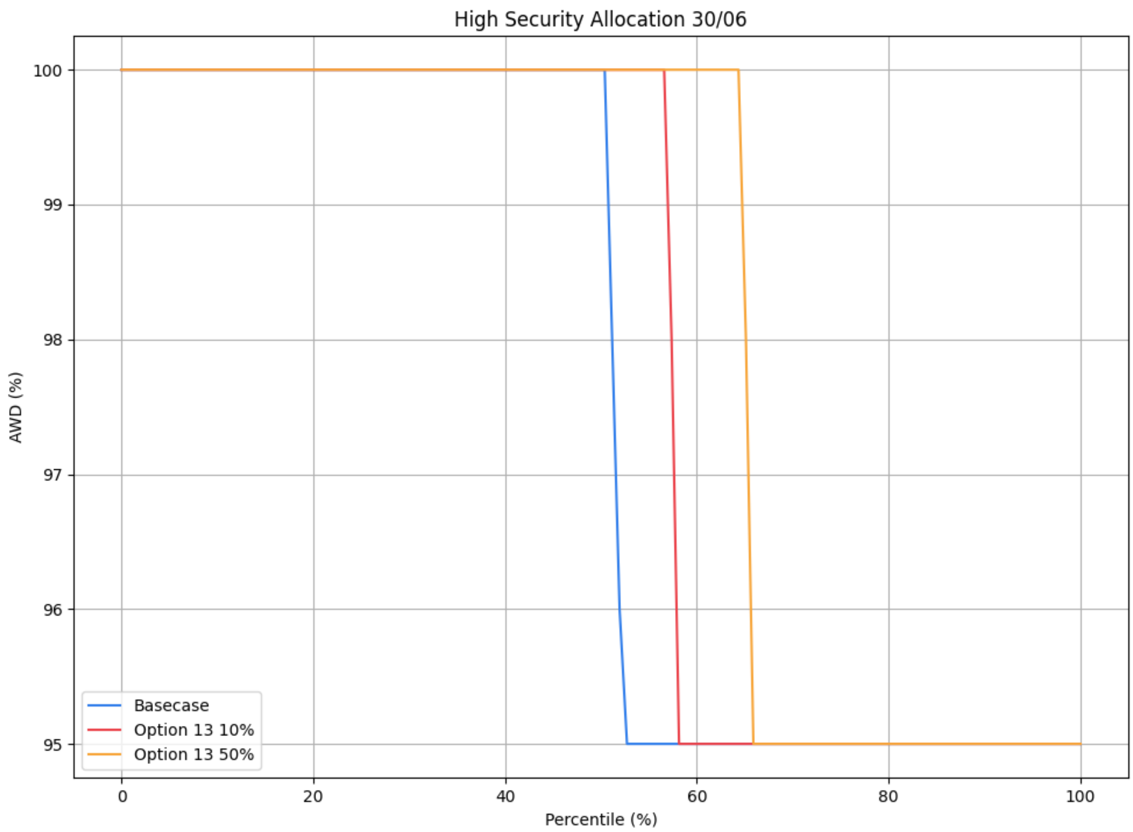


Figure 8 shows that the 50% conversion has a reduced allocation on the planting date which would impact on the planting decision. However, the reliability has improved by the end of the year (Figure 9). This suggests that the reserve is sufficient but could be more optimally spread across the year with less reserve required earlier in the water year.

Figure 9. End of water year high security allocation reliability for the base case and Option 13 ((i) 10% and (ii) 20% conversion of general to high security entitlement)



Storage behaviour changes

Blowering Dam and Burrinjuck Dam storage behaviour for the base case and conversion of general to high security entitlements options are shown in Table 10 and Table 11. The table shows there is limited impact on storage behaviour because total system diversions were matched to the base case. The increased reserve had a minor impact on the percentage of time at lower storage volumes (1% and 7% less time below 50% volume in Burrinjuck for the 10% and 50% conversions respectively). The increased reserve in the 50% conversion caused greater spills in Burrinjuck and Blowering dams.

Table 10. Blowering Dam and Burrinjuck Dam spill behaviour for the base case and Option 13 ((i) 10% and (ii) 20% conversion of general to high security entitlement)

Storage Spills (GL/y)	Base Case	Option 13(i)	Change (%)	Option 13(ii)	Change (%)
Blowering Dam	313.3	313.4	0%	341.1	9%
Burrinjuck Dam	365.6	368.7	1%	395.6	8%

Table 11. Blowering Dam and Burrinjuck Dam storage behaviour for the base case and Option 13 ((i) 10% and (ii) 20% conversion of general to high security entitlement)

% of time below	Base Case	Option 13(i)	Difference (%)	Option 13(ii)	Difference (%)
Blowering Dam					
1631.4 GL (FSV)	100%	100%	0%	100%	0%
1531.4 GL	86%	86%	0%	84%	-2%
50%	27%	27%	0%	23%	-4%
25%	7%	7%	0%	6%	-1%
10%	3%	3%	0%	3%	0%
5%	2%	2%	0%	2%	0%
Burrinjuck Dam					
1026 GL (FSV)	97%	97%	0%	96%	-1%
80%	70%	70%	0%	65%	-5%
50%	16%	15%	-1%	9%	-7%
25%	1%	0%	-1%	0%	-1%
10%	0%	0%	0%	0%	0%
5%	0%	0%	0%	0%	0%

and Figure 11 show comparisons of Blowering and Burrinjuck dams storage behaviour from 1/1/1891–30/6/2020 for the base case and the conversion option. The figures show similar behaviours; higher dam reserves lead to less drawdown in dry years (except for Burrinjuck during the Millennium drought). There is also a 9% increase in total spill volume under the 50% conversion option.

Figure 10: Comparison of Blowering Dam storage behaviour for the base case and Option 13 ((i) 10% and (ii) 20% conversion of general to high security entitlement)

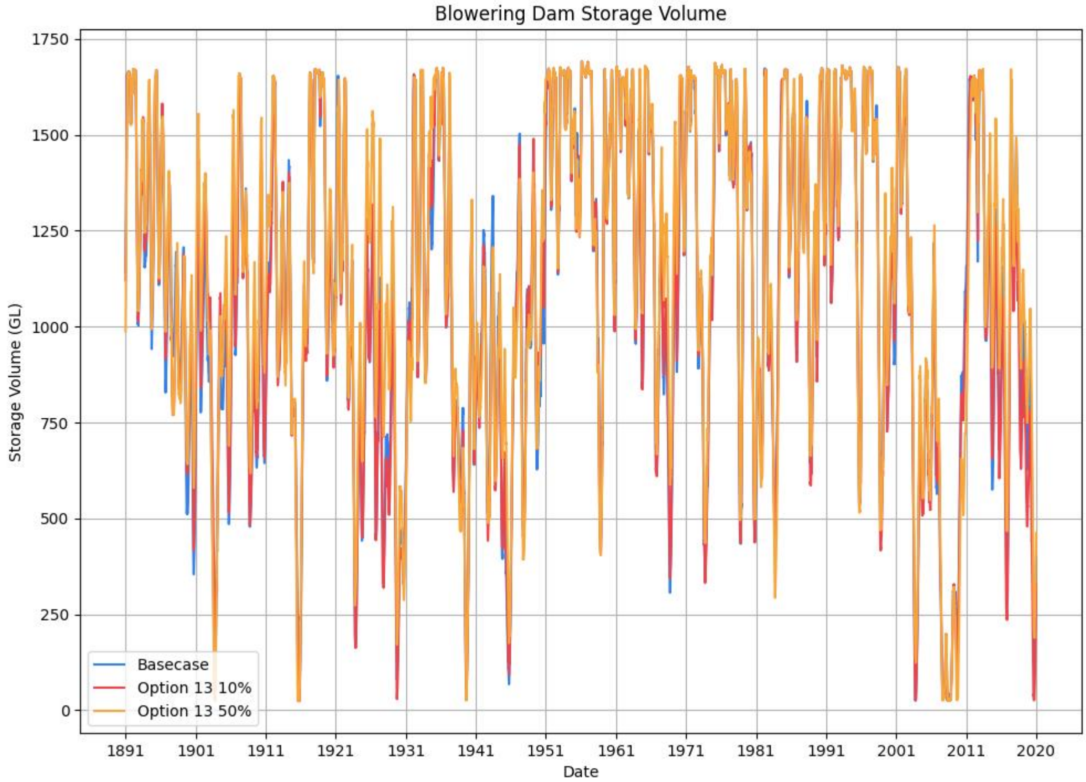
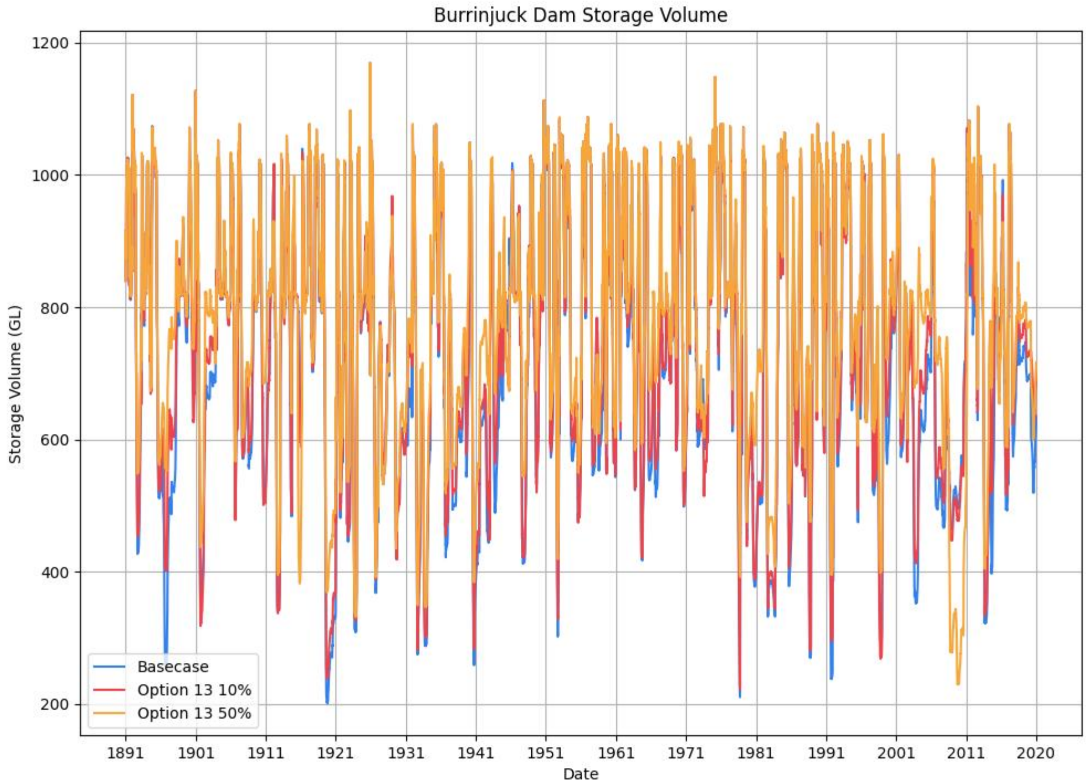


Figure 11: Comparison of Burrinjuck Dam storage behaviour for the base case and Option 13 ((i) 10% and (ii) 20% conversion of general to high security entitlement)



River flow changes

Table 12 shows mean annual flow for 1/7/1891 to 30/7/2020 for the base case and conversion of general to high security entitlements options. The table shows there are no impacts on end-of-system flows for a 10% conversion. For the 50% conversion, there is less flow at Balranald, but this is offset by more flow at Billabong Creek. The change in flow at both locations is largely due to changes in environmental replenishment behaviour above Balranald.

Table 12: Comparison of the mean annual flow for the base case and Option 13 ((i) 10% and (ii) 20% conversion of general to high security entitlement)

Gauging sites (GL/y)	Base Case	Option 13(i)	Change (%)	Option 13(ii)	Change (%)
Murrumbidgee River at Gundagai	3,432.2	3,433.0	0%	3,436.5	0%
Murrumbidgee River at Wagga Wagga	3,799.1	3,799.9	0%	3,803.8	0%
Murrumbidgee River at Balranald	1,188.6	1,183.5	0%	1,160.2	-2%
Billabong Creek at Darlot	227.5	227.8	0%	235.6	4%

5. Option 33a: On-river re-regulating buffer storage on the Tumut River above the Murrumbidgee River confluence

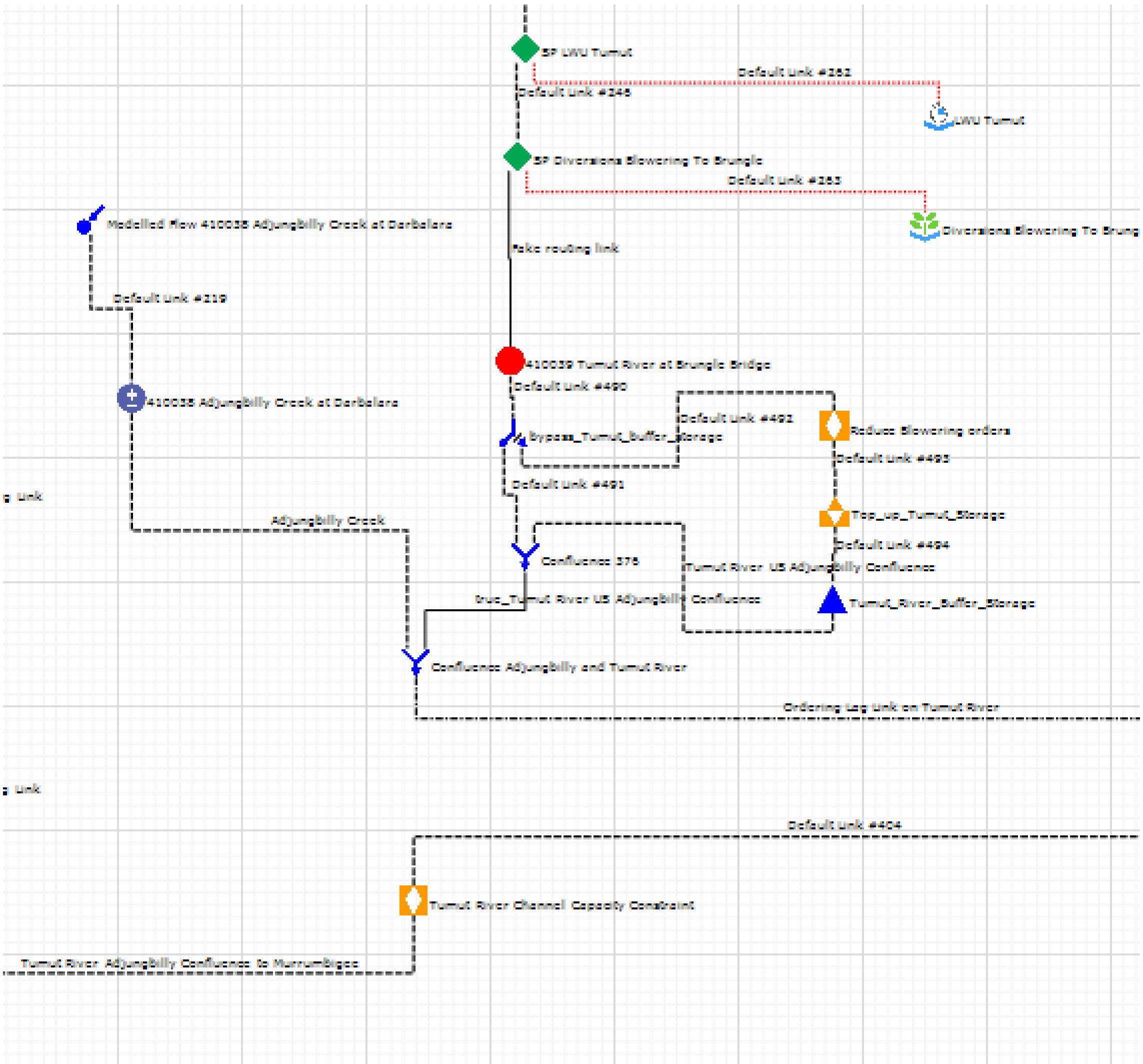
Option description

This option involves adding a 47 GL on-river storage on the Tumut River, just upstream of its confluence with the Murrumbidgee River.

Model configuration and assumptions

We inserted a 47 GL on-river storage on the Tumut River in the model, immediately upstream of the Murrumbidgee-Tumut rivers confluence node (Figure 12). We configured this option so that Source input sets could be configured to either use or bypass the storage, depending on the options modelled. The storage's primary purpose is to help overcome the effect of supply constraints from Blowering Dam caused by Tumut River capacity limits downstream of Blowering Dam.

Figure 12: Configuration of on-river storage on the Tumut River in the Murrumbidgee model



The storage node was configured with a 47 GL full storage volume, and zero dead storage volume. The level-volume-area relationship was provided by Water NSW (Table 13).

We configured the storage to work within the existing Burrinjuck and Blowering dams' harmonisation rules — that is, when Burrinjuck is less than 80% full as much flow as possible is drawn from the Tumut River.

When the possible new storage has sufficient capacity, more flow can be taken from the Tumut River. This draws the storage volume down, but it can be topped up when demands ease. This approach would support the Burrinjuck and Blowering dams' storage balance, given that the

Murrumbidgee River downstream of Burrinjuck does not have the same capacity constraints as the Tumut River.

Storage operational rules were divided into 2 seasons:

- irrigation, from October to April
- off-season, May to September

These periods do not exactly align with traditional irrigation season dates. This allows storage drawdown as the off-season approaches, and refill via unregulated inflows before irrigation season.

We created both fill and drawdown rules.

Fill rules.

- Off-season: order from upstream (either unregulated tributaries or from Blowering Dam) to maintain sufficient storage to pass minimum flow requirements.
- Irrigation season: order from upstream (either unregulated tributaries or from Blowering Dam) to target a minimum storage volume of 40,000 ML. The orders were smoothed over several days to avoid rapid flow rate changes, which would be detrimental to river health.

Drawdown rule

If Tumut River storage is greater than 40,000 ML, reduce upstream orders over several days. This allows the possible new storage to continue to supply regulated Murrumbidgee River demands at greater than Tumut River capacity, while allowing the supply to the new storage from Blowering Dam to be maintained at appropriate rates. The storage has some regulation capacity for unregulated inflows.

Table 13: Tumut River on-river storage level-volume-area relationships, based on WaterNSW data.

Level (m)	Volume (ML)	Area (ha)
0	0	0
2	850	94
4	4,180	247
6	10,680	399
8	20,560	615
11	46,780	1,082

Assumptions

The new storage would allow greater releases from Blowering Dam for longer periods of time without exceeding release rate limits and would re-regulate these additional releases for later use.

We did not explicitly model any benefits resulting from reduced water order delivery times, as these cannot be readily analysed in systems where travel times are long and in-stream storages small. Our configuration allowed some modelling of unregulated tributary inflow harvesting. Further analysis could identify a more optimal mix to support these objectives.

No data were available on outlet works including valves, spillways and fishways. Similarly, there was no information available about Tumut River channel capacity downstream of the storage site; however, we assumed that the river's in-bank flow capacity downstream of the storage site was higher than immediately downstream of Blowering Dam (9,000 ML/d).

We assumed an outlet capacity of approximately 10,400 ML/d when the buffer storage was at its assumed target minimum irrigation season operating level (8,000 ML). We configured a gated spillway to pass flood flows. We selected a target minimum operating level for the irrigation season that ensured sufficient head to provide the desired outlet capacity.

Recognising that required flow rates would be lower in the off season we assumed a lower minimum off-season operating level (corresponding to 2,000 ML storage), which also maximised harvesting opportunities. Should off-season environmental flow releases for the mid-Murrumbidgee River be planned, the off-season target may need to be reconsidered. It is likely, however, that such releases would be from Burrinjuck rather than Blowering Dam. In any case, releases from Blowering Dam would be driven from upstream of the re-regulating storage.

We retained the model's default configuration for sharing demand shortfalls caused by capacity constraints across affected demand types. This means that, in the model, increases in general security demand mean flow capacity is sometimes reached, which in turn leads to restrictions (or rationing) on both irrigation and local water utility (LWU) supply. LWU use may not be rationed in such circumstances if the option were implemented in the real world.

Murray Darling Basin Plan compliance

We assumed that, per Basin planning principles, extractions would remain at baseline case levels in the long term. To achieve this, we reduced supplementary use by limiting supplementary use allowances, in accordance with *Water Management Act 2000* section 58 priorities.

Through an iterative approach compliance was achieved at 90% of baseline entitlements.

Discussion

Downstream orders (for example, for the Coleambally Irrigation Area, Murrumbidgee Irrigation Area, and local water utilities) were passed up to Blowering and/or Burrinjuck Dam according to the pre-existing harmony rule.

In general, and subject to Tumut River capacity constraints, this rule prioritises supply from Blowering Dam. When capacity is available in the storage this increases the Tumut River flow rate because it allows a supply greater than the channel capacity downstream of Blowering Dam. When Burrinjuck Dam is at high levels, supply from Burrinjuck is prioritised.

The storage would supply downstream orders for most of the irrigation season (October to April, inclusive) and, when there is capacity in the Tumut River, would attempt to top up with water from Blowering Dam. In off season the storage would target a much lower operating level from Blowering Dam, and instead fill via unregulated inflows downstream of Blowering Dam.

If the storage were nearly full — due to unregulated inflows or a reduction in downstream requirements, for example — it would supply downstream orders from itself without needing to order from Blowering Dam.

The storage would potentially offer a slightly shorter travel time but because this would not be the case if storage were low, we did not configure the model to take advantage of this.

There are 2 types of supplementary water use in the regulated Murrumbidgee River system:

- river supplementary
- Lowbidgee supplementary.

We adjusted river supplementary water use, which is indirectly associated with general security water use. Lowbidgee supplementary water, however, is used only for the environment. The model does not consider the environmental use of river supplementary water and, as such, we cannot report on related impacts. While the model would allow the Lowbidgee supplementary water to flow to Balranald (and thereby possibly overestimate flows at Balranald) this water may in practice be directed down the Yanco system.

Lowbidgee supplementary water use is modelled as additional flow to 8 Lowbidgee assets. It is subject to flows being below 10,000 ML/day at Wakool Junction in the Murray, or below 5,000 ML/day at Balranald. Wakool junction flows are a fixed time series input and do not vary between scenarios, so Lowbidgee flows change with any changes to the frequency of flows of less than 5,000 ML/day at Balranald. We report these to indicate the potential impacts of directing environmental supplementary flows to Lowbidgee.

Modelling results

This section presents modelling results for Option 33a, a re-regulating storage on the Tumut River above the Murrumbidgee River confluence.

Alterations in water diversions

Table 14 shows the average annual diversions for consumptive use for the base case, and for the optional Tumut River storage, from 1/7/1895 to 30/6/2010. The storage would allow a small increase in consumptive regulated diversions and a corresponding reduction in supplementary diversions to maintain the same overall diversions (within sustainable diversion limits) as the base case.

Table 14: Mean annual water diversions for the base case and Option 33a (Tumut River storage)

Water diversions (GL/y)	Base Case	Option 33a	Change (%)
General Security	674.8	680.1	1%
High Security	294.1	295.0	0%
Murrumbidgee Irrigation Conveyance	161.6	164.1	2%
Coleambally Irrigation Conveyance	103.8	104.0	0%
Premium High Security	18.1	18.1	0%
Stock and Domestic	19.4	19.8	2%
Local Water Utility	10.1	9.9	-2%
Supplementary	116.0	105.6	-9%
Lowbidgee consumptive	48.6	47.6	-2%
Inter-valley transfer	105.5	104.9	-1%
Total diversions	**1,552.0**	**1,549.1**	**0%**

As noted, in the Assumptions section, there is some reduction in local water utility diversions due to system flow capacity constraints. This could be managed by applying rationing rules during such periods of capacity constraints.

Total annual distributions of general and high security diversions are shown in Figure 13 and Figure 14, respectively. Annual diversions for these license classes are generally, but not always, higher with the possible storage in place. Annual diversions will be lower in years when less water is available due to higher diversions in preceding years.

Figure 13: Total annual general security diversions for the base case and Option 33a (Tumut River storage)

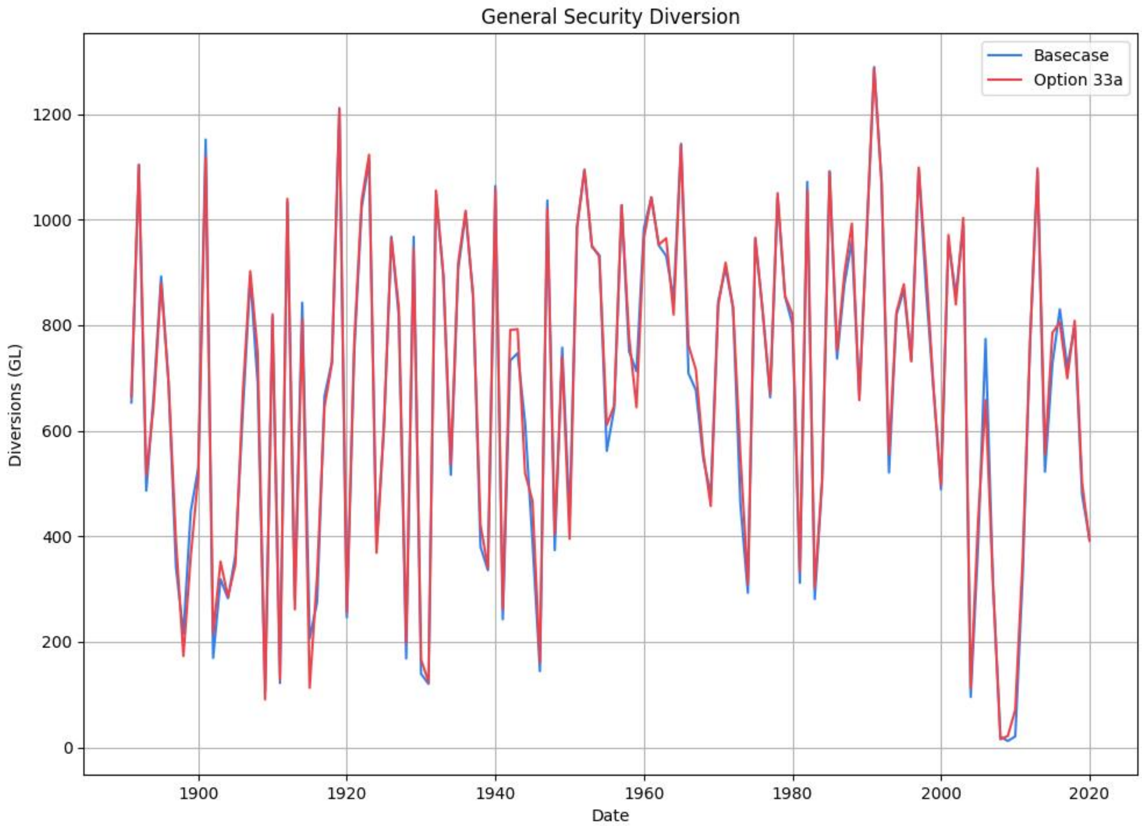
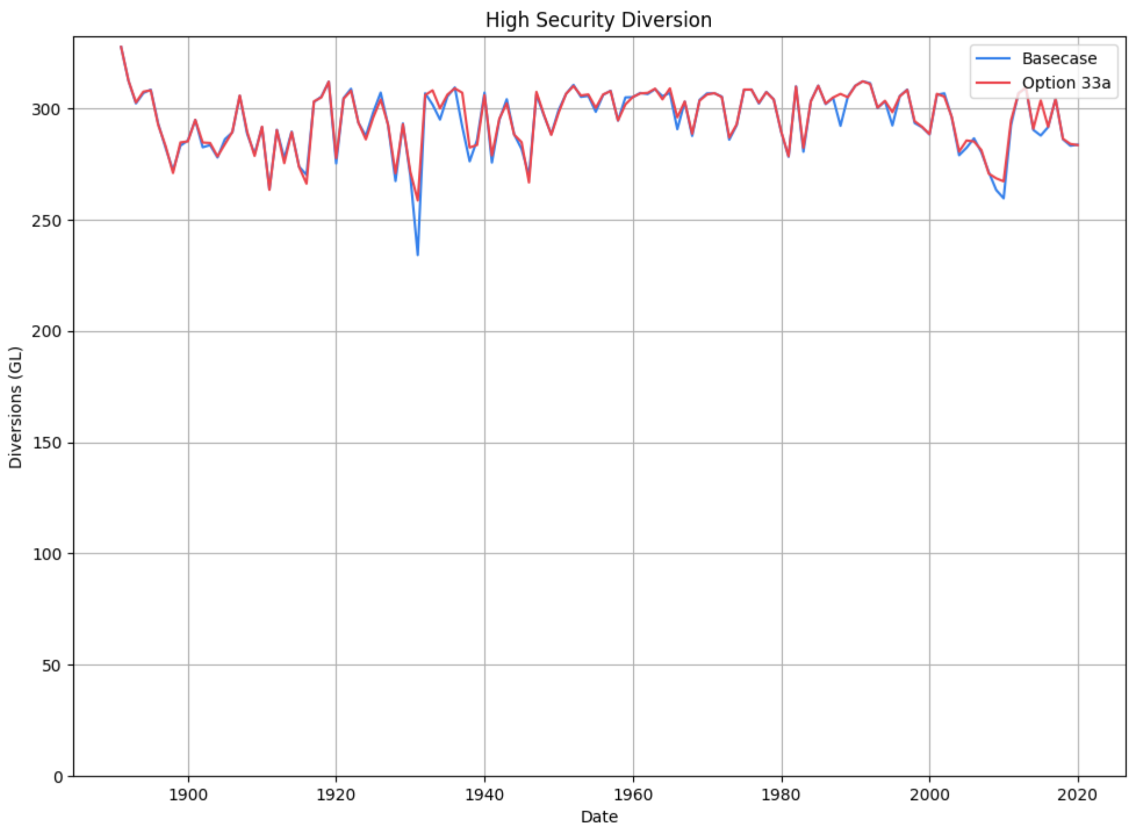


Figure 14: Total annual high security diversions for the base case and Option 33a (Tumut River storage)



Alterations in environmental water delivery

Table 15 shows average annual held and planned environmental water deliveries for the base case and the Tumut River optional storage, from 1/7/1895 to 30/6/2010. The table shows increased application of held environmental water due to higher allocations. The higher allocations also see an increase in general and high security diversions and conveyance losses.

Planned environmental water is largely driven by Burrinjuck Dam, and consequently is not significantly impacted by this option.

Table 15: Mean annual environmental water delivery for the base case and Option 33a (Tumut River storage), 1895–2010, showing difference.

Water delivery (GL/y)	Base Case	Option 33a	Change (%)
Held environmental water	144.6	149.4	3%
Lowbidgee environment	70.0	66.7	-5%
Planned environmental water	133.4	132.1	-1%
Total environmental water	348.0	348.2	0%

Alterations in allocation reliability

Table 10 shows water allocations for the base case and optional Tumut River storage, at start and end of water year and on 30 September.

Results show that the optional storage slightly increases:

- general security allocations across the year
- high security allocations at the start of the water year.

Table 16: Average water allocations (1895–2010) for the base case and Option 33a (Tumut River storage), showing allocation difference.

Average allocations (%)	Base Case	Option 33a	Difference (%)
General security effective allocation on 1 July	39%	40%	1%
General security effective allocation on 30 September	61%	61%	0%
General Security effective allocation on 30 June	80%	81%	1%
General security allocation on 1 July	31%	32%	1%
General security allocation 30 September	53%	53%	0%

Average allocations (%)	Base Case	Option 33a	Difference (%)
General Security allocation on 30 June	72%	73%	1%
High security allocation on 1 July	93%	94%	1%
High security allocation 30 September	96%	96%	0%
High security allocation on 30 June	98%	98%	0%
Coleambally Irrigation conveyance allocation on 1 July	88%	88%	0%
Coleambally Irrigation conveyance allocation 30 September	92%	92%	0%
Coleambally Irrigation conveyance allocation on 30 June	95%	95%	0%
Murrumbidgee Irrigation conveyance allocation on 1 July	76%	76%	0%
Murrumbidgee Irrigation conveyance allocation 30 September	85%	85%	0%
Murrumbidgee Irrigation conveyance allocation on 30 June	92%	92%	0%

Effective general security reliability at the start and end of the water year, for 1/7/1891–30/6/2020, is shown in Figure 15 and Figure 16, respectively. These figures show the additional regulation an optional Tumut River storage would slightly increase general security allocations at the start of the water year on 1 July, and significantly increase allocations of less than 100% by 30 June of each water year.

Figure 15: Comparison of base case and Option 33a (Tumut River storage) effective general security allocation reliability

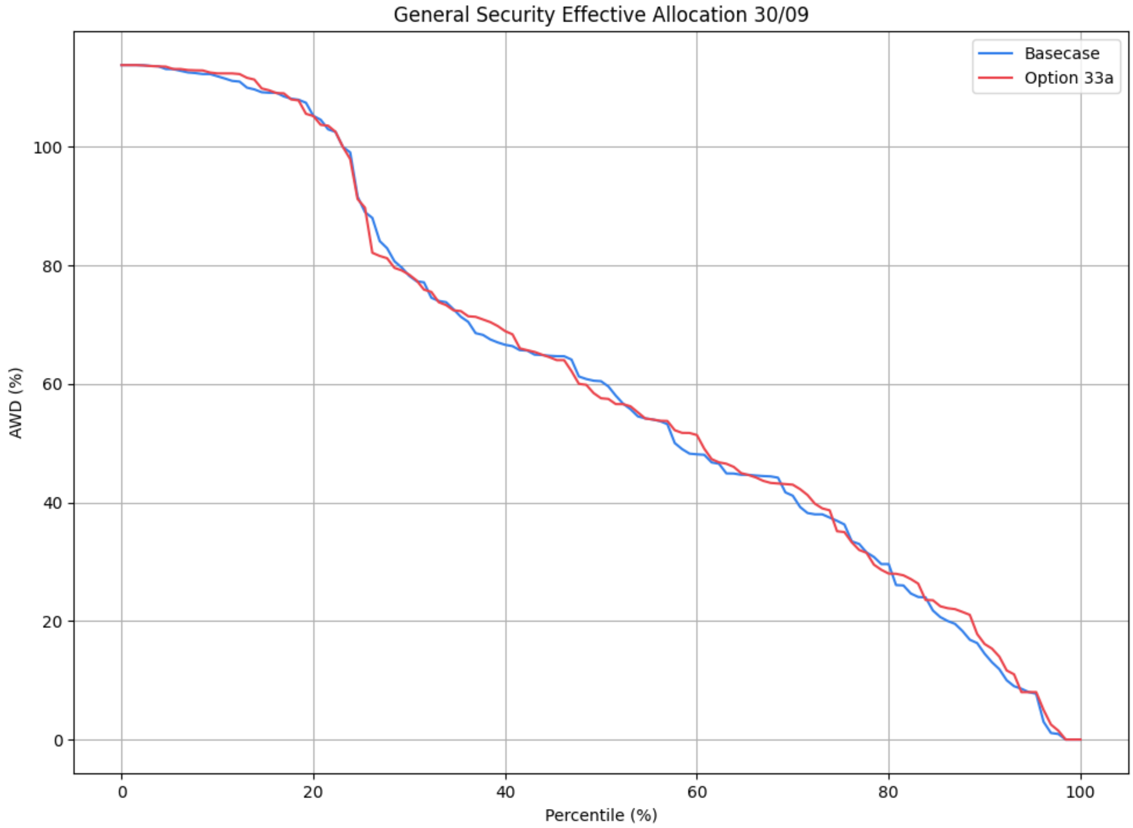
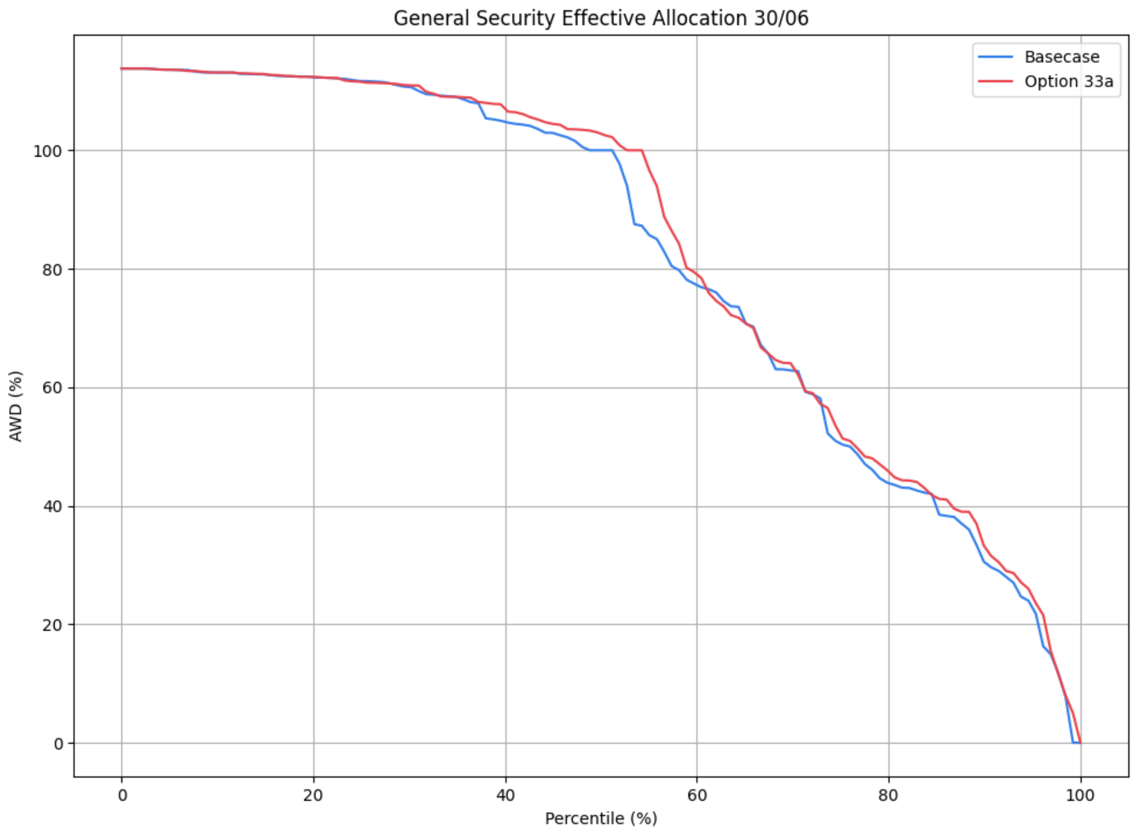


Figure 16: Comparison of base case and Option 33a (Tumut River storage) effective general security allocation reliability at end of water year (30/6)



Alterations in storage behaviour

Table 17, Table 18, Figure 17 and Figure 18 show Blowering Dam and Burrinjuck Dam behaviour for the base case and the optional Tumut River storage from 1891–2021.

Table 17 shows a 6% decrease in spills from Blowering dam and a corresponding 10% increase in spills from Burrinjuck dam. Table 18 shows that time above 25% and 50% for Blowering increases while Burrinjuck correspondingly decreases. This suggests that a change in the harmony rule would improve this imbalance.

Table 17: Blowering Dam and Burrinjuck Dam storage spill behaviour for the base case and Option 33a (Tumut River storage)

Storage Spills (GL/y)	Base Case	Option 33a	Change (%)
Blowering Dam	313.3	296.0	-6%
Burrinjuck Dam	365.6	403.6	10%

Table 18: Percent of time at different storage volumes, including full storage volume (FSV), Blowering Dam, 1891–2021

% of time below	Base Case	Option 33a	Difference (%)
Blowering Dam			
1631.4 GL (FSV)	100%	100%	0%
1531.4 GL	86%	86%	0%
50%	27%	32%	5%
25%	7%	9%	2%
10%	3%	3%	0%
5%	2%	2%	0%
Burrinjuck Dam			
1026 GL (FSV)	97%	96%	-1%
80%	70%	64%	-6%
50%	16%	8%	-8%
25%	1%	0%	-1%
10%	0%	0%	0%
5%	0%	0%	0%

Figure 17: Blowering Dam storage volumes for the base case and Option 33a (Tumut River storage), 1891–2020

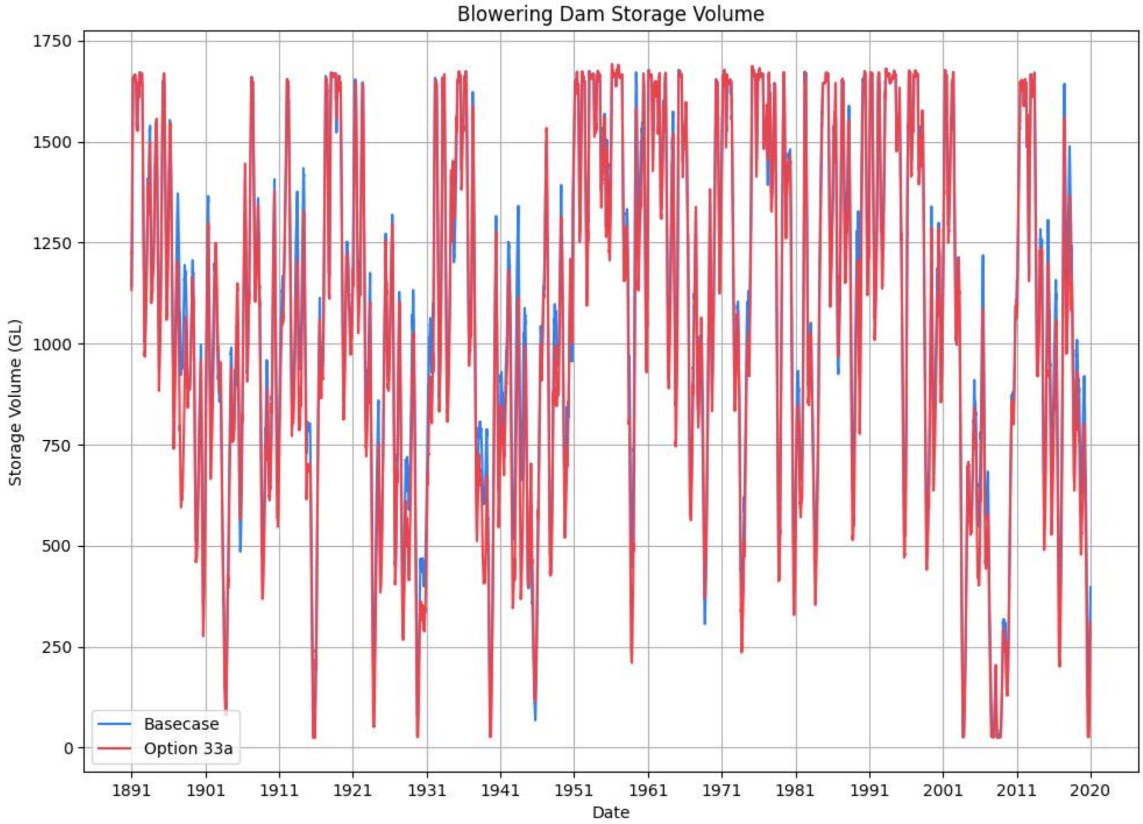
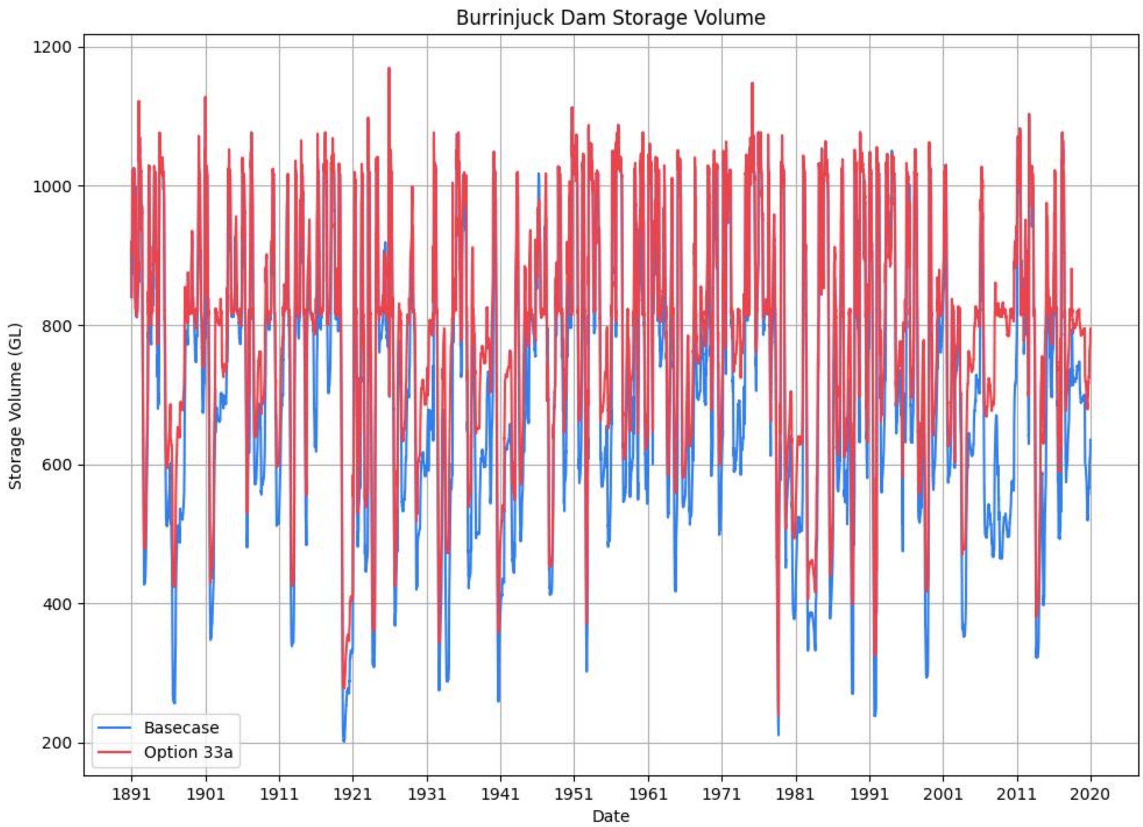


Figure 18: Burrinjuck Dam storage volumes for the base case and Option 33a (Tumut River storage), 1891–2020



Alterations in river flows

Table 18 lists mean annual flow for 1/7/1891–30/7/2020 for the base case and optional Tumut River storage (option 33a). It shows a no change in end-of-system flows at Balranald because the optional storage water is consumed.

Table 18: Base case and Option 33a (Tumut River storage) mean annual flow comparison, 1891–2020.

Gauging sites (GL/y)	Base Case	Option 33a	Change (%)
Murrumbidgee River at Gundagai	3,432.2	3,432.4	0%
Murrumbidgee River at Wagga Wagga	3,799.1	3,799.3	0%
Murrumbidgee River at Balranald	1,188.6	1,187.6	0%
Billabong Creek at Darlot1	227.5	228.3	0%

6. Option 33b and 33c: On-river storage on the Murrumbidgee River above Gundagai

Option description

Options 33b and 33c involve adding a storage on the Murrumbidgee River downstream of its confluence with the Tumut River before Gundagai.

Option 33b considered storage of 20 GL and option 33c considered storage of 1,000 GL.

Model configuration and assumptions

We inserted an on-river storage on the Murrumbidgee River downstream of the node representing the Murrumbidgee and Tumut rivers' confluence, just upstream of Gundagai (Figure 19).

We set up the storage so that Source input sets could be configured to either use the storage or bypass it, depending on what we wanted to model. The storage's primary purpose is to address the Tumut River's lack of capacity downstream of Blowering Dam to carry additional flow diverted by the Snowy Scheme. This will assist in balance issues between Burrinjuck and Blowering reservoirs and will also allow the Tumut River to be run at full capacity less of the time, helping to reduce erosion in the river.

We modelled 2 storage capacities:

- Option 33b – 20GL
- Option 33c – 1,000GL

Option 33b: 20 GL storage

For this option we configured the storage node with a 20 GL full storage volume (FSV) and zero dead storage volume (DSV).

In the absence of survey data, we adopted the level-volume-area relationship used for the nearby lower Tumut River storage (option 33a), subject to an FSV of 20,000 ML. We configured the storage to work within existing Burrinjuck and Blowering dam harmonisation rules — that is, when Burrinjuck Dam is less than 80% full, as much flow as possible is drawn from the Tumut River.

The optional storage's operation centres on the relationship between downstream orders and the Tumut River's capacity.

Downstream orders would be drawn from the storage when they are greater than Tumut River capacity, thus creating space in the storage for future supply from the Tumut River and/or Blowering Dam.

When the harmonisation rules assign release priority to Blowering Dam and downstream orders are less than Tumut River capacity, the spare river capacity could be used to top up any storage airspace with additional orders from Blowering Dam.

Because the Murrumbidgee River downstream of Burrinjuck Dam does not have the same capacity constraints as the Tumut River, these arrangements would help manage the Blowering dam and Burrinjuck dam storage balance.

Storage operational rules were divided into 2 seasons:

- irrigation, from October to April
- off-season, from May to September.

These periods do not exactly align with traditional irrigation season dates. This allows storage drawdown as the off-season approaches, and refill via unregulated inflows before irrigation season.

Fill rules.

- Off-season: order from upstream (unregulated tributaries or Blowering Dam) to maintain sufficient storage to meet minimum flow requirements.
- Irrigation season: when releases are prioritised to Blowering Dam according to the Burrinjuck and Blowering dam harmonisation rules, order from unregulated upstream tributaries or from Blowering Dam to target a minimum storage volume of 14,000 ML (subject to total orders being less than Tumut River capacity). Orders are smoothed over several days to avoid rapid flow rate changes, which would be detrimental to river health.

Drawdown rule

When orders from downstream exceed the Tumut River capacity reduce orders to upstream, subject to maintaining a minimum storage volume in the possible new storage. This has the effect of creating airspace for subsequent top-ups from Blowering Dam when Tumut River capacity allows.

Option 33c: 1,000 GL storage

The storage node was configured with a 1,000 GL FSV and a nominal dead storage level of 1m, which corresponds to a 34.4 GL DSV.

The level-volume-area relationship was determined by WaterNSW from a desktop study of topographic information.

We configured the system to change the existing Burrinjuck and Blowering dam harmonisation rules, instead always taking as much flow as possible from Blowering Dam during regulated flow conditions. This will result in additional spill from Burrinjuck, which can be re-regulated in the new storage.

Fill rules:

- Off-season: target a minimum buffer storage of 200 GL.
- Irrigation season: if the buffer storage volume is less than 700 GL and Tumut River orders are less than 8 GL/day, increase orders to Blowering to 8 GL/day. If the buffer storage volume is less than 200 GL, generate orders to attempt to refill to this volume. Orders up to Tumut River capacity will be sent to Blowering Dam, with any balance over that capacity sent to Burrinjuck Dam. Total orders are capped at 30 GL/d.

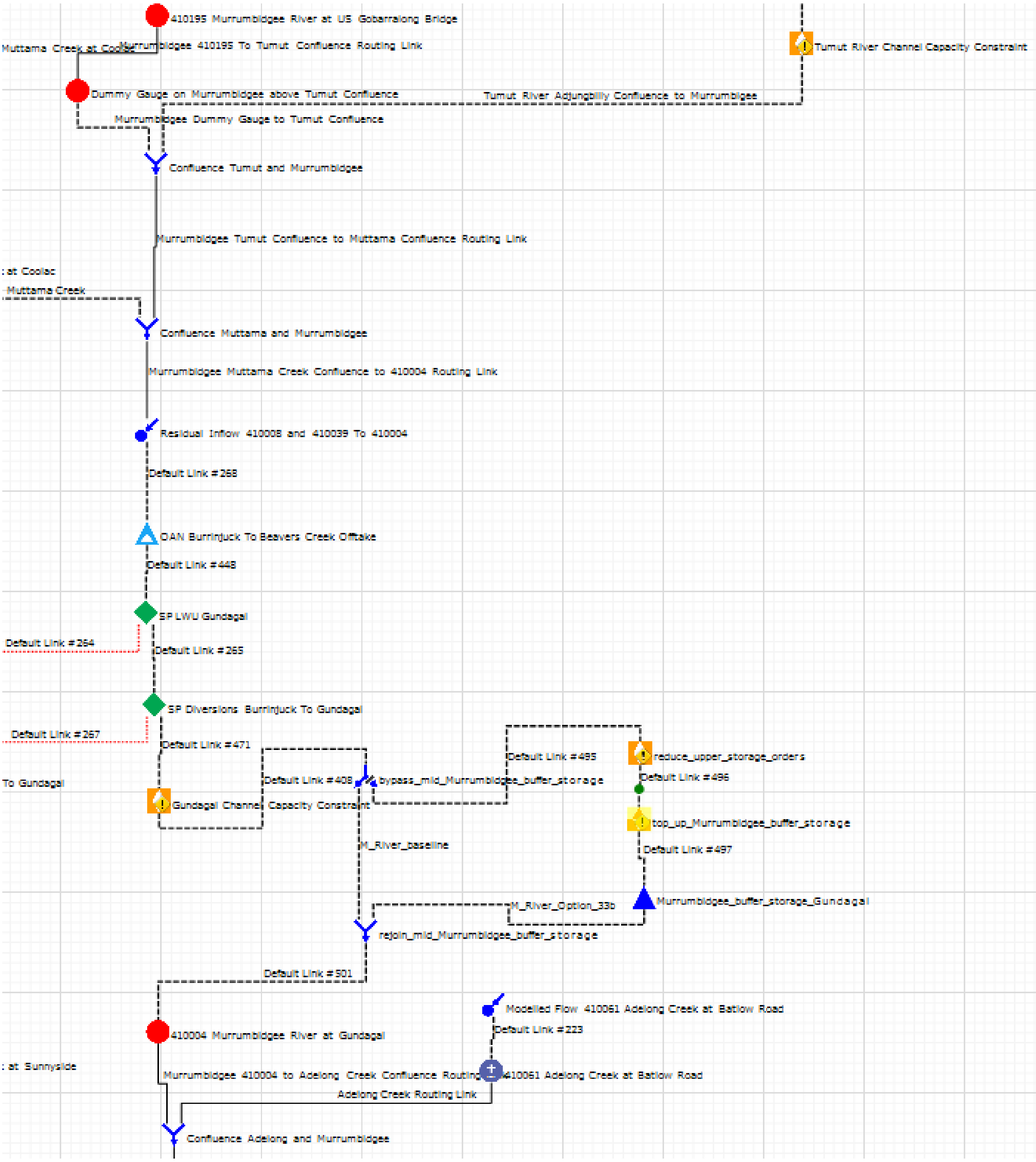
Drawdown rule

Draw-down behaviour is governed by the fill rule, unregulated inflows, and downstream demands.

Table 19: Level–volume–area data for option 33c (1,000 GL storage on the Murrumbidgee River near Gundagai)

Level above bed (m)	Volume (GL)	Area (km^2)
0	0	0
10	343.8	48.83
15	636.9	68.92
20	1,040	92.97

Figure 19: Model configuration for options 33b and 33c (storage on the Murrumbidgee River upstream of Gundagai)



Assumptions

We have made broad assumptions about the physical characteristics of the possible 20 GL storage. The most important of these assumptions is storage size, which is the key attribute modelled at this stage. Other minor attributes, such as outlet capacities and level–volume–area relationships would be worked out before or during the design phase of any future investigation. We assumed 3 GL of storage would provide sufficient head to pass regulated flow requirements. The physical characteristics of the 1,000 GL storage are based on topographic data, but the outlet characteristics were assumed.

Discussion

We modelled the operation of the 2 storage options to overcome capacity constraints in the Tumut River downstream of Blowering Dam. The storages could also harvest some of the unregulated flow coming into the system downstream of Burrinjuck and Blowering dams, and some of the environmental releases from both storages.

Modelling results

Alterations in water diversions

Table 20 shows average annual water diversions from 1/7/1895 to 30/6/2010 for consumptive water users, under the base case and options 33b and 33c.

For the 20 GL storage the results show a modest (3%) increase in general security and Murrumbidgee Irrigation conveyance use, and a corresponding 23% reduction in supplementary diversions and 7% reduction in Lowbidgee consumptive, managed to maintain overall diversions the same as the baseline case. The 20 GL storage is creating about a 30 GL redistribution of water between supplementary and regulated supplies.

For the 1,000 GL storage there is a modest increase in high security (3%), a significant increase in general security (17%) and Murrumbidgee Irrigation conveyance (14%) use and a 100% reduction in supplementary and Lowbidgee consumptive diversions and 13% reduction in General security entitlements to maintain overall diversions the same as the baseline case. The 1000 GL storage is creating about a 160 GL redistribution of water between supplementary and regulated supplies.

The increases in diversions were due to the capture of environmental releases, spills, and unregulated flows upstream of the storage that are subsequently regulated.

Table 20: Mean annual water diversions for the Base Case, Option 33b and Option 33c (20 GL and 1,000 GL respective Murrumbidgee on-river storages)

Water diversions (GL/y)	Base Case	Option 33b	Change (%)	Option 33c	Change (%)
General Security	674.8	695.7	3%	792.7	17%
High Security	294.1	295.6	1%	301.8	3%

Murrumbidgee Irrigation Conveyance	161.6	167.0	3%	184.6	14%
Coleambally Irrigation Conveyance	103.8	104.3	0%	107.5	4%
Premium High Security	18.1	18.0	-1%	19.1	6%
Stock and Domestic	19.4	20.5	6%	24.5	26%
Local Water Utility	10.1	10.0	-1%	10.2	1%
Supplementary	116.0	89.0	-23%	0.0	-100%
Lowbidgee consumptive	48.6	45.1	-7%	0.0	-100%
Inter-valley transfer	105.5	103.7	-2%	105.3	0%
Total diversions	1,552.0	1,548.9	0%	1,545.7	0%

The annual distribution of total general and high security diversions are shown in Figure 20 and Figure 21, respectively. The figures show that annual diversions for these license classes are generally, but not always, higher with the optional Murrumbidgee River storage in place. When higher diversions in a given water year result in less available water in subsequent years, annual diversions in those subsequent years may be lower. Overall diversions are capped to the average baseline level by restricting supplementary access. For the 20 GL storage option supplementary entitlements were reduced to 73% of baseline values. For the 1,000 GL storage option, general security entitlements were also reduced to zero.

Figure 20: Total general security annual diversions for the Base Case, Option 33b and Option 33c (20 GL and 1,000 GL respective Murrumbidgee on-river storages), 1891–2020

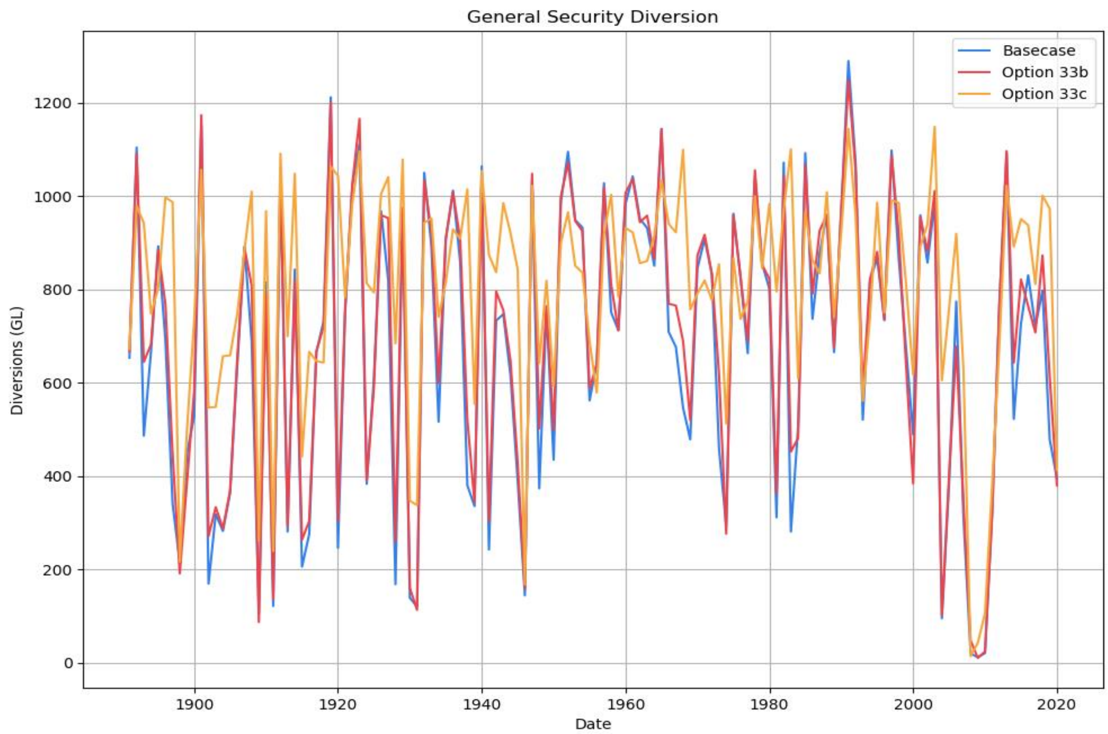
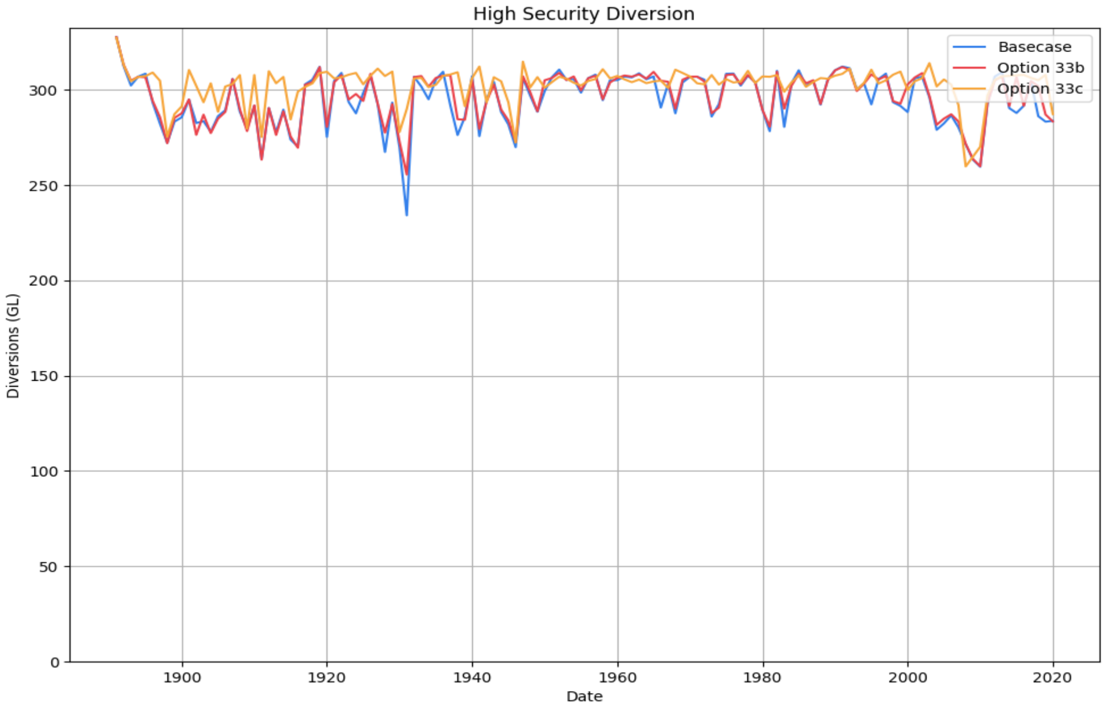


Figure 21: Total high security annual diversions the Base Case, Option 33b and Option 33c (20 GL and 1,000 GL respective Murrumbidgee on-river storages), 1891–2020



Environmental water delivery changes

Table 22 shows average annual held and planned environmental water deliveries from 1/7/1895 to 30/6/2010 under the base case, and for options 33b and 33c.

With option 33b, use of held environmental increases as held entitlements become more reliable. Lowbidgee environmental access is reduced as there are less supplementary flow events of sufficient size to divert to Lowbidgee environmental assets despite the 27% reduction in supplementary entitlements.

With option 33c held environmental water use decreases. Lowbidgee supplementary environmental access increases by 168 GL (240%). This is caused by more events at Maude and Redbank weirs that trigger diversions to Lowbidgee environmental assets. The 238.1 GL average is less than the 747,00 Lowbidgee supplementary unit shares. Planned environmental water use increases because more water is kept in Burrinjuck Reservoir impacting environmental release rules.

Table 21. Mean annual environmental water delivery for the Base Case, Option 33b and Option 33c (Murrumbidgee on-river storage)

Water delivery (GL/y)	Base Case	Option 33b	Change (%)	Option 33c	Change (%)
Held environmental water	144.6	157.1	9%	139.8	-3%
Lowbidgee environment	70.0	60.9	-13%	238.1	240%
Planned environmental water	133.4	132.6	-1%	148.5	11%
Total environmental water	348.0	350.6	1%	526.4	51%

Murray Darling Basin Plan Compliance

It was assumed that per MDB Basin Planning principles, long term extractive use would stay the same as the baseline case. To achieve this, for option 33b supplementary use was reduced by reducing supplementary use allowances to 73% of baseline entitlements. Without curtailing use of Supplementary water addition of a new 20GL regulating storage on the Murrumbidgee River upstream of Gundagai would result in an additional average annual consumptive use of 14.3 GL/y. For option 33c it was necessary to cease consumptive supplementary access and reduce general security entitlements to 87% of baseline entitlement volumes. Without curtailing use of Supplementary water and reducing general security entitlements addition of a new 1,000GL regulating storage on the Murrumbidgee River upstream of Gundagai would result in an additional average annual consumptive use of 157 GL/y.

Alterations in allocation reliability

30 September, start, and end of water year allocations from 1/7/1891 to 30/6/2020 are shown in Table 22 for the Base Case and the Murrumbidgee River 20 GL and 1,000 GL on-river re-regulating storage below the Tumut confluence, options 33b and 33c.

The results for the 20 GL storage show a modest (3-4%) increase in General Security allocation over the year. The results for the 1,000 GL storage show a large increase (20-40%) in General Security allocation over the year, and a minor increase in High Security allocation over the year. These increases are due to the resource assessment considering the additional water held in the storages. Noting less secure entitlements will benefit more.

Table 22. Allocations for the Base Case, Option 33b and Option 33c (20 GL and 1,000 GL respective Murrumbidgee on-river storages)

Average allocations (%)	Base Case	Option 33b	Difference (%)	Option 33c	Difference (%)
General security effective allocation on 1 July	39%	43%	4%	78%	39%
General security effective allocation on 30 September	61%	64%	3%	88%	27%

Average allocations (%)	Base Case	Option 33b	Difference (%)	Option 33c	Difference (%)
General Security effective allocation on 30 June	80%	83%	3%	98%	18%
General security allocation on 1 July	31%	35%	4%	72%	41%
General security allocation 30 September	53%	55%	2%	82%	29%
General Security allocation on 30 June	72%	75%	3%	92%	20%
High security allocation on 1 July	93%	93%	0%	97%	4%
High security allocation 30 September	96%	96%	0%	98%	2%
High security allocation on 30 June	98%	98%	0%	99%	1%
Coleambally Irrigation conveyance allocation on 1 July	88%	89%	1%	95%	7%
Coleambally Irrigation conveyance allocation 30 September	92%	92%	0%	97%	5%
Coleambally Irrigation conveyance allocation on 30 June	95%	95%	0%	98%	3%
Murrumbidgee Irrigation conveyance allocation on 1 July	76%	78%	2%	92%	16%
Murrumbidgee Irrigation conveyance allocation 30 September	85%	86%	1%	95%	10%
Murrumbidgee Irrigation conveyance allocation on 30 June	92%	92%	0%	98%	6%

The effective general security reliability on the 30 September and at the end of the water year are shown respectively in Figure 22 and Figure 23. The figures show that the Murrumbidgee River re-regulating storage would result in a modestly higher General Security allocation regime for option 33b, and a significantly higher General Security allocation regime for option 33c.

Figure 22. 30 September effective general security allocation reliability for the Base Case, Option 33b and Option 33c (20 GL and 1,000 GL respective Murrumbidgee on-river storages)

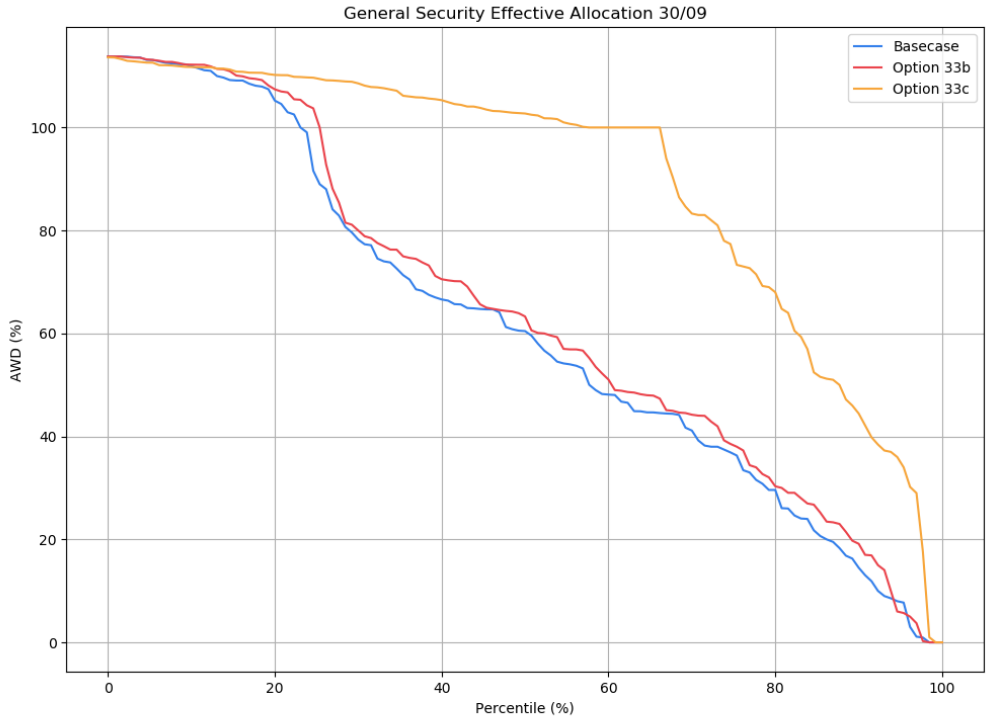
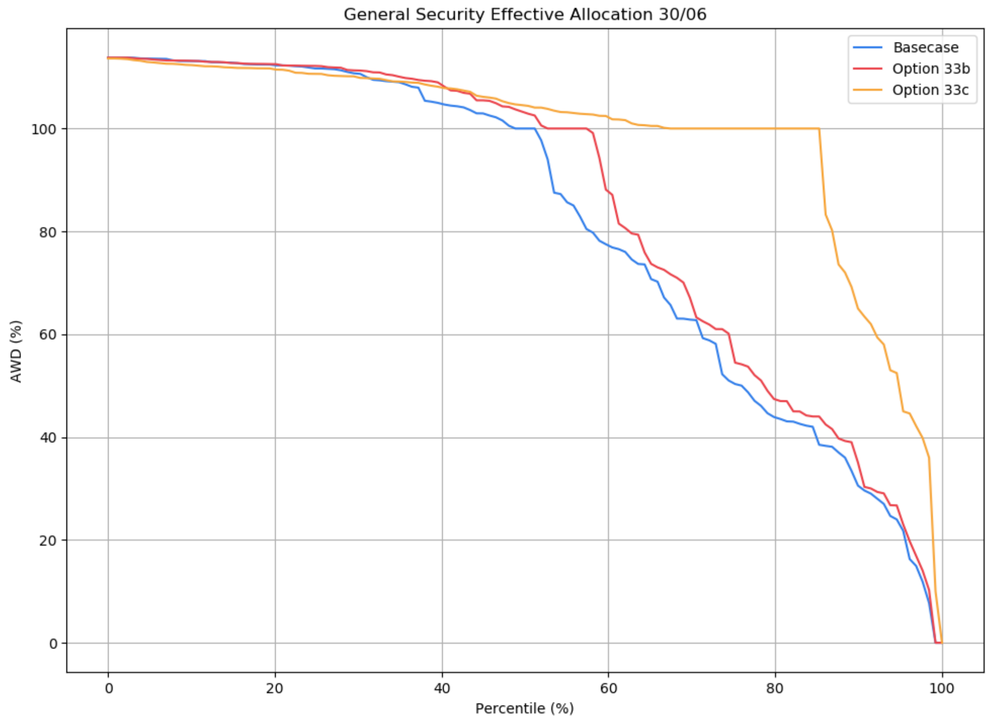


Figure 23. End of water year (30/6) effective general security allocation reliability for general security for the Base Case, Option 33b and Option 33c (20 GL and 1,000 GL respective Murrumbidgee on-river storages)



Alterations in storage behaviour

Blowering Dam and Burrinjuck Dam storage behaviour for the Base Case and Murrumbidgee River 20 GL and 1,000 GL on-river re-regulating storage below the Tumut confluence, options 33b and 33c are shown in Table 23 and Table 24. Table 24 shows that both storages generally remain at higher levels because of the contribution of the Murrumbidgee River re-regulating storage.

Table 23. Blowering Dam and Burrinjuck Dam spill behaviour for the Base Case, Option 33b and Option 33c (20 GL and 1,000 GL respective Murrumbidgee on-river storages)

Storage Spills (GL/y)	Base Case	Option 33b	Change (%)	Option 33c	Change (%)
Blowering Dam	313.3	354.8	13%	404.7	29%
Burrinjuck Dam	365.6	445.4	22%	736.0	101%

Table 24. Blowering Dam and Burrinjuck Dam storage behaviour for the Base Case, Option 33b and Option 33c (20 GL and 1,000 GL respective Murrumbidgee on-river storages)

% of time below	Base Case	Option 33b	Difference (%)	Option 33c	Difference (%)
Blowering Dam					
1631.4 GL (FSV)	100%	100%	0%	100%	0%
1531.4 GL	86%	84%	-2%	81%	-5%
50%	27%	27%	0%	29%	2%
25%	7%	8%	1%	9%	2%
10%	3%	3%	0%	4%	1%
5%	2%	2%	0%	2%	0%
Burrinjuck Dam					
1026 GL (FSV)	97%	96%	-1%	95%	-2%
80%	70%	62%	-8%	16%	-54%
50%	16%	6%	-10%	3%	-13%
25%	1%	0%	-1%	0%	-1%
10%	0%	0%	0%	0%	0%
5%	0%	0%	0%	0%	0%

Comparisons of Blowering Dam and Burrinjuck Dam storage behaviour from 1/7/1891 to 30/6/2020 are shown respectively in Figure 24 and Figure 25. The figures show generally greater amounts of water stored in Blowering, and more particularly in Burrinjuck. In some years, in particular with option 33c, Burrinjuck is drawn on more heavily to support the higher General Security allocations.

Figure 24. Blowering Dam storage behaviour for the Base Case, Option 33b and Option 33c (20 GL and 1,000 GL respective Murrumbidgee on-river storages)

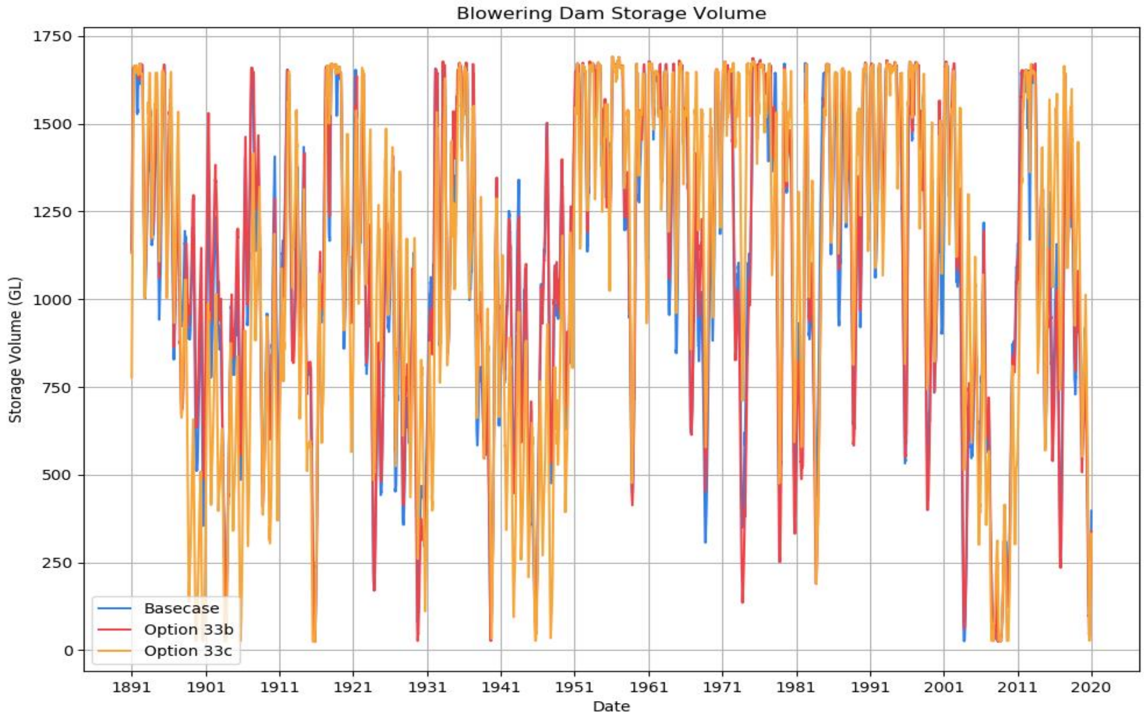
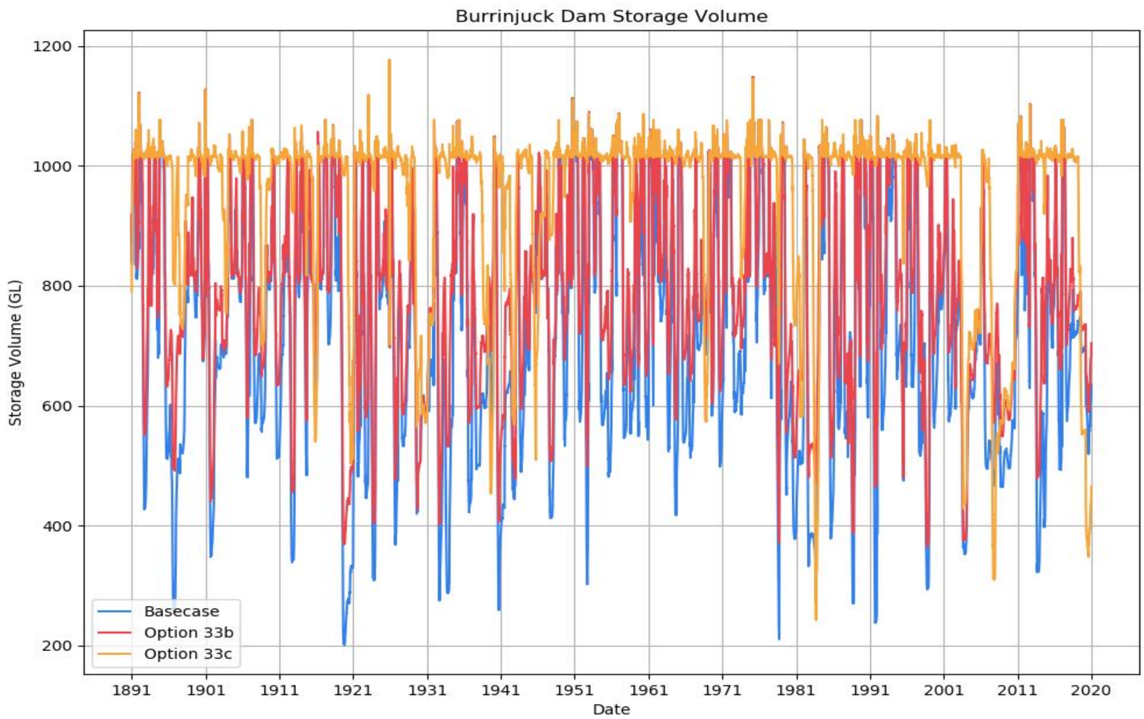


Figure 25. Burrinjuck storage behaviour for the Base Case, Option 33b and Option 33c (20 GL and 1,000 GL respective Murrumbidgee on-river storages)



Alterations in river flows

Mean annual flow for 1/7/1891 to 30/7/2020 for the Base Case and Murrumbidgee 20 GL and 1,000 GL on-river storage options 33b and 33c are shown in Table 25. The table shows for the 1000 GL storage a 3% decrease in end of system flows to Balranald which is expected given we have more re-regulation and additional supplementary being diverted to Lowbidgee.

Table 25. Comparison of the mean annual flow for the Base Case, Option 33b and Option 33c (20 GL and 1,000 GL respective Murrumbidgee on-river storages)

Gauging sites (GL/y)	Base Case	Option 33b	Change (%)	Option 33c	Change (%)
Murrumbidgee River at Gundagai	3,432.2	3,428.6	0%	3,401.8	-1%
Murrumbidgee River at Wagga Wagga	3,799.1	3,795.5	0%	3,768.6	-1%
Murrumbidgee River at Balranald	1,188.6	1,173.2	-1%	1,156.5	-3%
Billabong Creek at Darlot	227.5	228.2	0%	227.4	0%

7. Option 35. Tumut River gravity pipeline

Option description

This option involves adding a 2,000 ML/day additional outlet on Blowering Dam and a gravity pipeline that returns water just upstream of the Tumut River confluence with the Murrumbidgee River.

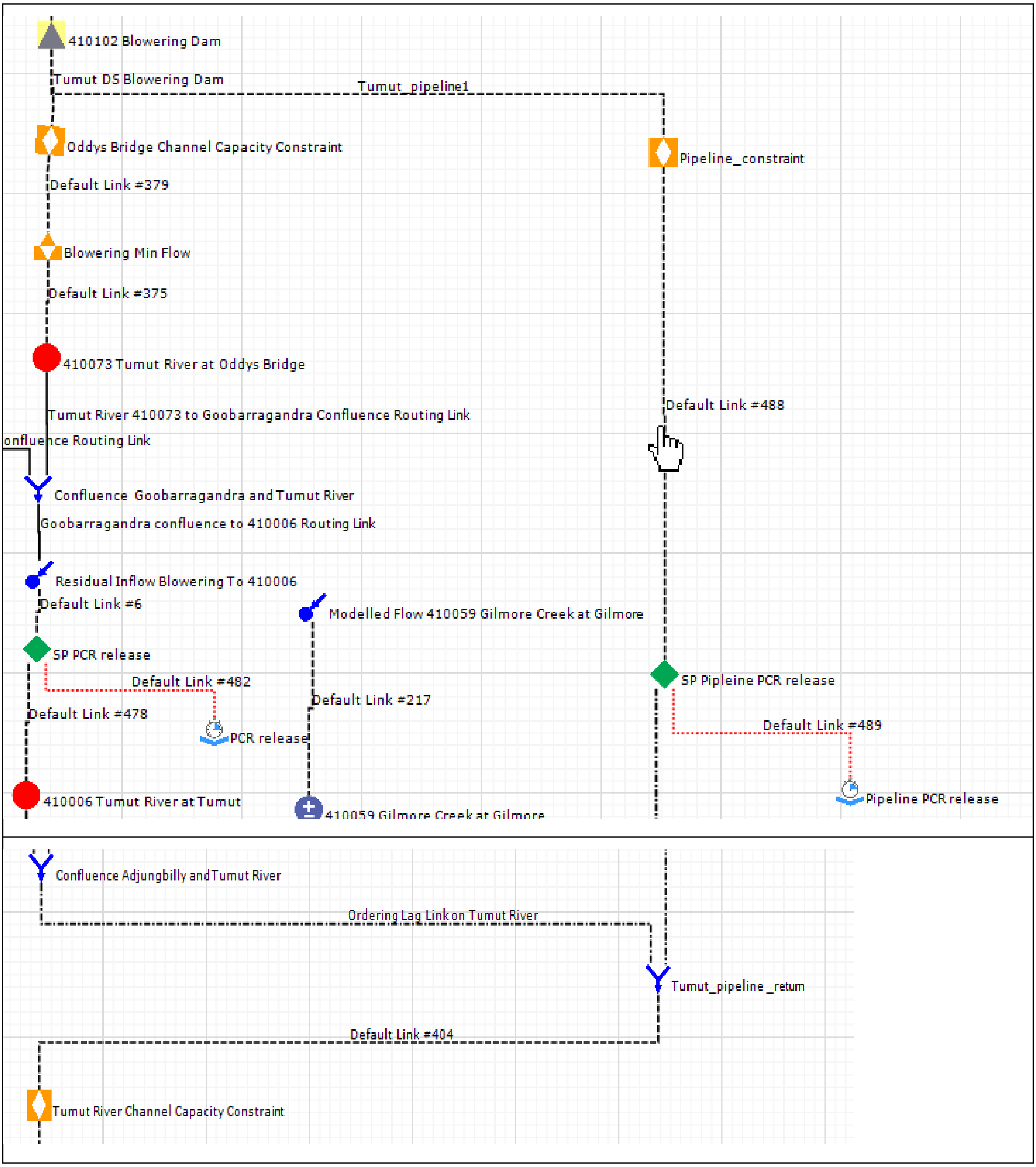
Model configuration and assumptions

The option was configured by adding an additional outlet path from Blowering Dam. It was assumed the pipeline would connect to the existing outlet works, upstream of the power station. This modelled outlet path contains:

- pipeline constraint node
- pre-release compensation reserve (PCR) supply point and water user node
- 2 days of lag routing
- confluence node upstream of the Tumut River capacity constraint node

The node configuration is shown in Figure 26.

Figure 26: Configuration of Tumut gravity pipeline in the Murrumbidgee model



The outlet relationship included in Blowering Dam is shown in Table 26. The outlet relationship commences at the current dead storage level. The maximum outlet capacity is available from 305.6 m AHD up to the dam's full supply level. The intermediate points are based on a square root power function.

Table 26 Blowering Dam gravity pipeline outlet relationship.

Level (m AHD)	Discharge (ML/day)
288.44	0
305.144	0
305.244	879
305.444	1,523
305.662	2,000
379.261	2,000

The node parameters are configured in the Option 35 scenario input set. This input set configures the pipeline constraint to 2,000 ML/day, turns the pipeline at the confluence node into a priority regulated branch and changes the Tumut maximum channel capacity constraint to 11,250 ML/day. Note in the Base Case the pipeline constraint is 0, the pipeline is not regulated at the confluence and the Tumut maximum channel capacity constraint is 9,250 ML/day.

The supply point node orders water for the Pipeline PCR release water user but is configured to not extract water i.e., the water goes down the pipeline. The Pipeline PCR release water user is used to meet any shortfall in PCR release. It does this via the $f_CompRelease_pipeline function shown below.

```
min(max(0,MurrumbidgeeSnowyStateCompRelease()*1,000.0-$f_CompRelease_river),
 $f_pipeline_order_constraint)
```

The function takes the lesser of the PCR release from the Snowy model plugin output variable (MurrumbidgeeSnowyStateCompRelease) that is converted to ML less any compensation release that has gone down the river ($f_CompRelease_river) and the pipeline order constraint ($f_pipeline_order_constraint) which is the pipeline capacity of 2,000 ML/day. The amount of water that can go down the river is limited to 9,300 ML/day less Goobarragandra inflows at Lacmalac (410057) and residual inflows from Blowering Dam to Tumut gauge (410006). This tries to meet the PCR release down the river first and then excess release is down the pipeline.

The increased outlet capacity will impact the harmony operations between Blowering and Burrinjuck dams. The Base Case harmony relationship was modified to include a variable to change the harmony operations ($f_BJairspace), that is set to 0.8 for the Base Case.

```
if($Storages.BurrinjuckDam.mv_StorageVolume < $Storages.BurrinjuckDam.mv_FullSupplyVolume
* $f_BJairspace, $f_tumutconstraint,
if($Environment.MidRiverWetlandsEWR.f_actively_ordering=1,$f_tumutconstraint,0))
```

Initially the harmony variable was modified to confirm that the 0.8 for the Base Case was close to optimum operation behaviour. Optimum behaviour was defined as minimising the combined spills from the dams. For this scenario different harmony variables were trialled until the combined spill was similar to the Base Case.

The energy generation from Jounama storage is calculated as:

$$E = 0.97 * (L - 365.9) * \min(56.4, Q) * 9.81 * 0.001 * 0.024$$

Where:

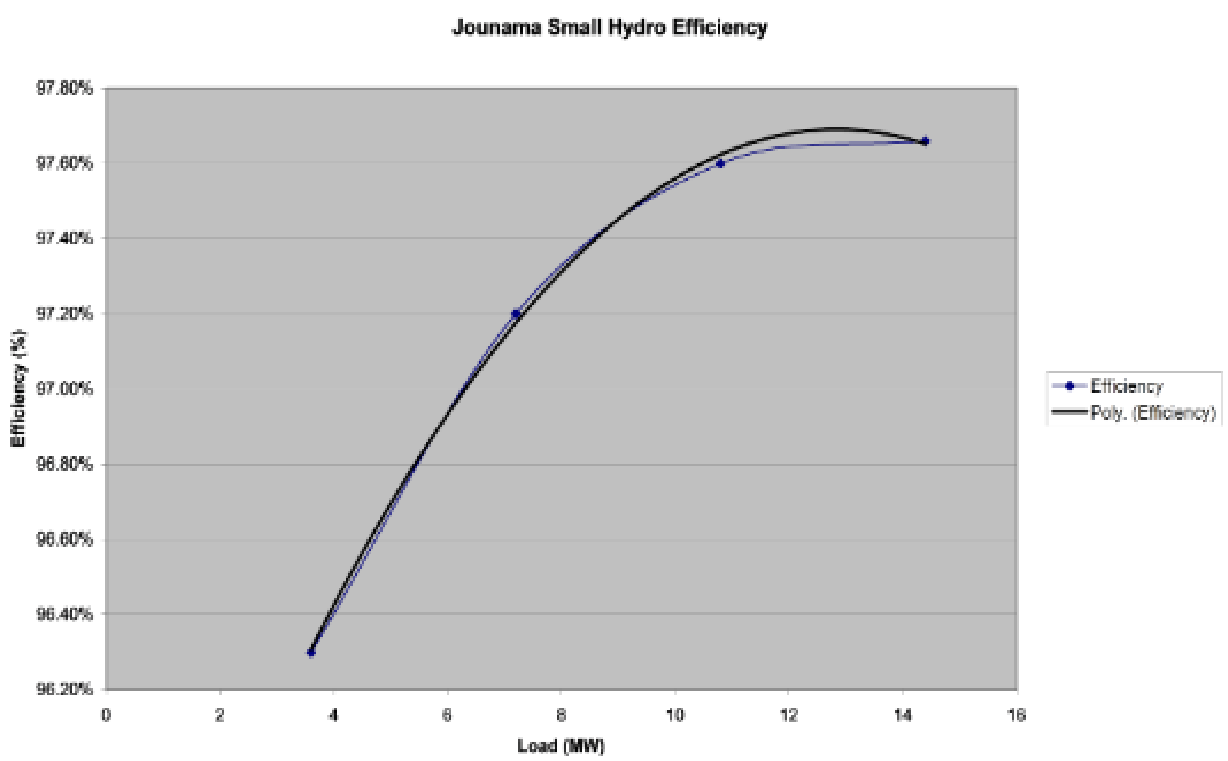
E Energy in GWh/day

L Jounama level (m SHD)

Q Jounama discharge (m^3/s)

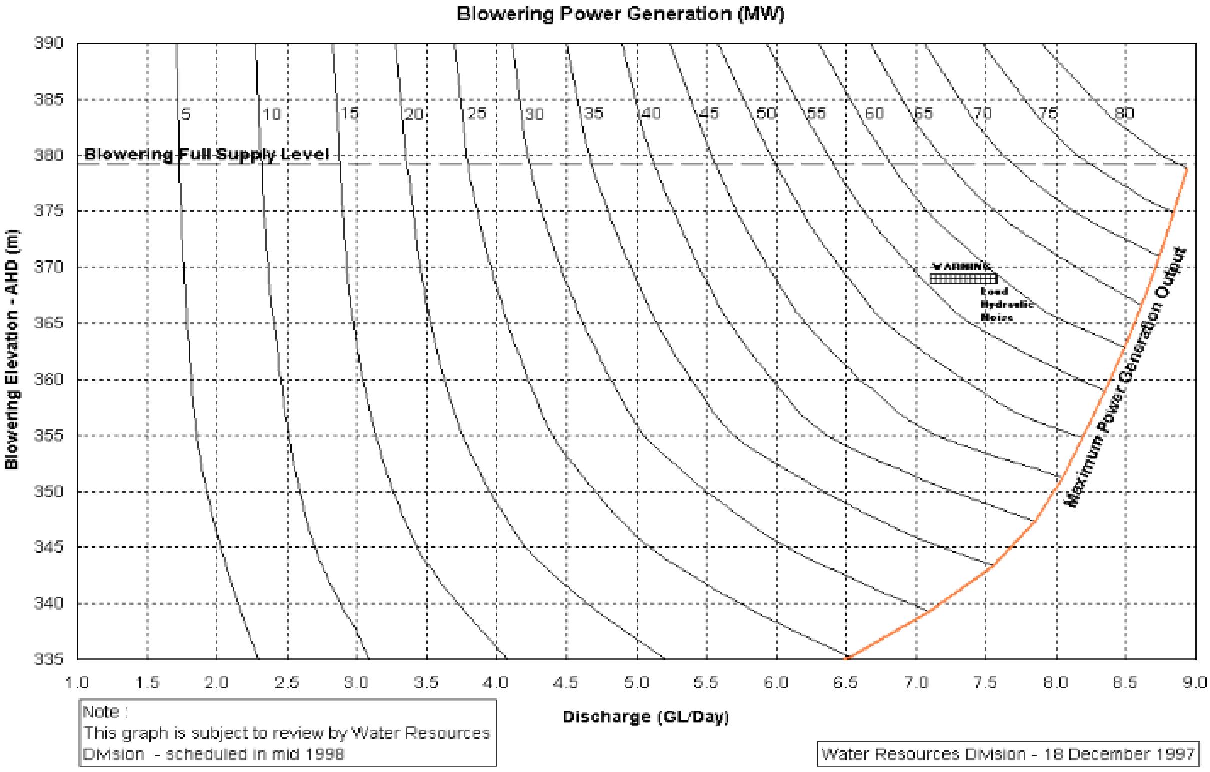
The maximum turbine discharge is limited to 4873 ML/day (56.4 m^3/s). The turbine head is relative to 365.9 m SHD. The minimum operating level for Jounama is 381 m SHD at which point there is 12m head to the turbine outlet. It is assumed that when Blowering Dam level reaches the turbine outlets generation cannot occur. This is at 381 m SHD less 12 m of head which is equivalent 367.88 m AHD. Note average efficiency of 0.97 is based on a curve provided by SHL (Figure 27**Error! Reference source not found.**).

Figure 27 Jounama generation efficiency



The energy generation from Blowering is based on 2D lookup table of discharge versus Blowering level provide by SHL (Figure 28). This is multiplied by 0.024 to get GWh/day.

Figure 28 Blowering energy generation curves.



Note the energy generation values calculated by the above equations compared well against numbers provided by the Snowy model outputs.

Assumptions

The travel time in the pipeline has been configured to be the same as the river. This would not be the case with the valve located at the Tumut River confluence with the Murrumbidgee River the pipeline release could be 2 days earlier. This was required to deal with different travel time ordering issues in Source. This assumption is not likely to have a significant impact on results.

It was originally proposed that pipeline orders would progressively increase once the downstream order reached 5,000 ML/day. The aim of this was to ensure that orders up to 5,000 ML/day would be supplied by the river and then progressively increased until channel capacity of 9,300 ML/day at which point the pipeline would not be constrained. Due to the Source placing orders prior to flows up to channel capacity (time of evaluation), it was not possible to configure this to work correctly in the model. The consequence of this is more water will be supplied by the pipeline. Given that reach losses are small the release impacts will be small.

For energy generation calculations it was assumed that the spilt of total discharge between the river and the pipeline was as detailed in Table 27.

Table 27 Discharge splitting relationship for Blowering Dam.

Total Blowering Dam discharge (ML/day)	Tumut River discharge (ML/day)
0	0
5,000	5,000
5,100	5,020
6,000	5,200
7,200	5,200
9,000	7,000
11,000	9,000

Modelling results

In this section, modelling results are shown for the Tumut gravity pipeline (Option 35). The optimised harmony variable (i.e., spills from both storages minimised) was found to be 0.7 i.e., orders are directed to Burrinjuck when it is above 70% of FSV.

Alteration in dam releases

This option shows that the results are more sensitive to the harmony operation of Blowering and Burrinjuck dams rather than the pipeline impact on Blowering Dam release. The change in harmony operation has increased spills by 1% and this causes a corresponding decrease in general security allocations and diversions. It shows that the pipeline does not have a significant impact on the system reliability and the current harmony operation can be used to manage channel constraints. The increase in release from Blowering is only 0.1%.

Alteration in hydropower generation

There is a hydro-power station downstream of Blowering Dam. The pipeline will impact on power generation. Table 28 shows a reduction of 30 GWh/year in energy generation due to water diverted down the pipeline.

Table 28 Jounama and Blowering Dams average annual energy generation.

Site	Base Case (GWh/y)	Tumut pipeline (GWh/y)
Jounama Dam	72.2	72.2
Blowering Dam	162.8	132.6
Total	235	204.8

Alterations in water diversions

Table 29 shows the average annual water diversions from 1/7/1895 to 30/6/2010 for consumptive water users under the Base Case, and the Tumut pipeline option. The table shows that there are no significant differences in diversions.

Table 29 Mean annual water diversions for the Base Case and Option 35 (Tumut pipeline).

Water diversions (GL/y)	Base Case	Option 35	Change (%)
General Security	674.8	665.7	-1%
High Security	294.1	294.2	0%
Murrumbidgee Irrigation Conveyance	161.6	161.5	0%
Coleambally Irrigation Conveyance	103.8	103.7	0%
Premium High Security	18.1	18.0	-1%
Stock and Domestic	19.4	19.3	-1%
Local Water Utility	10.1	10.1	0%
Supplementary	116.0	116.4	0%
Lowbidgee consumptive	48.6	48.8	0%
Inter-valley transfer	105.5	105.3	0%
Total diversions	1,552.0	1,543.0	-1%

The annual distribution of total general and high security diversions is shown in Figure 29 and Figure 30, respectively. The figure shows a close match on general security diversions and an improvement in high security diversions in the driest year.

Figure 29. Total General security annual diversions for the Base Case and Option 35 (Tumut pipeline).

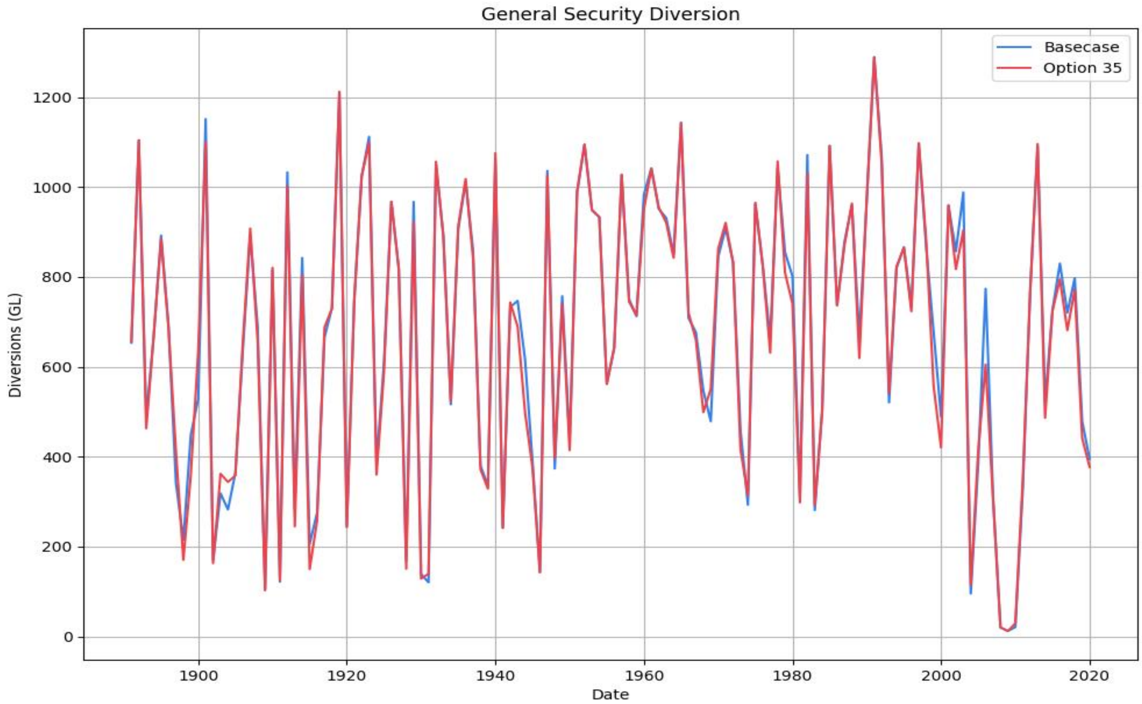
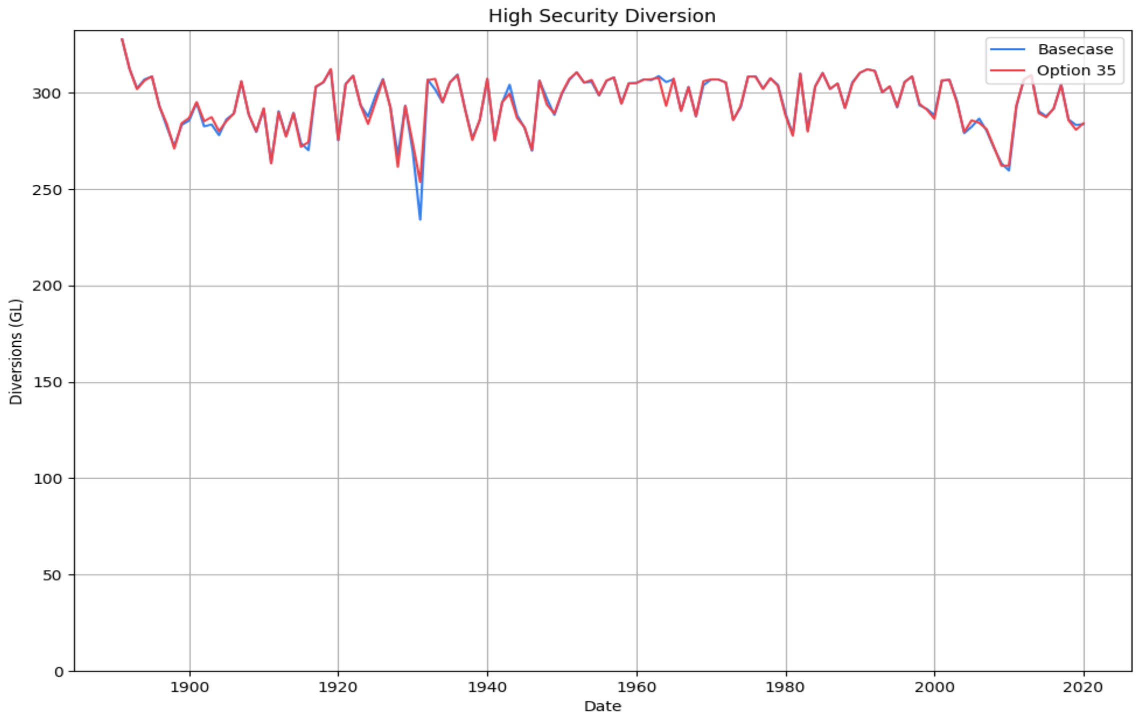


Figure 30. Total High security annual diversions for the Base Case and Option 35 (Tumut pipeline).



Alterations in environmental water delivery

Table 30 shows the average annual held and planned environmental water deliveries from 1/7/1895 to 30/6/2010. The table shows 3% increase in the held environmental water and only minor impacts on other environmental water.

Table 30. Mean annual environmental water delivery for the Base Case and Option 35 (Tumut pipeline).

Water delivery (GL/y)	Base Case	Option 35	Change (%)
Held environmental water	144.6	148.9	3%
Lowbidgee environment	70.0	70.8	1%
Planned environmental water	133.4	132.6	-1%
Total environmental water	348.0	352.3	1%

Alterations in allocation reliability

30 September, start and end of water year allocations from 1/7/1891 to 30/6/2020 are shown in Table 31 for the Base Case and the Tumut pipeline option.

The results show only 1% decrease in allocation reliability across lower security licence types.

Table 31. Allocations for the Base Case and Option 35 (Tumut pipeline).

Average allocations (%)	Base Case	Option 35	Difference (%)
General security effective allocation on 1 July	39%	38%	-1%
General security effective allocation on 30 September	61%	60%	-1%
General Security effective allocation on 30 June	80%	80%	0%
General security allocation on 1 July	31%	30%	-1%
General security allocation 30 September	53%	52%	-1%
General Security allocation on 30 June	72%	71%	-1%
High security allocation on 1 July	93%	94%	1%
High security allocation 30 September	96%	96%	0%
High security allocation on 30 June	98%	97%	-1%
Coleambally Irrigation conveyance allocation on 1 July	88%	88%	0%

Average allocations (%)	Base Case	Option 35	Difference (%)
Coleambally Irrigation conveyance allocation 30 September	92%	91%	-1%
Coleambally Irrigation conveyance allocation on 30 June	95%	95%	0%
Murrumbidgee Irrigation conveyance allocation on 1 July	76%	75%	-1%
Murrumbidgee Irrigation conveyance allocation 30 September	85%	85%	0%
Murrumbidgee Irrigation conveyance allocation on 30 June	92%	91%	-1%

The effective general security reliability from 1/7/1891 to 30/6/2020 on the 30 September and at the end of the water year are shown respectively in Figure 31and **Error! Reference source not found.**. The figures show that the reliability of effective general security allocation is maintained through the year.

Figure 31. 30 September effective general security allocation reliability for the Base Case and Option 35 (Tumut pipeline)

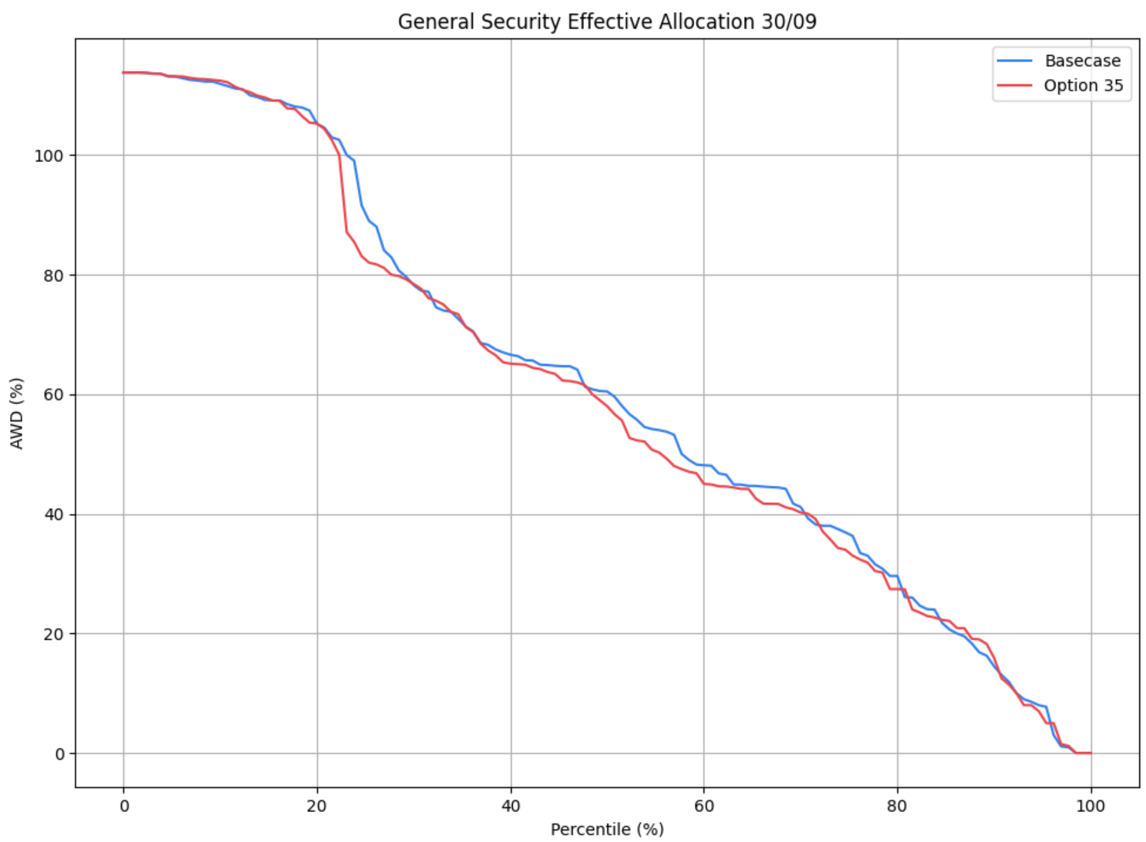
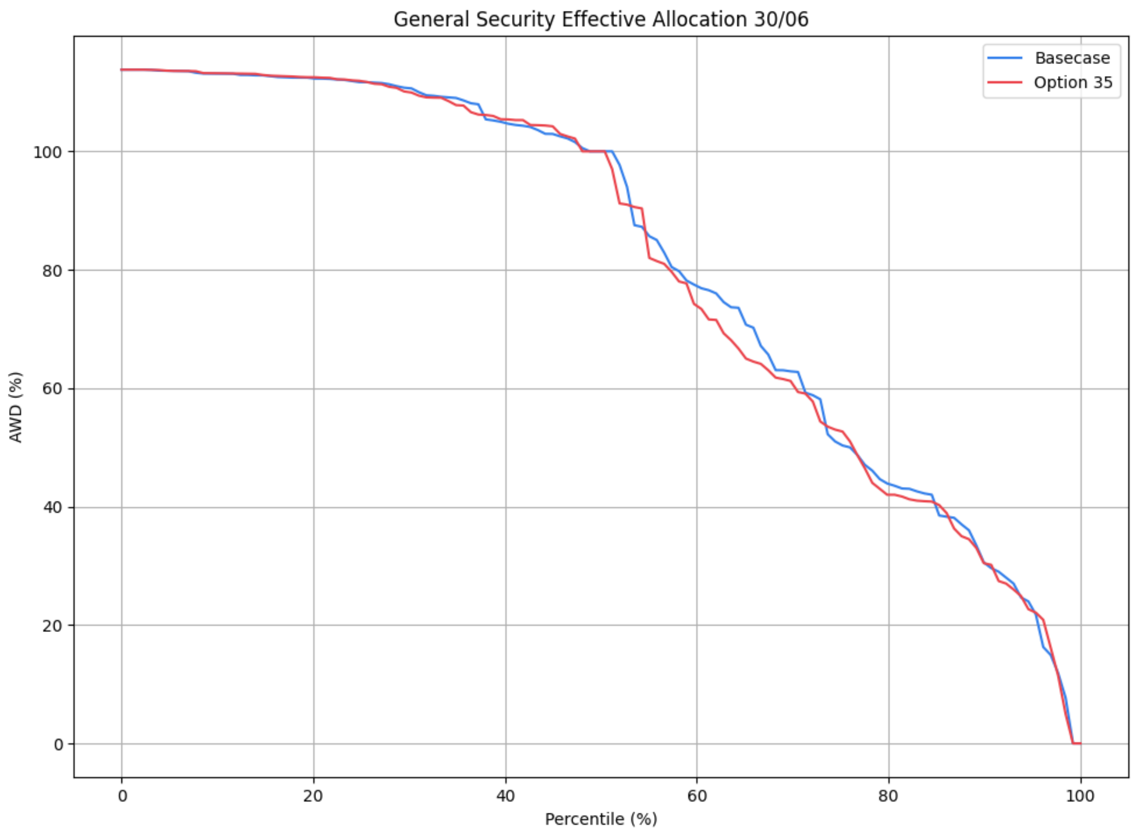


Figure 32. End of water year (30/6) effective general security allocation reliability for general security for the Base Case and Option 35 (Tumut pipeline)



Alterations in storage behaviour

Blowering Dam and Burrinjuck Dam storage behaviour for the Base Case and the Tumut pipeline option are shown in Table 32 and Table 33 shows an 1% decrease in spills from Blowering and 2% increase in Burrinjuck dams. Table 33 shows that Blowering Dam percentage of time below 50% increases and correspondingly Burrinjuck dam is reduced. This is largely due to the change in harmony operation and the increased capacity of the Tumut River.

Table 32. Blowering Dam and Burrinjuck Dam spill behaviour for the Base Case and Option 35 (Tumut pipeline)

Storage Spills (GL/y)	Base Case	Option 35	Change (%)
Blowering Dam	313.3	311.4	-1%
Burrinjuck Dam	365.6	371.1	2%

Table 33. Blowering Dam and Burrinjuck Dam storage behaviour for the Base Case and Option 35 (Tumut pipeline)

% of time below	Base Case	Option 35	Difference (%)
Blowering Dam			
1631.4 GL (FSV)	86%	86%	0%
1531.4 GL	79%	80%	1%
50%	27%	32%	5%
25%	7%	9%	2%
10%	3%	3%	0%
5%	2%	2%	0%
Burrinjuck Dam			
1026 GL (FSV)	97%	96%	-1%
80%	70%	73%	3%
50%	16%	7%	-9%
25%	1%	0%	-1%
10%	0%	0%	0%
5%	0%	0%	0%

Comparison of Blowering Dam and Burrinjuck Dam storage behaviour from 1/1/1891 to 30/6/2020 are shown respectively in Figure 34and Figure 34. The figures show Blowering Dam is drawn down more in the mid storage levels due to the extra release capacity correspondingly Burrinjuck is not drawn down as much in dry periods.

Figure 33. Blowering Dam storage behaviour for the Base Case and Option 35 (Tumut pipeline)

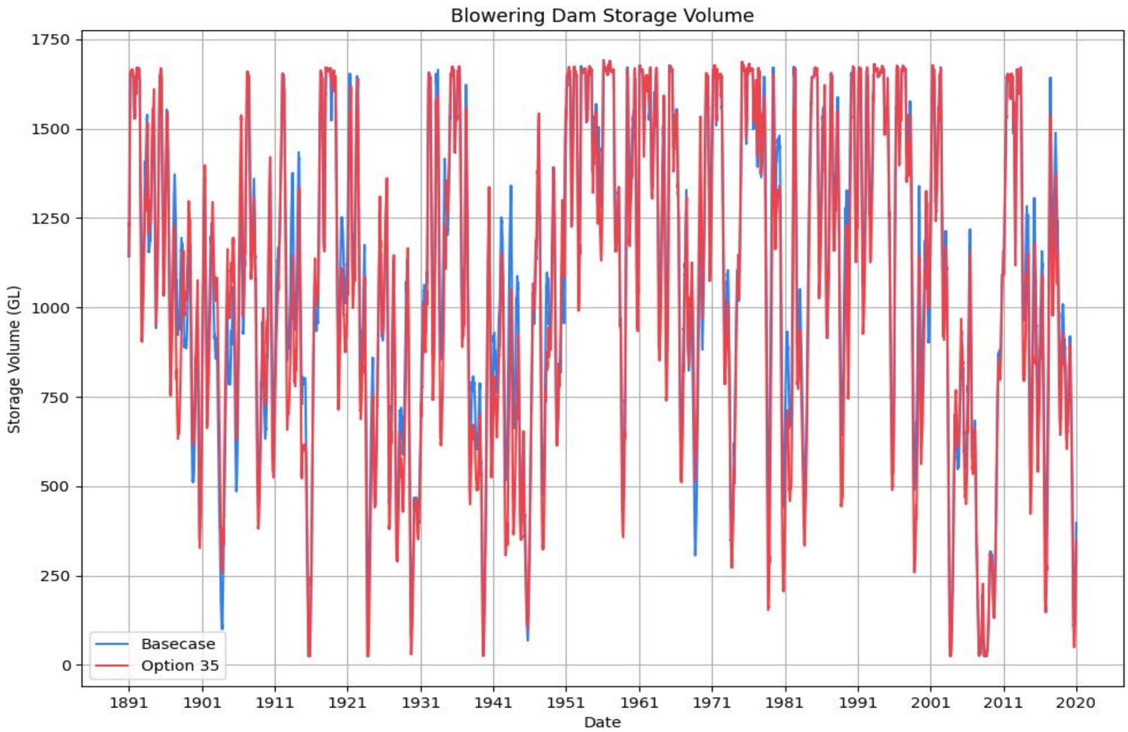
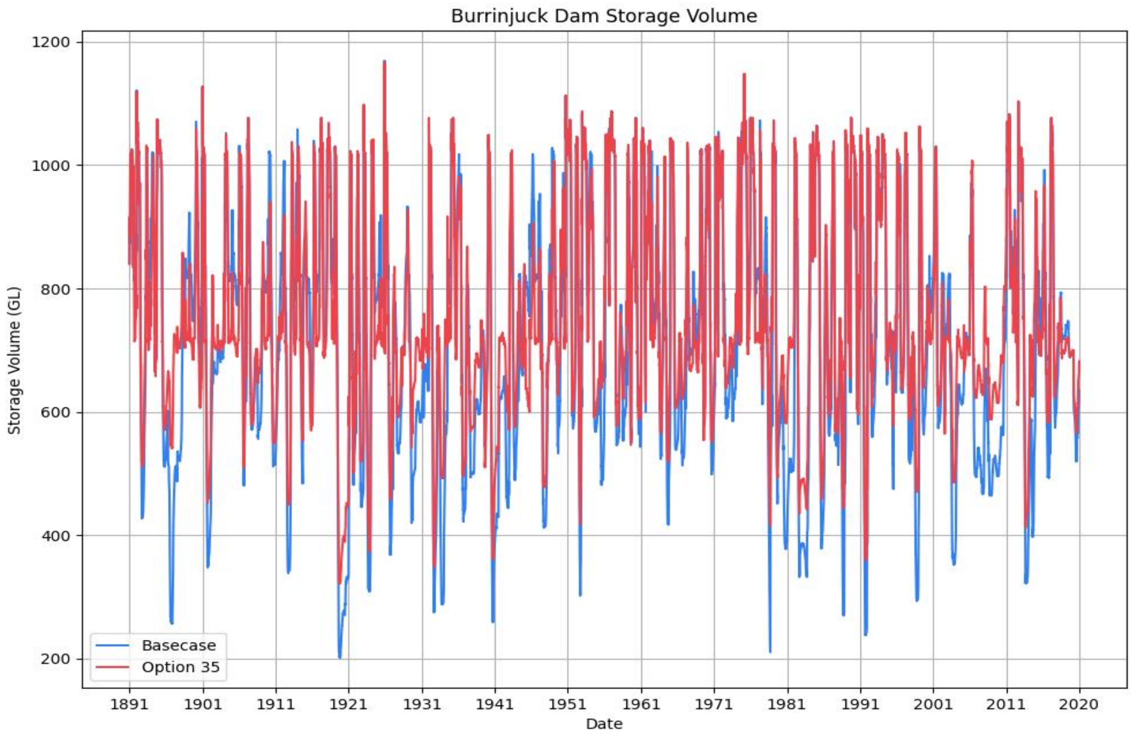


Figure 34. Burrinjuck storage behaviour for the Base Case and Option 35 (Tumut pipeline)



Alterations in river flows

Mean annual flow for 1/7/1891 to 30/7/2020 for the Base Case and Tumut pipeline option are shown in Table 34. The table shows minor changes to flows at Balranald.

Table 34. Comparison of the mean annual flow for the Base Case and Option 35 (Tumut pipeline)

Gauging sites (GL/y)	Base Case	Option 35	Change (%)
Murrumbidgee River at Gundagai	3,432.2	3,432.2	0%
Murrumbidgee River at Wagga Wagga	3,799.1	3,799.0	0%
Murrumbidgee River at Balranald	1,188.6	1,196.6	1%
Billabong Creek at Darlot	227.5	227.8	0%

8. Option 36. Enlarged Blowering Dam

Option description

This option involves adding 200 GL additional storage capacity to Blowering Dam (increasing it to 1,828 GL). It considers sensitivity to the nominated PCR airspace in two airspace scenarios:

- 100 GL
- 200 GL

Model configuration and assumptions

The option was configured by modifying Blowering Dam level-volume-area relationship, raising the spillway relationship, and correspondingly increasing the full supply volume.

The level-volume-area relationship in Blowering Dam above FSV was modified based on information provided by Water NSW (Table 35).

Table 35 Blowering Dam extended level-volume-area relationship.

Level (m AHD)	Volume (ML)	Area (km^2)
379.27	1,631,410	43.8
380	1,663,415	44.3
381	1,707,257	45.0
382	1,751,099	45.7
383	1,795,129	46.5
383.78	1,831,410	47.0
384	1,841,582	47.2
385	1,888,035	47.9
386	1,934,488	48.6
387	1,980,941	49.4
388	2,027,394	50.1
389.27	2,086,389	51.0

The spillway relationship included in Blowering Dam was modified as shown in Table 36. The existing spillway was raised from the Base Case full supply level 379.27 m AHD to the supply level of 383.78 m AHD for this option.

Table 36 Blowering Dam revised spillway outlet relationship.

Level (m AHD)	Discharge (ML/day)
383.78	0
384.88	12,200
385.52	24,500
387.43	73,400
389.65	146,800
390.26	171,300
390.81	195,800

The model is also configured with a scenario input set (option 36) that configures the FSV and spillway relationship. The model was run concurrently for several harmony options and until the option with the closest match to Base Case Burrinjuck spills was found.

Assumptions

The raising of Blowering Dam has implications for SHL hydro-power releases from Jounama reservoir. At the revised storage volume, the headwaters of the dam are at the toe of Jounama storage. When the dam is at these higher volumes this restricts the generation of hydropower. To compensate SHL could specify a larger airspace to be maintained. The impact of the airspace was explored with two airspace options.

Modelling results

In this section, modelling results are shown for the Enlarged Blowering Dam The optimised harmony variable was found to be 0.7 i.e., orders are directed to Burrinjuck when it is above 70% of FSV. To ensure SDL compliance a 50% reduction factor was applied to supplementary allocations.

Murray Darling Basin Plan Compliance

It was assumed that per MDB Basin Planning principles, long term extractive use would stay the same as the baseline case. To achieve this, supplementary use was reduced by reducing supplementary allocation caps and thresholds to 50% of baseline entitlements. Without reducing supplementary take there would be an additional average annual consumptive use increase of 1.8% for both the 100 and 200 GL airspace scenarios.

The impacts of changes of supplementary caps on environmental regulated river supplementary allocations is not modelled or considered.

Alteration in hydropower generation

Enlarged Blowering Dam will impact on energy generation from Jounama and Blowering dams. Table 37 shows a slight decrease in Jounama caused at times when Blowering Dam level limits generation. Blowering Dam energy generation has been improved by the large amount of time that Blowering is at higher levels.

Table 37 Jounama and Blowering dams average annual energy generation.

Site	Base Case (GWh/y)	Enlarge Blowering (GWh/y)
Jounama dam	72.2	71.9
Blowering dam	162.8	175.8
Total	235	247.7

Alterations in water diversions

Table 38 shows the average annual water diversions from 1/7/1895 to 30/6/2010 for consumptive water users under the Base Case, and the Enlarged Blowering Dam options. The table shows that there are slight improvements for most licence types except supplementary. Note supplementary access was reduced by 50% to ensure total diversions matched the Base Case. It also shows that diversions are not sensitive to the airspace with less than 1% difference in the entitlements and overall diversions.

Table 38 Mean annual water diversions for the Base Case and Option 36 (Enlarged Blowering Dam with 100(i) and 200(ii) GL airspace).

Water diversions (GL/y)	Base Case	Option 36(i)	Change (%)	Option 36(ii)	Change (%)
General Security	674.8	707.7	5%	705.8	5%
High Security	294.1	295.8	1%	295.4	0%
Murrumbidgee Irrigation Conveyance	161.6	165.0	2%	165.4	2%
Coleambally Irrigation Conveyance	103.8	104.0	0%	104.1	0%
Premium High Security	18.1	17.9	-1%	17.9	-1%
Stock and Domestic	19.4	21.3	10%	21.4	10%
Local Water Utility	10.1	10.1	0%	10.1	0%
Supplementary	116.0	62.8	-46%	62.4	-46%
Lowbidgee consumptive	48.6	47.5	-2%	48.3	-1%
Inter-valley transfer	105.5	106.4	1%	105.9	0%
Total diversions	1,552.0	1,538.5	-1%	1,536.7	-1%

The annual distribution of total general and high security diversions is shown in Figure 35 and Figure 36, respectively. The figures shows that the increased airspace improves the medium allocations with the 200 GL airspace being much less effective. Overall high security diversions are similar but are improved in drawn down periods particularly extreme droughts. This is due to the extra storage capacity of the system.

Figure 35. Total General security annual diversions for the Base Case and Option 36 (Enlarged Blowering Dam with 100 and 200 GL airspace).

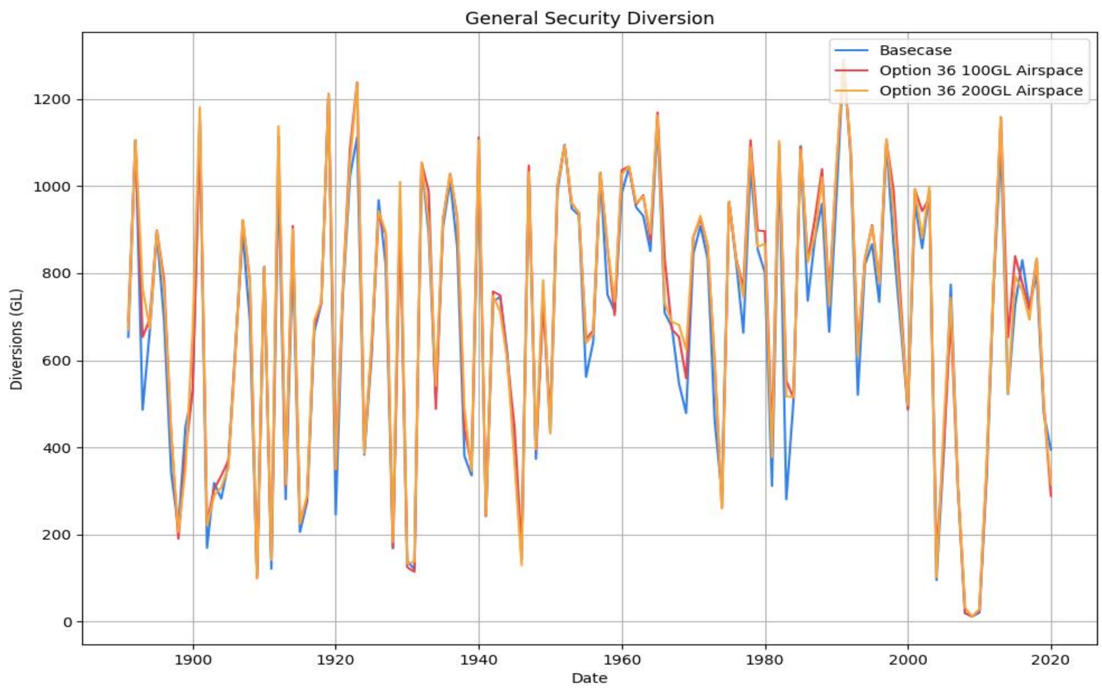
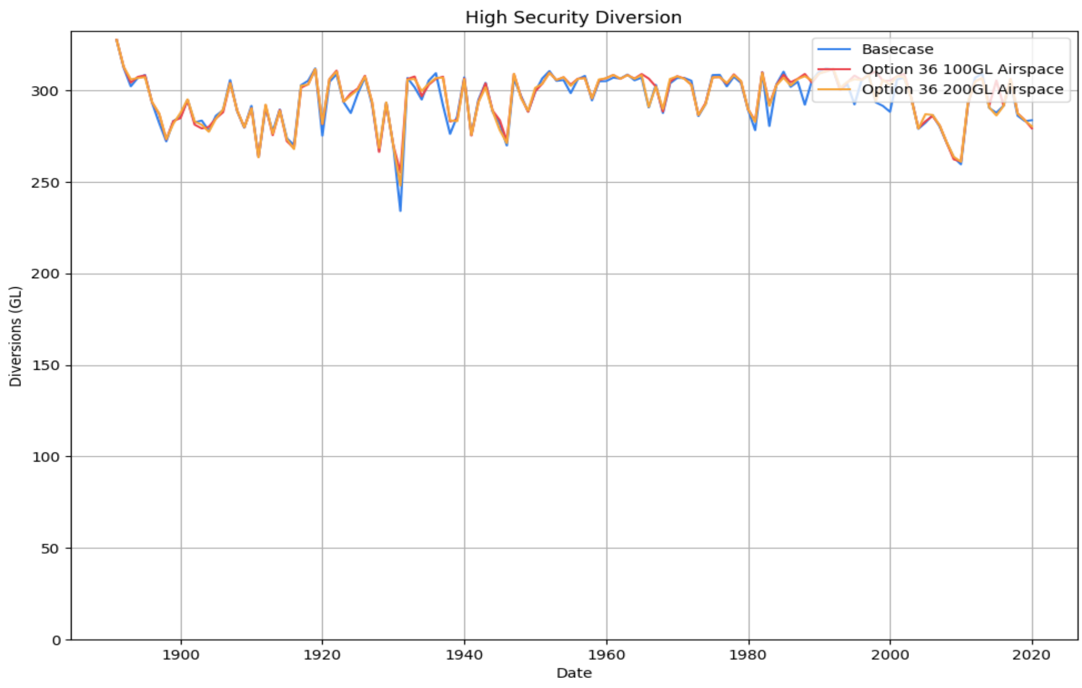


Figure 36.Total High security annual diversions for the Base Case and Option 36 (Enlarged Blowering Dam with 100 and 200 GL airspace).



Alterations in environmental water delivery

Table 39 shows the average annual held, Lowbidgee supplementary and planned environmental water deliveries from 1/7/1891 to 30/6/2020. The table shows a 6% increase in the held environmental water and a 1% increase in planned environmental water in 200 GL airspace scenario. The Lowbidgee supplementary is 3% less for 100 GL airspace and 2% less for 200 GL airspace. The held increase is due to increases in allocation and the planned increase is due to Blowering Dam spills being converted to planned environmental releases from Blowering Dam. The enlarged Blowering dam reduces spills that in turn reduces flows to Lowbidgee however this is compensated by an increased airspace.

Table 39. Mean annual environmental water delivery for the Base Case and Option 36 (Enlarged Blowering Dam with 100(i) and 200(ii) GL airspace).

Water delivery (GL/y)	Base Case	Option 36(i)	Change (%)	Option 36(ii)	Change (%)
Held environmental water	144.6	156.8	8%	152.8	6%
Lowbidgee environment	70.0	67.8	-3%	68.4	-2%
Planned environmental water	133.4	132.1	-1%	135.1	1%
Total environmental water	348.0	356.7	3%	356.3	2%

Alterations in allocation reliability

30 September, start and end of water year allocations from 1/7/1891 to 30/6/2020 are shown in Table 40. The results show improvements in allocation reliability across all licence types.

Table 40. Allocations for the Base Case and Option 36 (Enlarged Blowering Dam with 100(i) and 200(ii) GL airspace).

Average allocations (%)	Base Case	Option 36(i)	Difference (%)	Option 36(ii)	Difference (%)
General security effective allocation on 1 July	39%	44%	5%	43%	4%
General security effective allocation on 30 September	61%	65%	4%	64%	3%
General Security effective allocation on 30 June	80%	83%	3%	83%	3%
General security allocation on 1 July	31%	37%	6%	36%	5%
General security allocation 30 September	53%	57%	4%	57%	4%
General Security allocation on 30 June	72%	75%	3%	75%	3%
High security allocation on 1 July	93%	94%	1%	94%	1%

High security allocation 30 September	96%	96%	0%	96%	0%
High security allocation on 30 June	98%	98%	0%	98%	0%
Coleambally Irrigation conveyance allocation on 1 July	88%	89%	1%	89%	1%
Coleambally Irrigation conveyance allocation 30 September	92%	92%	0%	92%	0%
Coleambally Irrigation conveyance allocation on 30 June	95%	95%	0%	95%	0%
Murrumbidgee Irrigation conveyance allocation on 1 July	76%	78%	2%	78%	2%
Murrumbidgee Irrigation conveyance allocation 30 September	85%	87%	2%	87%	2%
Murrumbidgee Irrigation conveyance allocation on 30 June	92%	92%	0%	92%	0%

The effective general security reliability on the 30 September and at the end of the water year are shown respectively in Figure 37 and Figure 38. The figures show improvements across the range of effective allocations with the improvements being slightly more for the 100 GL airspace.

Figure 37. 30 September effective general security allocation reliability for the Base Case and Option 36 (Enlarged Blowering Dam with 100 and 200 GL airspace).

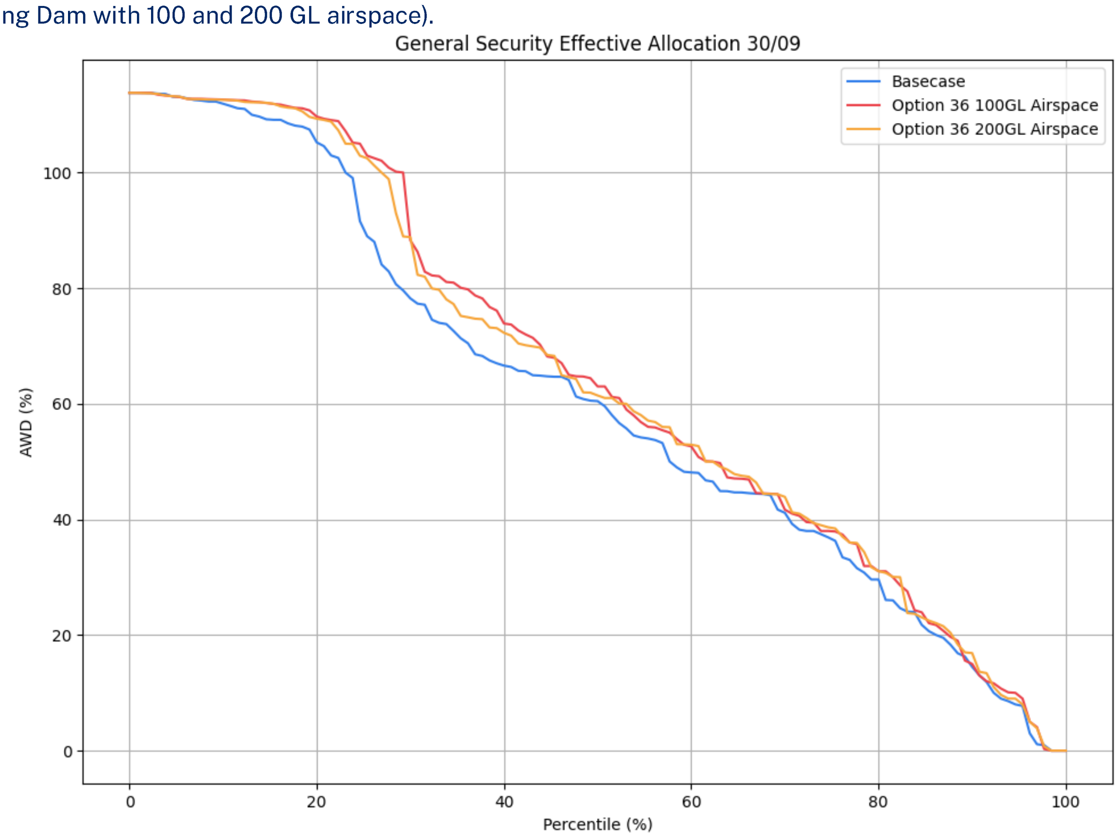
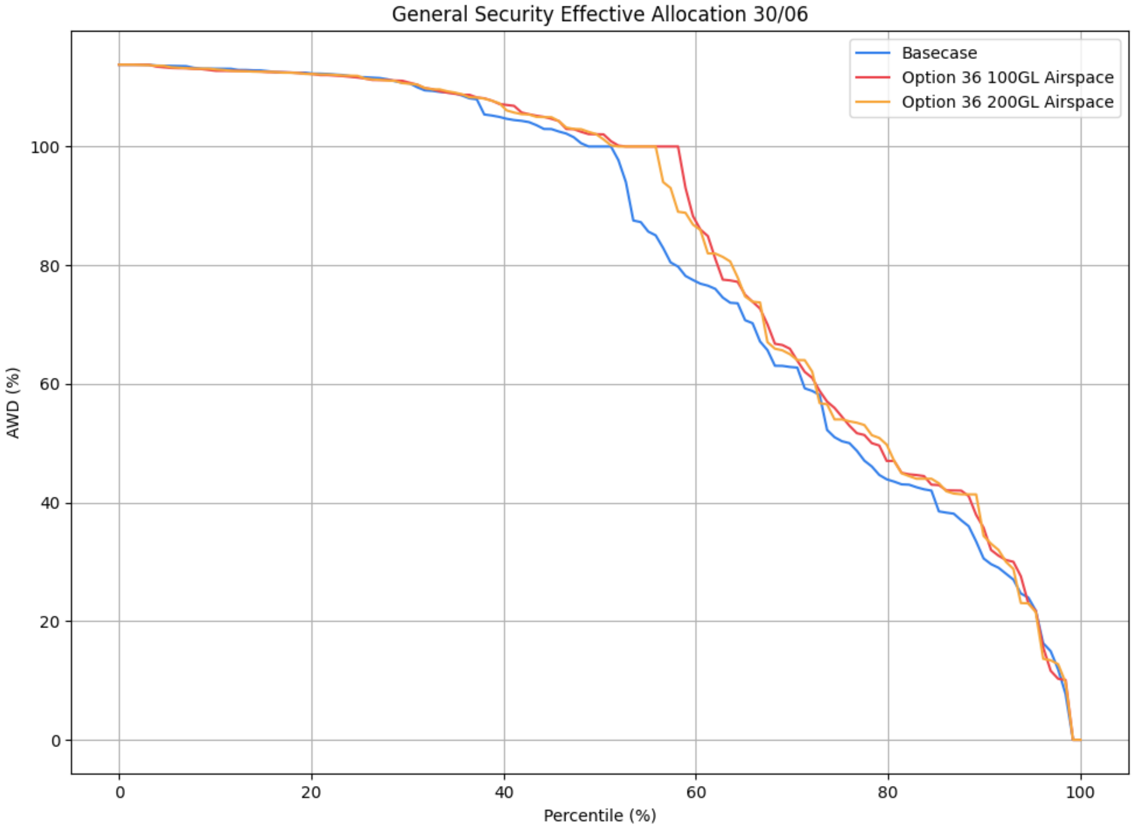


Figure 38. End of water year (30/6) effective general security allocation reliability for general security for the Base Case and Option 36 (Enlarged Blowering Dam with 100 and 200 GL airspace).



Alterations in storage behaviour

Blowering Dam and Burrinjuck Dam storage behaviour for the Base Case and Enlarged Blowering Dam options are shown in

Table 41 and Table 42. Table 42 shows less than 1% change for Burrinjuck storage behaviour. Under the 100 GL airspace scenario, for Blowering Dam it shows that 87% of the time it is below the upgraded FSV (1,831.4 GL) and 79% below the current full supply volume which is a 21-percentage point improvement. Under the 200 GL airspace scenario, Blowering Dam storage time above the current FSV improves by 16 percentage point. There are no significant changes to Burrinjuck storage behaviour.

Table 41. Blowering and Burrinjuck spill behaviour for the Base Case and Enlarged Blowering Dam with 100(i) and 200(ii) GL airspace.

Storage Spills (GL/y)	Base Case	Option 36(i)	Change (%)	Option 36(ii)	Change (%)
Blowering Dam	313.3	289.4	-8%	272.4	-13%
Burrinjuck Dam	365.6	361.7	-1%	357.9	-2%

Table 42. Blowering and Burrinjuck storage behaviour for the Base Case and Enlarged Blowering Dam with 100(i) and 200(ii) GL airspace.

% of time below	Base Case	Option 36(i)	Difference (%)	Option 36(ii)	Difference (%)
Blowering Dam					

1831.4 GL	100%	87%	-13%	88%	-12%
1731.4 GL	100%	81%	-19%	84%	-16%
1631.4 GL (FSV)	100%	79%	-21%	84%	-16%
1531.4 GL	86%	74%	-12%	78%	-8%
50%	27%	23%	-4%	24%	-3%
25%	7%	7%	0%	7%	0%
10%	3%	3%	0%	3%	0%
5%	2%	1%	-1%	1%	-1%
Burrinjuck Dam					
1026 GL (FSV)	97%	97%	0%	97%	0%
80%	70%	71%	1%	71%	1%
50%	16%	16%	0%	16%	0%
25%	1%	0%	-1%	0%	-1%
10%	0%	0%	0%	0%	0%
5%	0%	0%	0%	0%	0%

Comparison of Blowering and Burrinjuck storage behaviour from 1/7/1891 to 30/6/2020 are shown respectively in Figure 39 and Figure 40. The figure shows the extra capacity of Blowering Dam is filled in wet conditions and that there is not a substantial difference in this filling in the 100 and 200 GL airspace scenarios. This suggests that the PCR release does not have a large influence on the filling of the airspace. Burrinjuck behaviour is similar with slightly more water in Burrinjuck in drier years.

Figure 39. Blowering Dam storage behaviour for the Base Case and Option 36 (Enlarged Blowering Dam with 100 and 200 GL airspace).

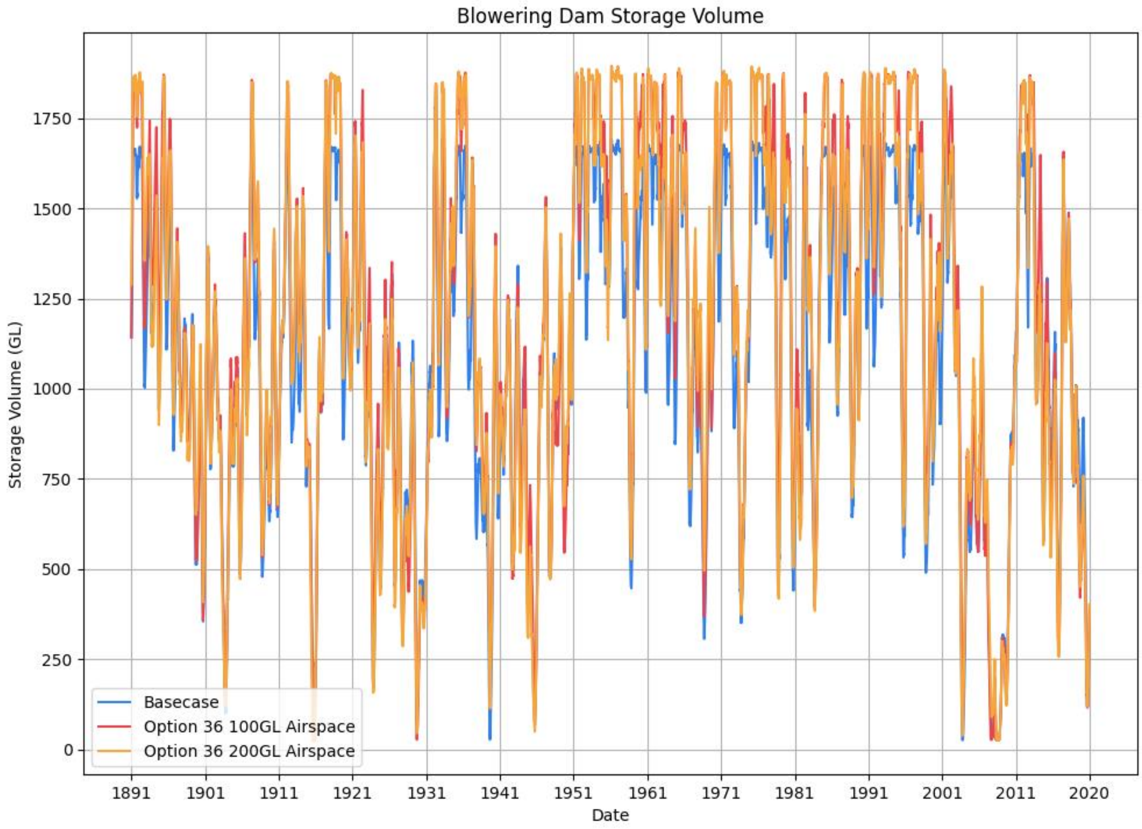
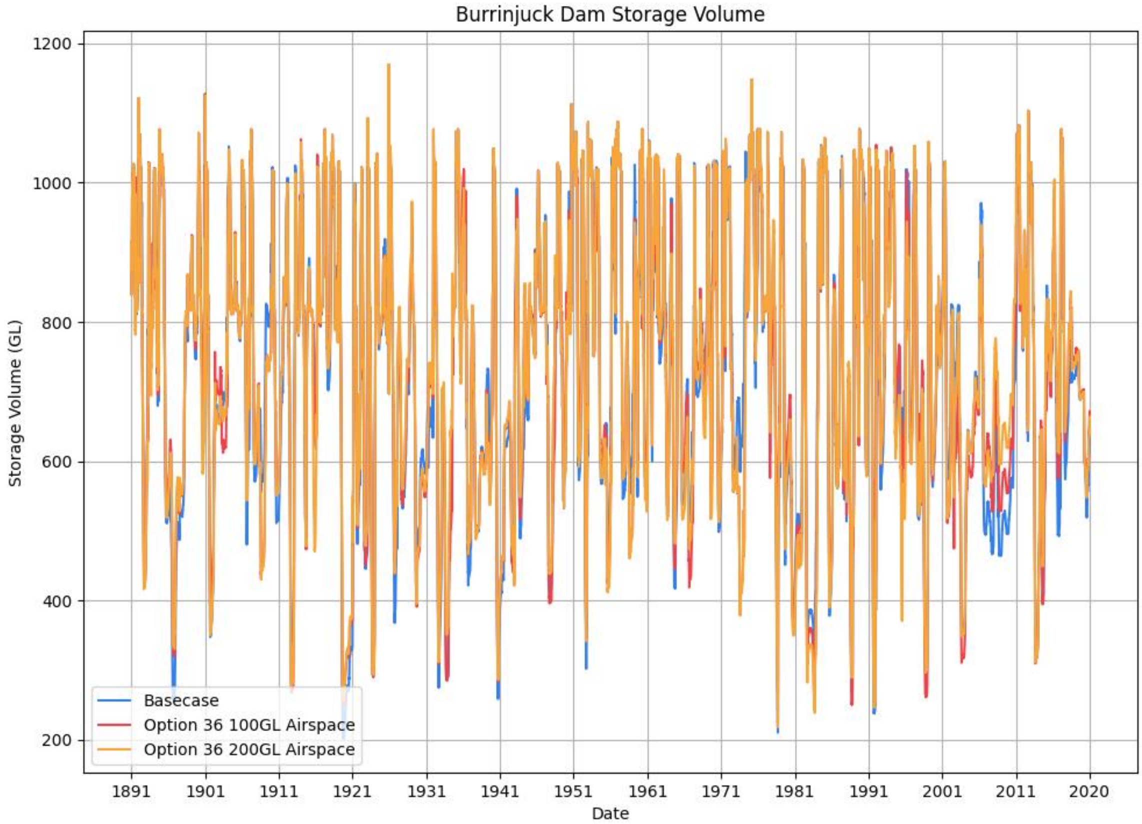


Figure 40. Burrinjuck storage behaviour for the Base Case and Option 36 (Enlarged Blowering Dam with 100 and 200 GL airspace).



Alterations in river flows

Mean annual flow for 1/7/1891 to 30/6/2020 for the Base Case and Enlarged Blowering Dam options are shown in Table 43. The table shows there is no significant change to mid river and end of system flows in all scenarios. This is because there is only a modest decrease in spills from Blowering and the larger spill volumes are largely unaffected.

Table 43. Comparison of the mean annual flow the Base Case and Option 36 (Enlarged Blowering Dam with 100(i) and 200(ii) GL airspace).

Gauging sites (GL/y)	Base Case	Option 36(i)	Change (%)	Option 36(ii)	Change (%)
Murrumbidgee River at Gundagai	3,432.2	3,429.7	0%	3,432.8	0%
Murrumbidgee River at Wagga Wagga	3,799.1	3,796.5	0%	3,799.6	0%
Murrumbidgee River at Balranald	1,188.6	1,190.9	0%	1,192.7	0%
Billabong Creek at Darlot	227.5	228.6	0%	228.6	0%

9. Option 36a. Enlarged Blowering Dam and Tumut gravity pipeline.

Option description

This is a combination of Tumut gravity pipeline and the enlarged Blowering Dam options and includes a 2,000 ML/day gravity pipeline from Blowering Dam which is enlarged by 200 GL. This also explores the two airspace options of 100 and 200 GL.

Model configuration and assumptions

The configuration of this option is discussed previously in Sections 7 and 8.

The model is configured with a scenario input set (option 36a) that configures the pipeline constraint to 2,000 ML/day, turns the pipeline at the confluence node into a priority regulated branch, changes the Tumut maximum channel capacity constraint to 11,250 ML/day, FSV to 1,831.4 GL and raise the spillway relationship. The model was run concurrently for several harmony options and until the option with the least combined spill was found.

The model was configured with a scenario input set (*GSHS Conversion*) that points to a local *conversion_inputset.txt* file that reloads on run. This file contains variables to set the system supplementary cap and each of the supplementary reach caps. The Base Case system cap is 200,783 ML and the reach caps are shown in Table 44.

Table 44 Base Case supplementary reach caps

Supplementary Reach	Annual usage limit (ML)
Blowering to Brungle	18.5
Burrinjuck to Beavers Ck	396.5
Old Man Creek system	337.3
DS Beavers Ck to Narrandera	36,849.5
Narrandera to Yanco Weir	175.5

Supplementary Reach	Annual usage limit (ML)
Yanco Weir to Morundah	1,886.0
Yanco Weir to Coly main offtake	31.0
Coleambally Canal	0
DS Coly Main Offtake to Gogeldrie Weir	7,770.7
Tombullen	0
CIA Net	20,990.5
Gogeldrie Weir to Darlington Point	548.9
Darlington Point to Hay Weir	46,621.9
Hay Weir to Maude Weir	34,504.6
Maude Weir to Redbank Weir	1,620.5
Redbank Weir to Balranald Weir	1,836.0
DS of Balranald Weir	224.5
Colombo Creek	991.5
Yanco Creek Morundah to Conargo	8,833.5
Billabong Ck Conargo to Darlot	2,970.2
Billabong Ck Innes Bridge to Forest Creek Offtake	5,004.5
Forest Creek	3,277.8
Billabong Ck DS of Darlot	4,755.5
Catchment Drain	0
DC800	0

The options model was run iteratively until total average annual diversions are within 0.1% (to keep overall diversions the same as the base case which is assumed to be SDL compliant). The iterative process uses a modified binary search algorithm to find the solution. The program solves for a supplementary entitlement factor that meets the convergence objective. The basic process is:

1. Read setup information including supplementary entitlements and supplementary cap.
2. Read Base Case results.
3. Start with an initial supplementary factor of 0.1, then a conversion factor of 1 and then interpolated factors. Note there are Source modelling issues if the supplementary factor is set to 0.
4. Based on the supplementary factor write the conversion_inputset.txt file.
5. Write the batch file to run the Murrumbidgee Source model from the command line.
6. Run the batch file.
7. Read, summarise (GL/y for licence type from 1/7/1895-30/6/2010) and write out results.
8. Check that the solution lies within upper and lower bound conversion factor of 0.1 and 1. If so, interpolate a new conversion factor. If not exit.
9. Go to step three if less than 8 iterations and the absolute difference in total demand is greater than 0.1%

Assumptions

The raising of Blowering Dam has implications for SHL hydro-power releases from Jounama reservoir. At the revised storage volume, the headwaters of the dam are at the toe of Jounama storage. When the dam is at these higher volumes this restricts the generation of hydropower. To compensate SHL could specify a large airspace to be maintained. The sensitivity of the airspace was considered by exploring a 100 and 200 GL airspace option.

The travel time in the pipeline has been configured to be the same as the river. This would not be the case with the valve located at the Tumut confluence the release could be 2 days earlier. This was required to deal with different travel time ordering issues in Source. This assumption is not likely to have a significant impact on results.

It was originally proposed that pipeline orders would progressively increase once the downstream order reached 5,000 ML/day. The aim of this was to ensure that orders up to 5,000 ML/day would be supplied by the river and then progressively increased until channel capacity of 9,300 ML/day at which point the pipeline would not be constrained. Due to the time of evaluation issues in Source, it was not possible to configure this to work correctly in the model. The consequence of this is more water will be supplied by the pipeline. Given that reach losses are small the release impacts will be small. However, it does mean that flow metrics cannot be considered in the Tumut River for this option. There are hydropower stations below both Jounama and Blowering dams that will be impacted by this scenario. The enlargement of Blowering Dam will impact power generation when the storage reaches the tailwater of the turbine outlet. Water that is diverted through the Tumut pipeline will by-pass the Blowering Dam turbines.

Modelling results

In this section, modelling results are shown for the Enlarged Blowering Dam and Tumut gravity pipeline options. The optimised harmony operation variable was found to be 0.7 i.e., orders are directed to Burrinjuck when it is above 70% of FSV. This keeps the Burrinjuck spills to approximately the same volume as the Base Case.

Murray Darling Basin Plan Compliance

It was assumed that per MDB Basin Planning principles, long term extractive use would stay the same as the baseline case. To achieve this, supplementary use was reduced by reducing supplementary allocation caps and thresholds to 84% of baseline entitlements. Without reducing supplementary take there would be an additional average annual consumptive use increase of 0.7% for both the 100 and 200 GL airspace scenarios. The impacts of changes of supplementary caps on environmental regulated river supplementary allocations is not modelled or considered.

Alteration in hydropower generation

Enlarged Blowering Dam will impact on energy generation from Jounama and Blowering dams.

Table 45 shows a slight decrease in Jounama generation caused at the times when Blowering Dam level limits generation. Blowering Dam energy generation is reduced due to water going down the pipeline.

Table 45 Jounama and Blowering dams average annual energy generation.

Site	Base Case (GWh/y)	Enlarged Blowering Dam with Tumut pipeline and 100 GL airspace (GWh/y)	Enlarged Blowering Dam with Tumut pipeline and 200 GL airspace (GWh/y)
Jounama Dam	72.2	71.9	71.6
Blowering Dam	162.8	143.4	143.6
Total	235	215.3	215.2

Alterations in water diversions

Table 46 shows the average annual water diversions from 1/7/1895 to 30/6/2010 for consumptive water users under the Base Case, and the Enlarged Blowering Dam with Tumut gravity pipeline options. The table shows that there is a slight increase for general security diversions. Note Supplementary access was reduced to ensure total diversions matched. The additional water that is captured improves the security of other licence classes. Note the diversions are not sensitive to the airspace.

It is worth noting that the general security diversions without a pipeline (option 36) are 5% more while with the pipeline (option 36a) these are only 1% more. This is counterintuitive. However, the differences are caused by the adjustment to supplementary take to make the overall take SDL compliant. In option 36 the adjustment was 50% while in this case it is 84%. The combined GS and supplementary take for option 36(ii) and 36a(ii) is respectively 768.2 GL and 786 GL which overall makes option 36a(ii) 17.8 GL better than option 36(ii).

Table 46 Mean annual water diversions for the Base Case and Option 36a (Enlarged Blowering Dam with Tumut pipeline with 100(i) and 200(ii) GL airspace).

Water diversions (GL/y)	Base Case	Option 36a(i)	Change (%)	Option 36a(ii)	Change (%)
General Security	674.8	681.1	1%	681.1	1%
High Security	294.1	294.6	0%	294.9	0%
Murrumbidgee Irrigation Conveyance	161.6	162.9	1%	163.9	1%
Coleambally Irrigation Conveyance	103.8	103.8	0%	103.9	0%
Premium High Security	18.1	18.1	0%	18.0	-1%
Stock and Domestic	19.4	19.7	2%	19.7	2%
Local Water Utility	10.1	10.1	0%	10.1	0%
Supplementary	116.0	104.2	-10%	104.9	-10%
Lowbidgee consumptive	48.6	47.8	-2%	48.4	0%
Inter-valley transfer	105.5	105.6	0%	106.2	1%
Total diversions	1,552.0	1,547.9	0%	1,551.1	0%

The annual distribution of total general and high security diversions is shown in Figure 41 and Figure 42, respectively. The figure shows some improvement in general security diversions in moderate years and improvement in high security in the driest year.

Figure 41. Total General security annual diversions for the Base Case and Option 36a (Enlarged Blowering Dam with Tumut pipeline with 100 and 200 GL airspace).

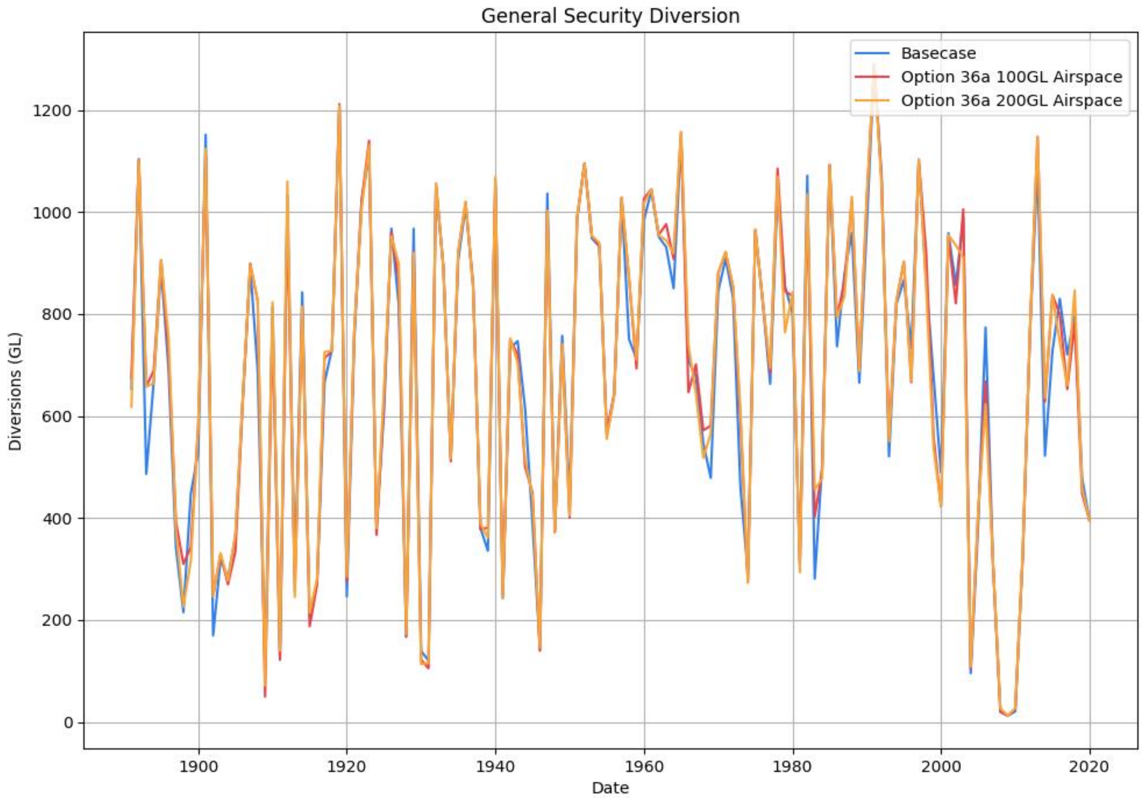
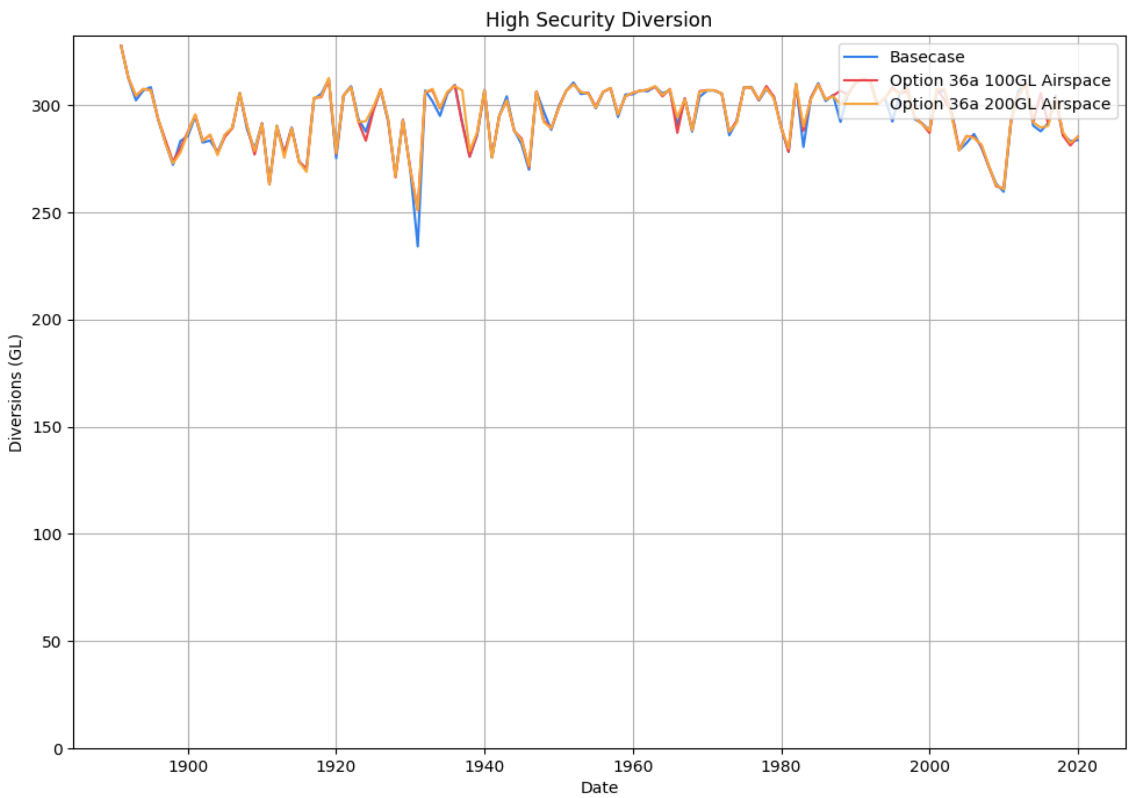


Figure 42. Total High security annual diversions for the Base Case and Option 36a (Enlarged Blowering Dam with Tumut pipeline with 100 and 200 GL airspace).



Alterations in environmental water delivery

Table 47 shows the average annual held, Lowbidgee supplementary and planned environmental water deliveries from 1/7/1895 to 30/6/2010. The table shows 5% increase in the held environmental water, 2% decrease in Lowbidgee supplementary and planned environmental water in the 100 GL airspace scenario. For the 200 GL airspace scenario this is an 6% increase in the held environmental water, no change to Lowbidgee supplementary and 2% decrease in planned environmental water. There is an improvement in held resource as a consequence of improvements in allocations.

Table 47. Mean annual environmental water delivery for the Base Case and Option 36a (Enlarged Blowering Dam with Tumut pipeline with 100(i) and 200(ii) GL airspace).

Water delivery (GL/y)	Base Case	Option 36a(i)	Change (%)	Option 36a(ii)	Change (%)
Held environmental water	144.6	152.0	5%	152.6	6%
Lowbidgee environment	70.0	68.7	-2%	69.8	0%
Planned environmental water	133.4	131.3	-2%	131.0	-2%
Total environmental water	348.0	352.0	1%	353.4	2%

Alterations in allocation reliability

30 September, start and end of water year allocations from 1/7/1891 to 30/6/2020 are shown in Table 48 for the Base Case and the Enlarged Blowering Dam and Tumut pipeline options. The results show improvements in allocation reliability across most licence types and similar results for both airspace scenarios.

Table 48. Allocations for the Base Case and Option 36a (Enlarged Blowering Dam with Tumut pipeline with 100(i) and 200(ii) GL airspace).

Average allocations (%)	Base Case	Option 36a(i)	Difference (%)	Option 36a(ii)	Difference (%)
General security effective allocation on 1 July	39%	42%	3%	41%	2%
General security effective allocation on 30 September	61%	62%	1%	62%	1%
General Security effective allocation on 30 June	80%	81%	1%	81%	1%
General security allocation on 1 July	31%	34%	3%	33%	2%
General security allocation 30 September	53%	54%	1%	54%	1%
General Security allocation on 30 June	72%	73%	1%	73%	1%
High security allocation on 1 July	93%	93%	0%	93%	0%

Average allocations (%)	Base Case	Option 36a(i)	Difference (%)	Option 36a(ii)	Difference (%)
High security allocation 30 September	96%	96%	0%	96%	0%
High security allocation on 30 June	98%	98%	0%	98%	0%
Coleambally Irrigation conveyance allocation on 1 July	88%	89%	1%	89%	1%
Coleambally Irrigation conveyance allocation 30 September	92%	92%	0%	92%	0%
Coleambally Irrigation conveyance allocation on 30 June	95%	95%	0%	95%	0%
Murrumbidgee Irrigation conveyance allocation on 1 July	76%	77%	1%	77%	1%
Murrumbidgee Irrigation conveyance allocation 30 September	85%	85%	0%	86%	1%
Murrumbidgee Irrigation conveyance allocation on 30 June	92%	92%	0%	92%	0%

The effective general security reliability on the 30 September and at the end of the water year are shown respectively in Figure 43 and Figure 44. The figures show improvements in effective general security reliability particularly at the start of the water year but by 30 September these are small. There is not much difference between the two airspace scenarios.

Figure 43. 30th September effective general security allocation reliability for the Base Case and Option 36a (Enlarged Blowering Dam with Tumut pipeline with 100 and 200 GL airspace).

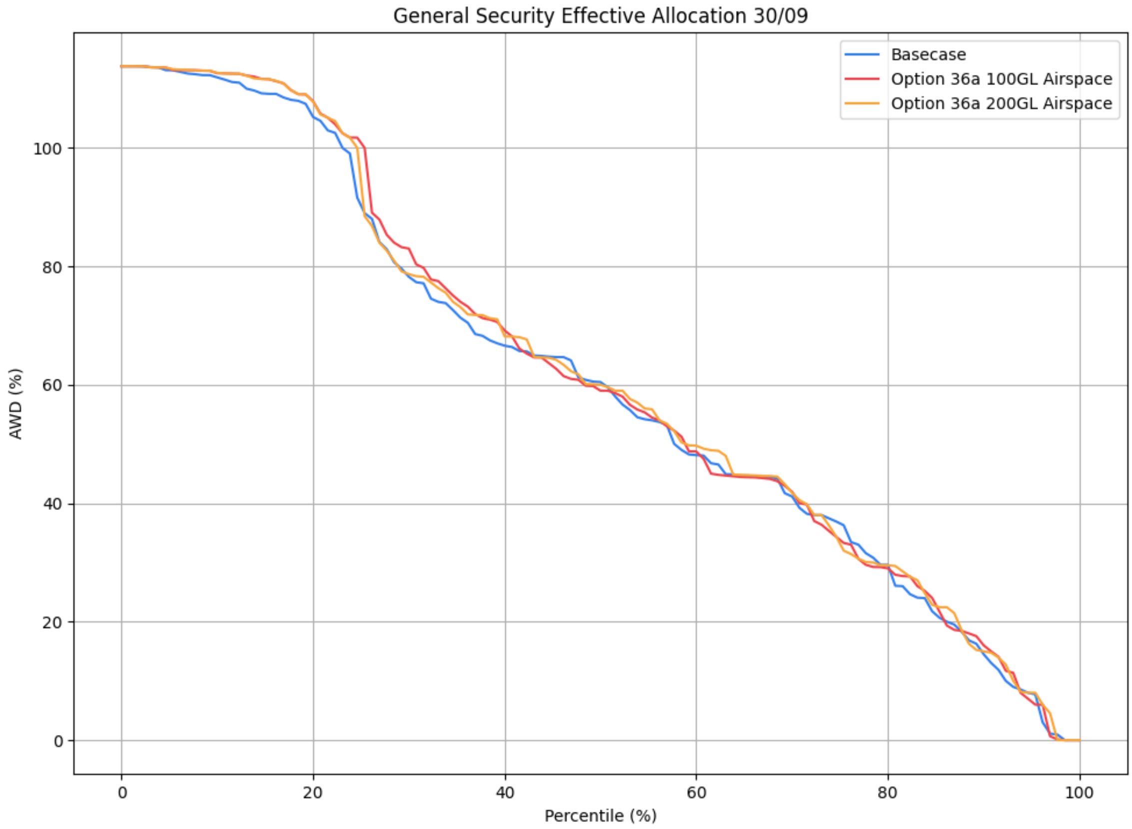
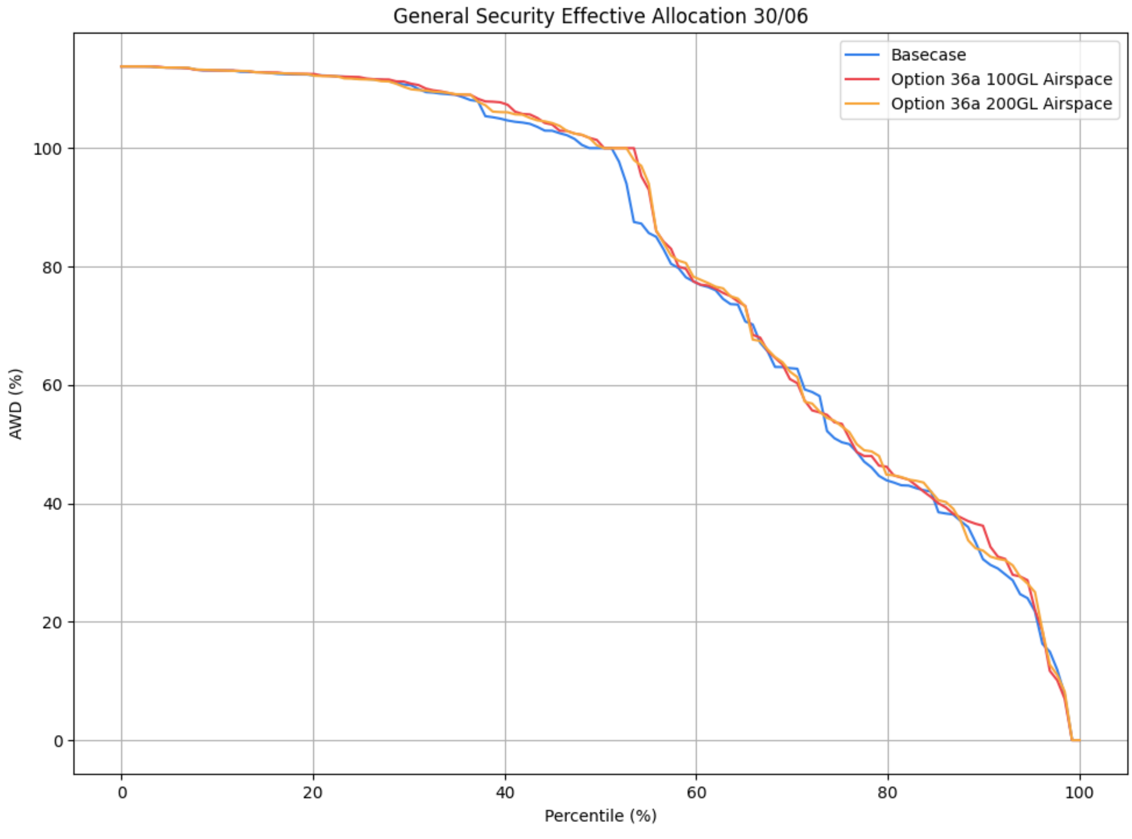


Figure 44. End of water year effective general security allocation reliability for general security for the Base Case and Option 36a (Enlarged Blowering Dam with Tumut pipeline with 100 and 200 GL airspace).



Alterations in storage behaviour

Blowering and Burrinjuck storage behaviour for the Base Case and Enlarged Blowering Dam and Tumut gravity pipeline options are shown in

Table 49 and Table 50. The table shows improvement in all Blowering Dam volumes with less improvement in the 200 GL airspace scenario above 50% capacity. Both the 100 and 200 GL options reduce Blowering Dam spills and not surprisingly a larger airspace means less spills. Burrinjuck behaviour is similar in all options.

Table 49. Blowering Dam and Burrinjuck Dam spill behaviour for the Base Case and Option 36a (Enlarged Blowering Dam with Tumut pipeline with 100(i) and 200(ii) GL airspace).

Storage Spills (GL/y)	Base Case	Option 36a(i)	Change (%)	Option 36a(ii)	Change (%)
Blowering Dam	313.3	285.9	-9%	271.7	-13%
Burrinjuck Dam	365.6	368.6	1%	369.6	1%

Table 50. Blowering Dam and Burrinjuck Dam storage behaviour for the Base Case and Option 36a (Enlarged Blowering Dam with Tumut pipeline with 100(i) and 200(ii) GL airspace).

% of time below	Base Case	Option 36a(i)	Difference (%)	Option 36a(ii)	Difference (%)
Blowering Dam					
1831.4 GL	100%	88%	-12%	89%	-11%
1731.4 GL	100%	83%	-17%	86%	-14%
1631.4 GL (FSV)	86%	78%	-8%	80%	-6%
1531.4 GL	79%	74%	-5%	74%	-5%
50%	27%	29%	2%	31%	4%
25%	7%	8%	1%	9%	2%
10%	3%	3%	0%	4%	1%
5%	2%	2%	0%	2%	0%
Burrinjuck Dam					
1026 GL (FSV)	97%	97%	0%	97%	0%
80%	70%	74%	4%	74%	4%
50%	16%	9%	-7%	9%	-7%
25%	1%	0%	-1%	0%	-1%
10%	0%	0%	0%	0%	0%
5%	0%	0%	0%	0%	0%

Comparison of Blowering Dam and Burrinjuck Dam storage behaviour from 1/7/1891 to 30/6/2020 are shown respectively in Figure 46 and Figure 47. The figures show the extra capacity of Blowering Dam is filled in wet conditions and that there is not a substantial difference in this filling in the 100 and 200 GL airspace scenarios. This suggests that the PCR release does not have a considerable influence on the filling of the airspace. Burrinjuck behaviour is similar with more water in Burrinjuck in drier years.

Figure 45. Blowering Dam storage behaviour for the Base Case and Option 36a (Enlarged Blowering Dam with Tumut pipeline with 100 and 200 GL airspace).

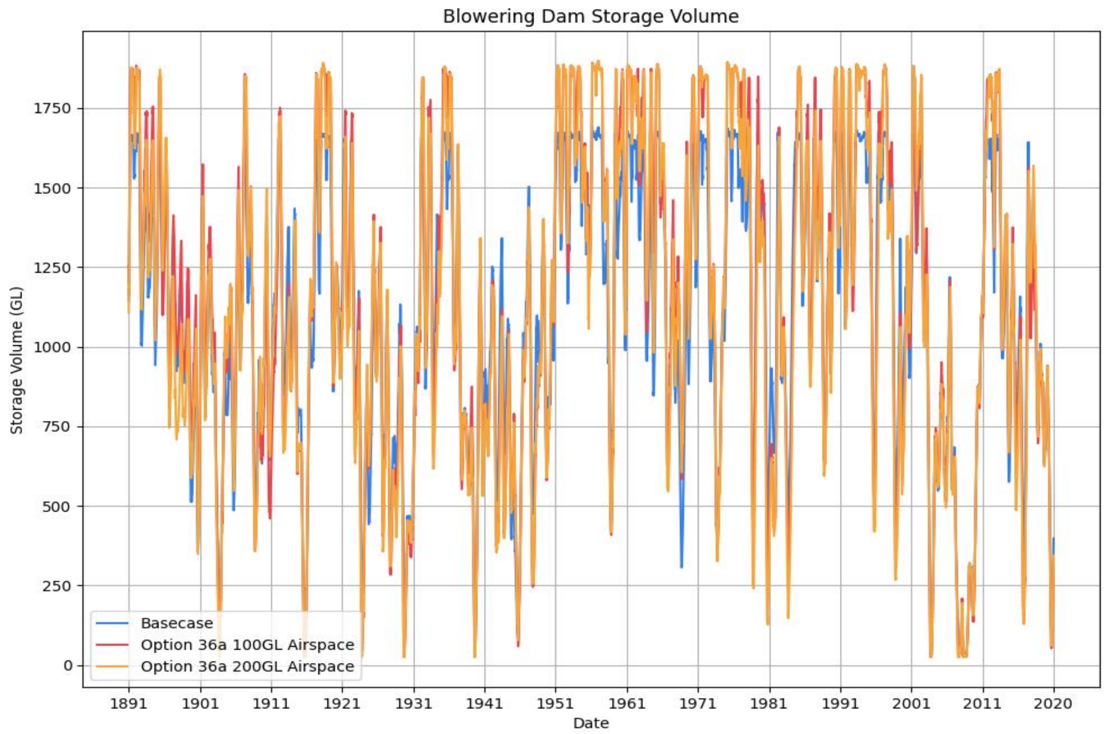
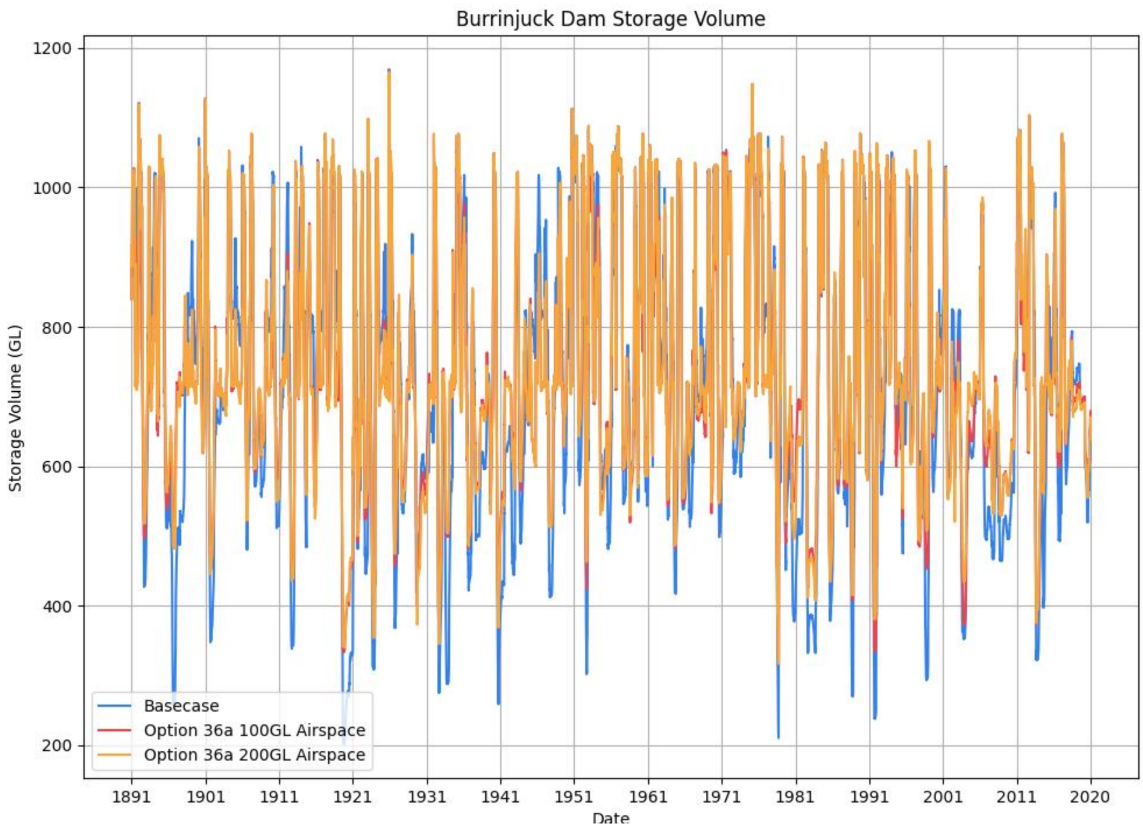


Figure 46. Burrinjuck storage behaviour for the Base Case and Option 36a (Enlarged Blowering Dam with Tumut pipeline with 100 and 200 GL airspace).



Alterations in river flows

Mean annual flow for 1/7/1891 to 30/6/2020 for the Base Case and Enlarged Blowering Dam and Tumut pipeline option are shown in Table 51. The table shows no significant change to mid river and end of system flows in both scenarios.

Table 51. Comparison of the mean annual flow for the Base Case and Option 36a (Enlarged Blowering Dam with Tumut pipeline with 100(i) and 200(ii) GL airspace).

Gauging sites (GL/y)	Base Case	Option 36a(i)	Change (%)	Option 36(ii)	Change (%)
Murrumbidgee River at Gundagai	3,432.2	3,439.1	0%	3,432.8	0%
Murrumbidgee River at Wagga Wagga	3,799.1	3,805.9	0%	3,799.6	0%
Murrumbidgee River at Balranald	1,188.6	1,194.0	0%	1,192.7	0%
Billabong Creek at Darlot	227.5	228.0	0%	228.6	0%

10. Option 37. Enlarged Burrinjuck Dam

Option description

This option involves adding 674 GL additional storage capacity to Burrinjuck Dam making a full supply volume of 1700 GL. The purpose is to provide additional regulation of Murrumbidgee inflows and provide more access to storage releases which are not constrained by limited river capacity.

Model configuration and assumptions

This section describes the model configuration for the Enlarged Burrinjuck Dam option 37.

The level-volume-area relationship in Burrinjuck Dam above the current relationship was extended as shown in Table 52. The new full supply details are linearly interpolated between the final two rows of the table. The new full supply level of 362.803m AHD is 8.2 m higher than the current FSL of 361.586m. The modelled spillway relationship was adjusted to lift the existing spillway 8.2m.

Table 52 Key points in the Burrinjuck Dam extended level-volume-area relationship.

Level (m AHD)	Volume (GL)	Area (km^2)
299.184	0	0
320.52	32.1	6.2
350.09	537.8	32.2
366.24	1306.9	70.8
381.59	3000	129.9

The option was implemented using an Input Set, in which the higher FSV was specified, and the spillway was raised 8.2m. The Harmony rule for allocating releases between Blowering Dam and Burrinjuck Dams was not altered.

Murray Darling Basin Plan Compliance

It was assumed that per MDB Basin Planning principles, long term extractive use would be managed to stay the same as the baseline case. To achieve this, supplementary use was curtailed by limiting supplementary access licences to 4% of baseline volumes, or in the case of Lowbidgee consumptive take, limiting the rate of take.

Modelling results

In this section, modelling results are shown for the Enlarged Burrinjuck Dam option 37.

Alterations in water diversions

Table 53, Figure 47 and Figure 48 show the average annual water diversions from 1/7/1895 to 30/6/2010 for consumptive water users under the Base Case, and the Enlarged Burrinjuck Dam option 37. These show that, due to the additional regulation and improved security offered by the enlarged Burrinjuck Dam, most categories of use show increase in use. Supplementary use is however limited to times when the General Security allocation is less than 12.5% to ensure compliance with MDB Plan principles.

Table 53 Mean annual water diversions for the Base Case and Option 37 (Enlarged Burrinjuck Dam)

Water diversions (GL/y)	Base Case	Option 37	Change (%)
General Security	674.8	765.2	13%
High Security	294.1	297.8	1%
Murrumbidgee Irrigation Conveyance	161.6	170.5	6%
Coleambally Irrigation Conveyance	103.8	104.7	1%
Premium High Security	18.1	18.6	3%
Stock and Domestic	19.4	23.7	22%
Local Water Utility	10.1	10.1	0%
Supplementary	116.0	4.9	-96%
Lowbidgee consumptive	48.6	49.9	3%
Inter-valley transfer	105.5	105.8	0%
Total diversions	1,552.0	1,551.2	0%

Figure 47. Total General security annual diversions for the Base Case and Option 37 (Enlarged Burrinjuck Dam)

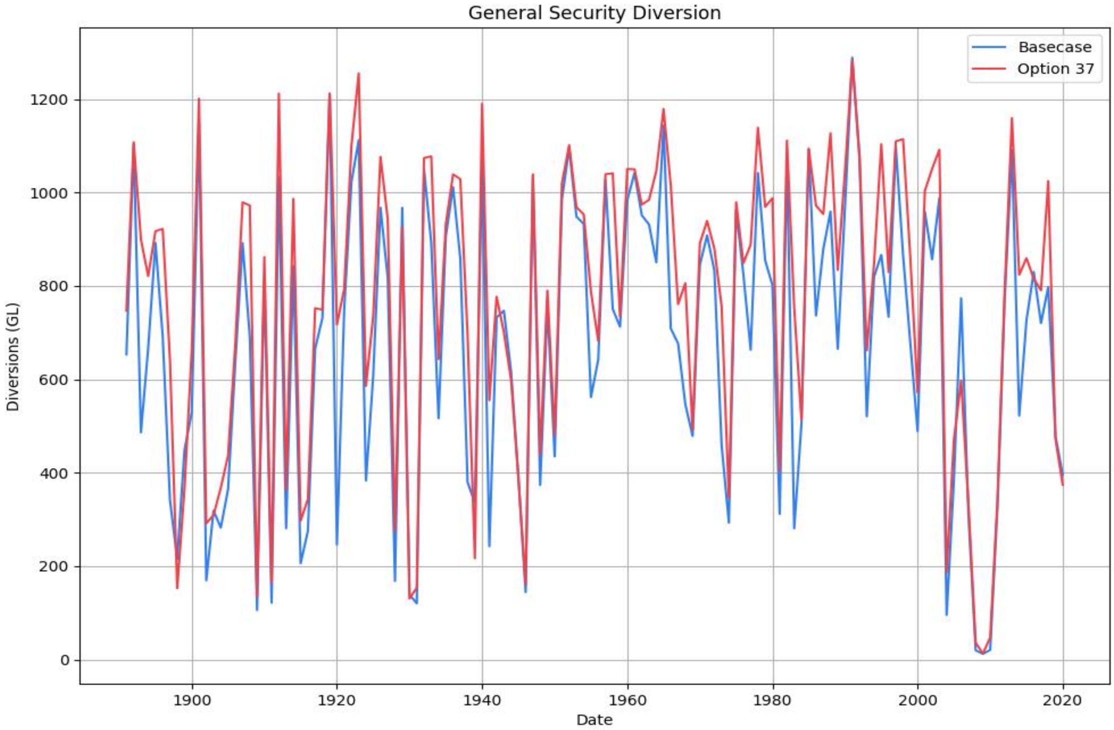
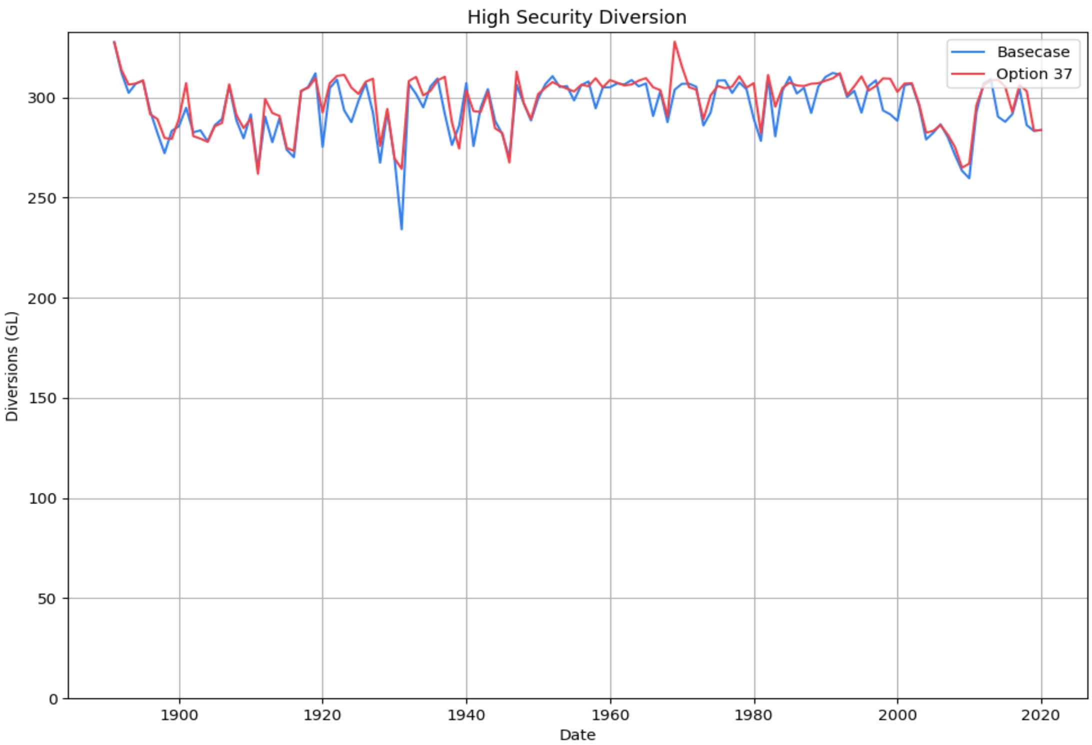


Figure 48. Total High security annual diversions for the Base Case and Option 37 (Enlarged Burrinjuck Dam)



Alterations in environmental water delivery

Table 54 shows the average annual held, Lowbidgee supplementary and planned environmental water deliveries from 1/7/1891 to 30/6/2020. The table shows a 13% increase in the held environmental water, a 7% increase in Lowbidgee supplementary and a 5% increase in planned environmental water. The held increase is due to increases in allocation and the planned increase is due to Burrinjuck spills being partially replaced by planned environmental releases from Burrinjuck, enabled by the increased regulation due to the enlargement of Burrinjuck Dam. The Lowbidgee supplementary is increased because the 5,000 ML/day threshold at Balranald is lower, and thus more supplementary announcement occurs.

Table 54. Mean annual environmental water delivery for the Base Case, and Enlarged Burrinjuck Dam

Water delivery (GL/y)	Base Case	Option 37	Change (%)
Held environmental water	144.6	163.8	13%
Lowbidgee supplementary environment	70.0	75.0	7%
Planned environmental water	133.4	140.8	5%
Total environmental water	348.0	379.5	9%

Alterations in allocation reliability

30 September, start, and end of water year allocations from 1/7/1891 to 30/6/2020 are shown in Table 55 for the Base Case and the Enlarged Burrinjuck Dam option 37.

The results show increases in General Security and conveyance allocations across the (water) year, with minor increases to High Security allocations.

Figure 49 and Figure 50 show the increase in effective general security reliability on the 30 September and at the end of the water year.

The increases in general security reliability are to be expected due to the greater regulation provided by the raising of Burrinjuck.

Table 55. Allocations for the Base Case and Option 37 (Enlarged Burrinjuck Dam)

Average allocations (%)	Base Case	Option 37	Difference (%)
General security effective allocation on 1 July	39%	53%	14%
General security effective allocation on 30 September	61%	73%	12%
General Security effective allocation on 30 June	80%	86%	6%
General security allocation on 1 July	31%	46%	15%

General security allocation 30 September	53%	66%	13%
General Security allocation on 30 June	72%	79%	7%
High security allocation on 1 July	93%	95%	2%
High security allocation 30 September	96%	97%	1%
High security allocation on 30 June	98%	98%	0%
Coleambally Irrigation conveyance allocation on 1 July	88%	91%	3%
Coleambally Irrigation conveyance allocation 30 September	92%	94%	2%
Coleambally Irrigation conveyance allocation on 30 June	95%	96%	1%
Murrumbidgee Irrigation conveyance allocation on 1 July	76%	82%	6%
Murrumbidgee Irrigation conveyance allocation 30 September	85%	89%	4%
Murrumbidgee Irrigation conveyance allocation on 30 June	92%	94%	2%

Figure 49. 30 September effective general security allocation reliability for the Base Case and Option 37 (Enlarged Burrinjuck Dam)

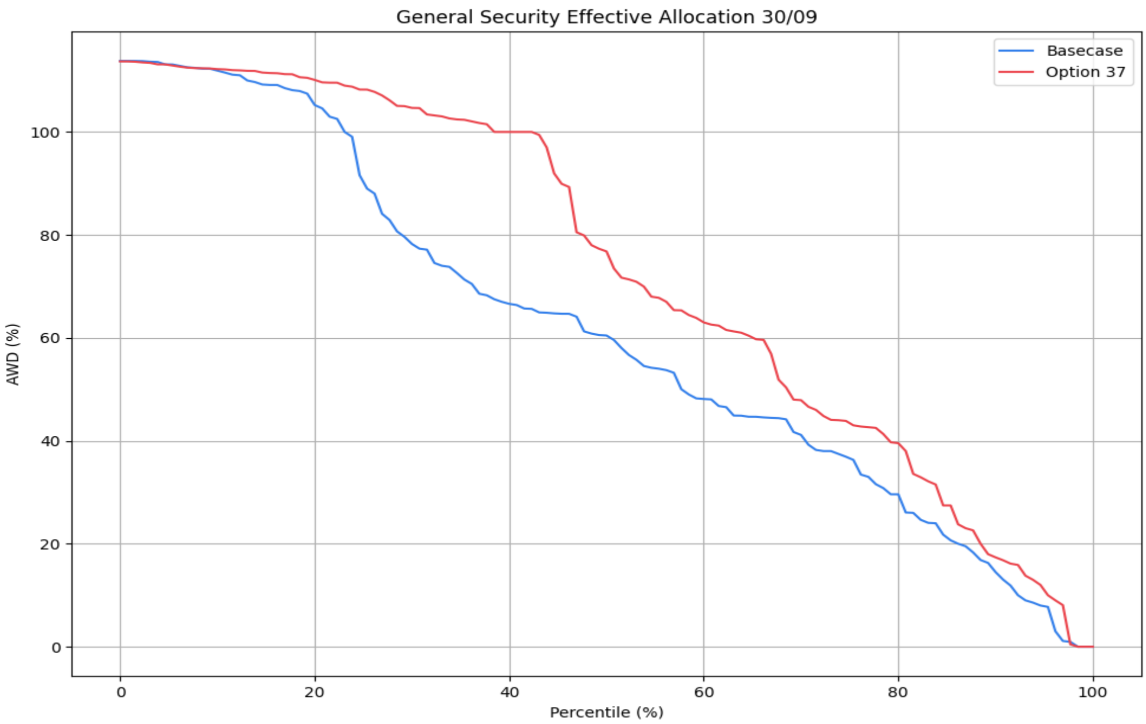
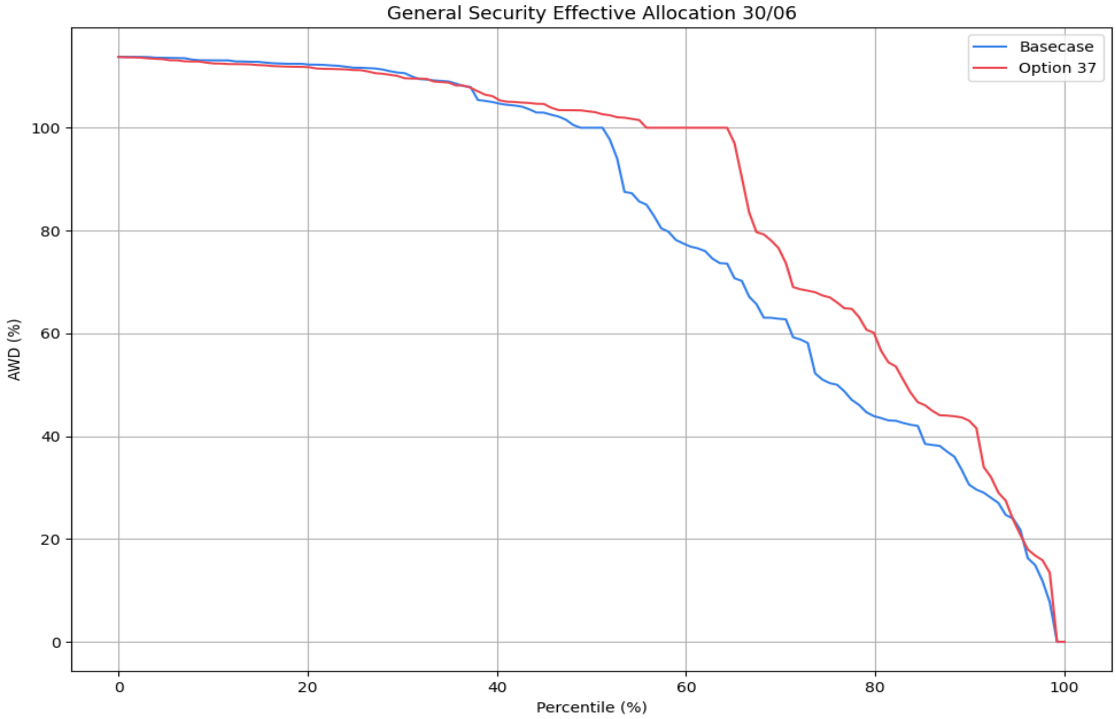


Figure 50. End of water year (30/6) effective general security allocation reliability for general security for the Base Case and Option 37 (Enlarged Burrinjuck Dam)



Alterations in storage behaviour

Key storage metrics for Blowering and Burrinjuck Dams for 1/7/1891 to 30/6/2020 for the Base Case and Enlarged Burrinjuck option 37 are shown in Table 56 and Table 57. Comparison of Blowering and Burrinjuck Dams storage behaviour from 1/7/1891 to 30/6/2020 are shown respectively in Figure 50 and Figure 51. These show that the enlarged Burrinjuck Dam, operating with the Burrinjuck/ Blowering Harmony rule, allows more drawdown of Blowering Dam. The higher allocation provided by the increased storage in Burrinjuck Dam leads to increased draw on Blowering Dam due to the operation of the Harmony rule, which typically puts priority of release on Blowering Dam. This is to minimise impact of the Tumut River capacity constraint. Burrinjuck Dam however is able to store more water, improving overall system reliability.

Table 56. Blowering and Burrinjuck spill behaviour for the Base Case and Enlarged Burrinjuck Dam

Storage Spills (GL/y)	Base Case	Option 37	Change (%)
Blowering Dam	313.3	301.6	-4%
Burrinjuck Dam	365.6	293.7	-20%

Table 57. Blowering and Burrinjuck storage behaviour for the Base Case and Enlarged Burrinjuck Dam

% of time below	Base Case	Option 37	Difference (%)
Blowering Dam			
1631.4 GL (FSV)	86%	86%	0%
1531.4 GL	79%	80%	1%
50%	27%	44%	17%
25%	7%	19%	12%
10%	3%	9%	6%
5%	2%	5%	3%
Burrinjuck Dam			
1700 GL	100%	97%	-3%
1026 GL (FSV)	97%	28%	-69%
80%	70%	9%	-61%
50%	16%	0%	-16%
25%	1%	0%	-1%
10%	0%	0%	0%
5%	0%	0%	0%

Figure 51. Blowering Dam storage behaviour for the Base Case and Option 37 (Enlarged Burrinjuck Dam)

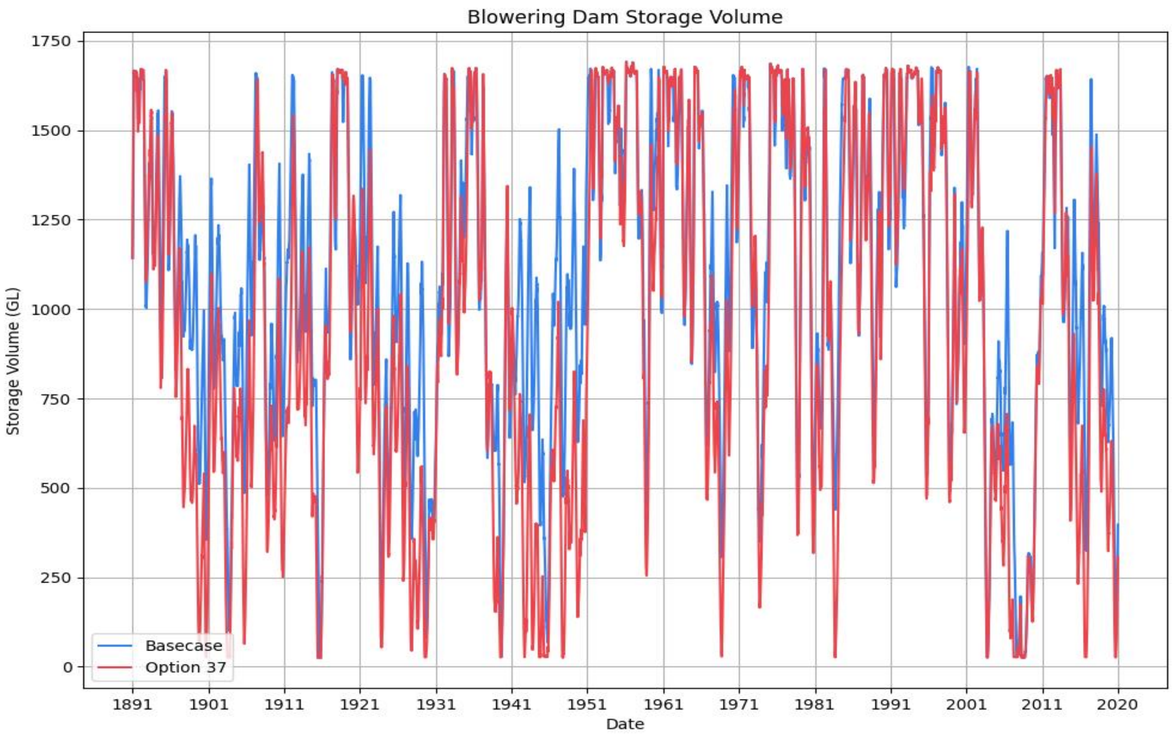
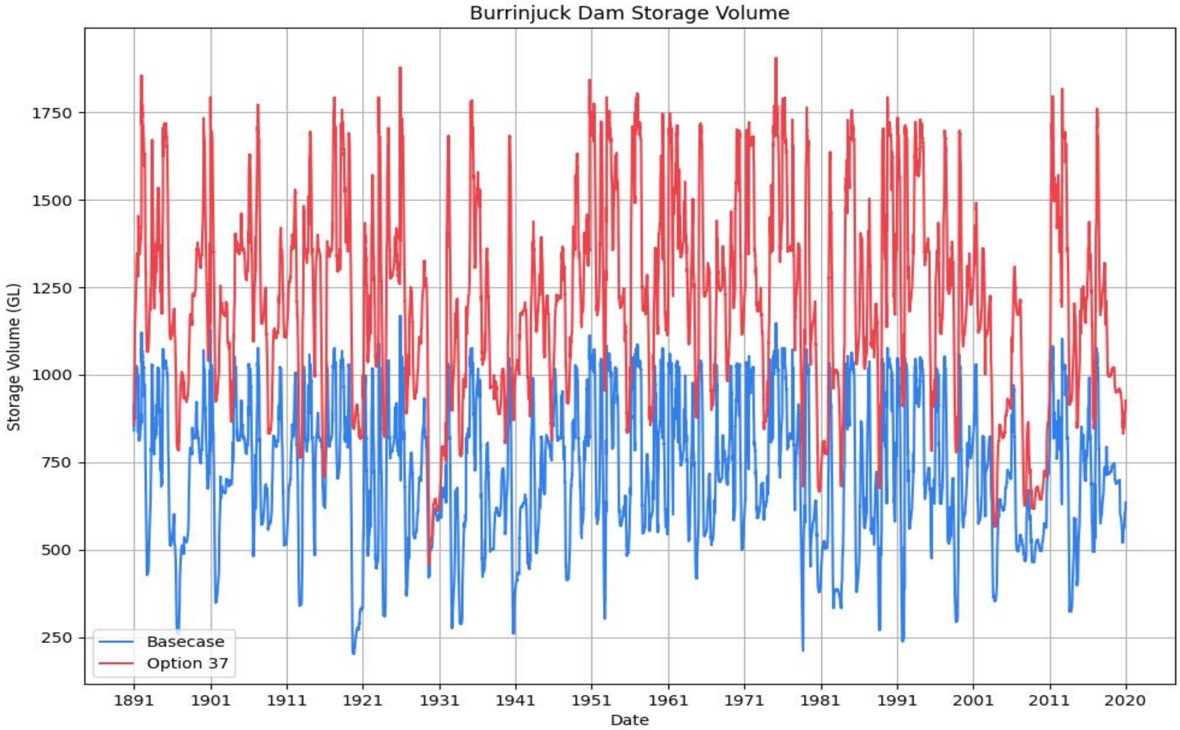


Figure 52. Burrinjuck storage behaviour for the Base Case and Option 37 (Enlarged Burrinjuck Dam)



Alterations in river flows

Mean annual flow for 1/7/1891 to 30/6/2020 for the Base Case and Enlarged Burrinjuck Dam option 37 are shown in Table 58. The table shows little change in mid river and end of system flows. This is because entitlements are adjusted to keep average consumptive diversions at baseline levels, so that end of system flows will only change as a result of changes to losses, or changes to extractive environmental flows.

Table 58. Comparison of the mean annual flow for the Base Case and Enlarged Burrinjuck Dam

Gauging sites (GL/y)	Base Case	Option 37	Change (%)
Murrumbidgee River at Gundagai	3,432.2	3,427.9	0%
Murrumbidgee River at Wagga Wagga	3,799.1	3,794.7	0%
Murrumbidgee River at Balranald	1,188.6	1,189.7	0%
Billabong Creek at Darlot	227.5	226.9	0%

11. Option 38. Enlarged Bundidgerry off-river storage and a new transfer canal.

Option description

The Bundidgerry Creek is used as an off-river storage supplying the MIA's Main Canal. Water is regulated from the Murrumbidgee River to the creek, and then from the creek to the Main Canal. There is diversion directly from the creek as well as to the Main Canal. This option expands the storage capacity within the creek and increases the supply capacity from the creek to the MIA.

Model configuration and assumptions

The baseline model has no representation of the Bundidgerry Creek or its storage. The model does have a representation of diversions from creek, taken directly from the Murrumbidgee River. Within the model, diversions to the MIA via the Main Canal are also taken directly from the Murrumbidgee River. The baseline model also has diversions from the Murrumbidgee River to the MIA from further down the Murrumbidgee River, via the Sturt Canal. The model lumps supply from the Main and Sturt canals to the MIA demand.

The enlarged Bundidgerry storage was modelled by adding an additional On Farm Storage (OFS) to the MIA Water User Demand node, i.e., placing the additional storage at the demand node, rather than on the creek. The new OFS was given a capacity of 5,490 ML, and a release capacity of 1,000 ML/d – representing a nominal increase in capacity of the Main Canal. The new OFS was configured to fill before the existing OFS, and empty after the existing OFS, which would reflect the priorities implicit with an enlarged Bundidgerry Creek storage. The OFSs were configured to both order water from Burrinjuck and Blowering and harvest surplus flows.

This approach was adopted, as addition of a new off-river storage node would cause inconsistencies with the baseline model. The fact that the new OFS could be implicitly supplied from the Sturt Canal was not seen as a significant issue.

Murray Darling Basin Plan Compliance

It was assumed that per MDB Basin Planning principles, long term extractive use would be required to stay the same as the baseline case. To achieve this, the take under supplementary use entitlements was reduced by capping at supplementary entitlements to 62% of baseline entitlement volumes.

Modelling results

In this section, modelling results are shown for the enlarged Bundidgerry Storage option 38.

Alterations in water diversions

Table 59 shows the average annual water diversions from 1/7/1895 to 30/6/2010 for consumptive water users under the Base Case, and the enlarged Bundidgerry option 38. The annual distributions of total general and high security diversions are shown in Figure 53 and Figure 54, respectively.

The table and figures show that General Security supplies show a 5% increase, and High Security supplies show a minor increase. The increase in supply arises because the increased storage (implemented as an OFS) can capture more surplus flows in the Murrumbidgee River. Supplementary use is reduced to maintain compliance with MDB Plan principles.

Table 59 Mean annual water diversions for the Base Case and Option 38 (Enlarged Bundidgerry off-river storage)

Water diversions (GL/y)	Base Case	Option 38	Change (%)
General Security	674.8	710.1	5%
High Security	294.1	295.6	1%
Murrumbidgee Irrigation Conveyance	161.6	168.3	4%
Coleambally Irrigation Conveyance	103.8	104.1	0%
Premium High Security	18.1	18.7	3%
Stock and Domestic	19.4	22.3	15%
Local Water Utility	10.1	10.1	0%
Supplementary	116.0	67.1	-42%
Lowbidgee consumptive	48.6	50.4	4%
Inter-valley transfer	105.5	104.3	-1%
Total diversions	1,552.0	1,551.0	0%

Figure 53. Total General security annual diversions for the Base Case and Option 38 (Enlarged Bundidgerry off-river storage)

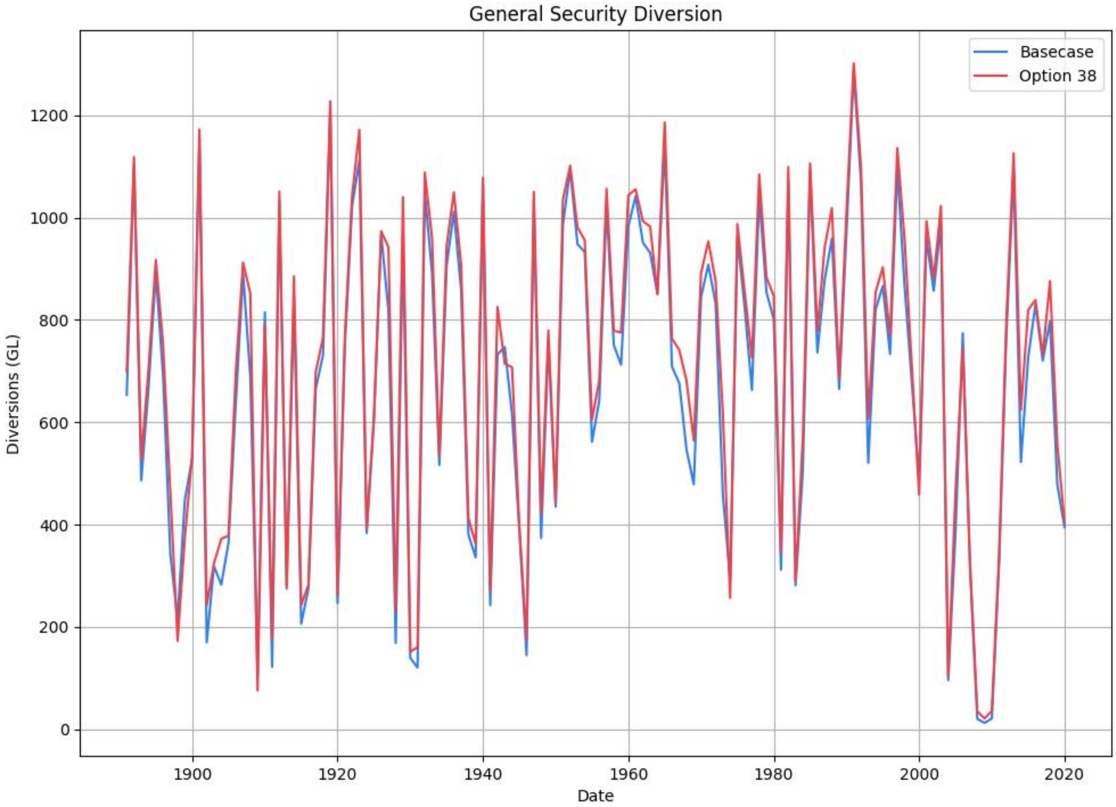
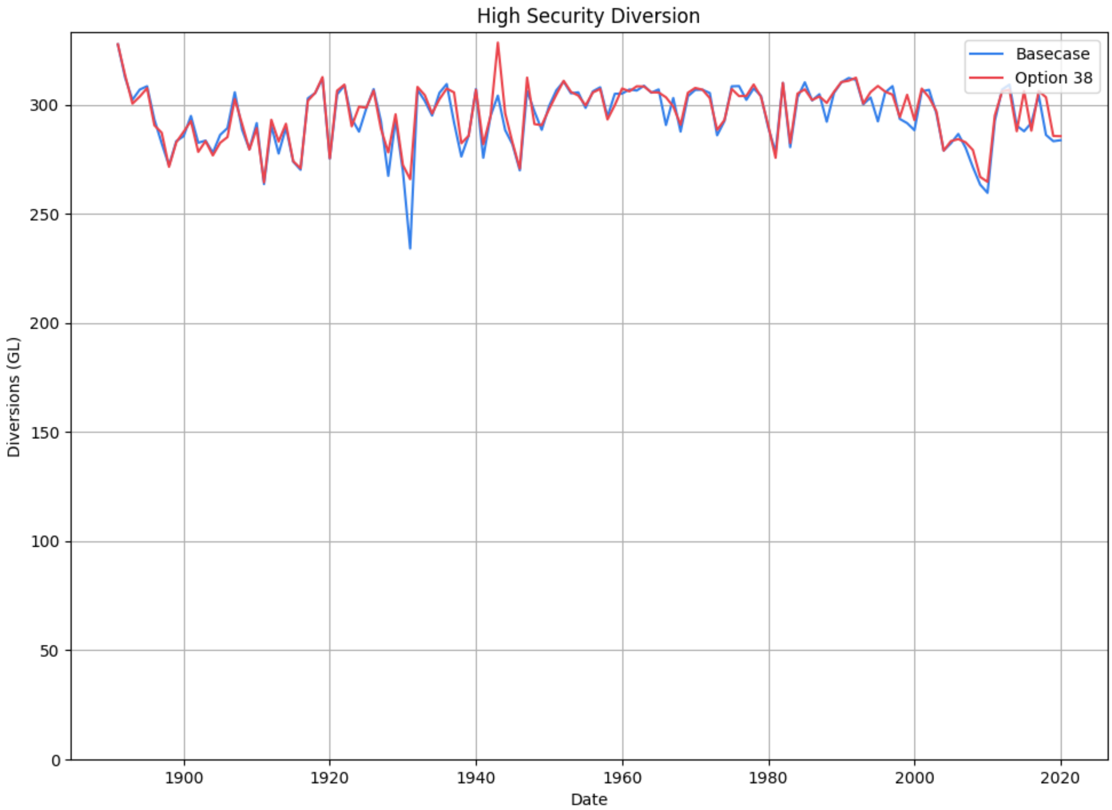


Figure 54. Total High security annual diversions for the Base Case and Option 38 (Enlarged Bundidgerry off-river storage)



Alterations in environmental water delivery

Table 60 Mean annual environmental water delivery for the Base Case and enlarged Bundidgerry off-river storage

Water delivery (GL/y)	Base Case	Option 38	Change (%)
Held environmental water	144.6	148.3	3%
Lowbidgee supplementary environment	70.0	74.2	6%
Planned environmental water	133.4	135.4	1%
Total environmental water	348.0	357.9	3%

Table 60 shows the average annual held, Lowbidgee supplementary and planned environmental water deliveries from 1/7/1891 to 30/6/2020. The table shows a 3% increase in held environmental water, 6% increase in Lowbidgee supplementary and a 1% increase in planned environmental water. The held increase is due to the positive impact on allocations as shown in

Alterations in allocation reliability

30 September, start, and end of water year allocations from 1/7/1891 to 30/6/2020 are shown in

Table 61 for the Base Case and the enlarged Bundidgerry option 38. The effective general security reliability on the 30 September and at the end of the water year are shown respectively in Figure 55 and Figure 56. These show around a 3% improvement to General Security allocations over the year, and a minor improvement to high security allocations at the start of the year on 1 July. This option will have also resulted in some reduction in delivery times to MIA demands.

Table 61. Allocations for the Base Case and Option 38 (Enlarged Bundidgerry off-river storage)

Average allocations (%)	Base Case	Option 38	Difference (%)
General security effective allocation on 1 July	39%	42%	3%
General security effective allocation on 30 September	61%	63%	2%
General Security effective allocation on 30 June	80%	83%	3%
General security allocation on 1 July	31%	34%	3%

General security allocation 30 September	53%	55%	2%
General Security allocation on 30 June	72%	75%	3%
High security allocation on 1 July	93%	94%	1%
High security allocation 30 September	96%	96%	0%
High security allocation on 30 June	98%	98%	0%
Coleambally Irrigation conveyance allocation on 1 July	88%	88%	0%
Coleambally Irrigation conveyance allocation 30 September	92%	92%	0%
Coleambally Irrigation conveyance allocation on 30 June	95%	96%	1%
Murrumbidgee Irrigation conveyance allocation on 1 July	76%	78%	2%
Murrumbidgee Irrigation conveyance allocation 30 September	85%	86%	1%
Murrumbidgee Irrigation conveyance allocation on 30 June	92%	93%	1%

Figure 55. 30 September effective general security allocation reliability for the Base Case and Option 38 (Enlarged

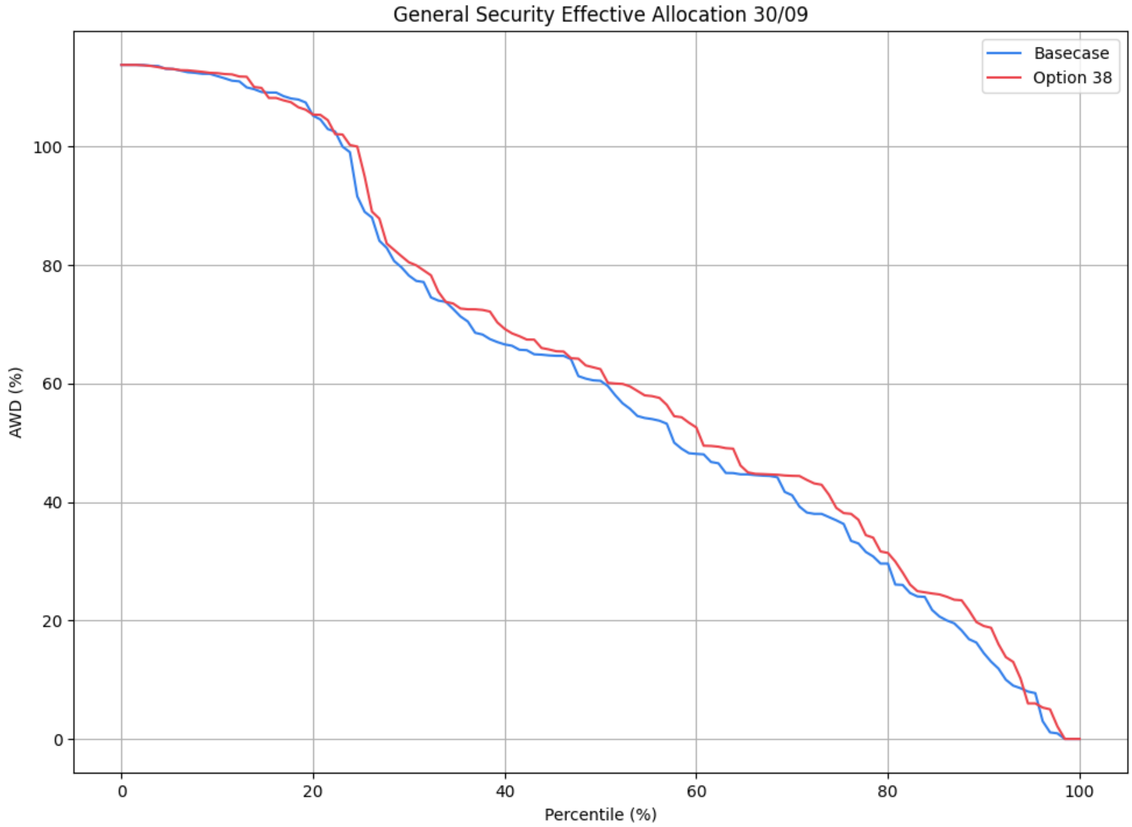
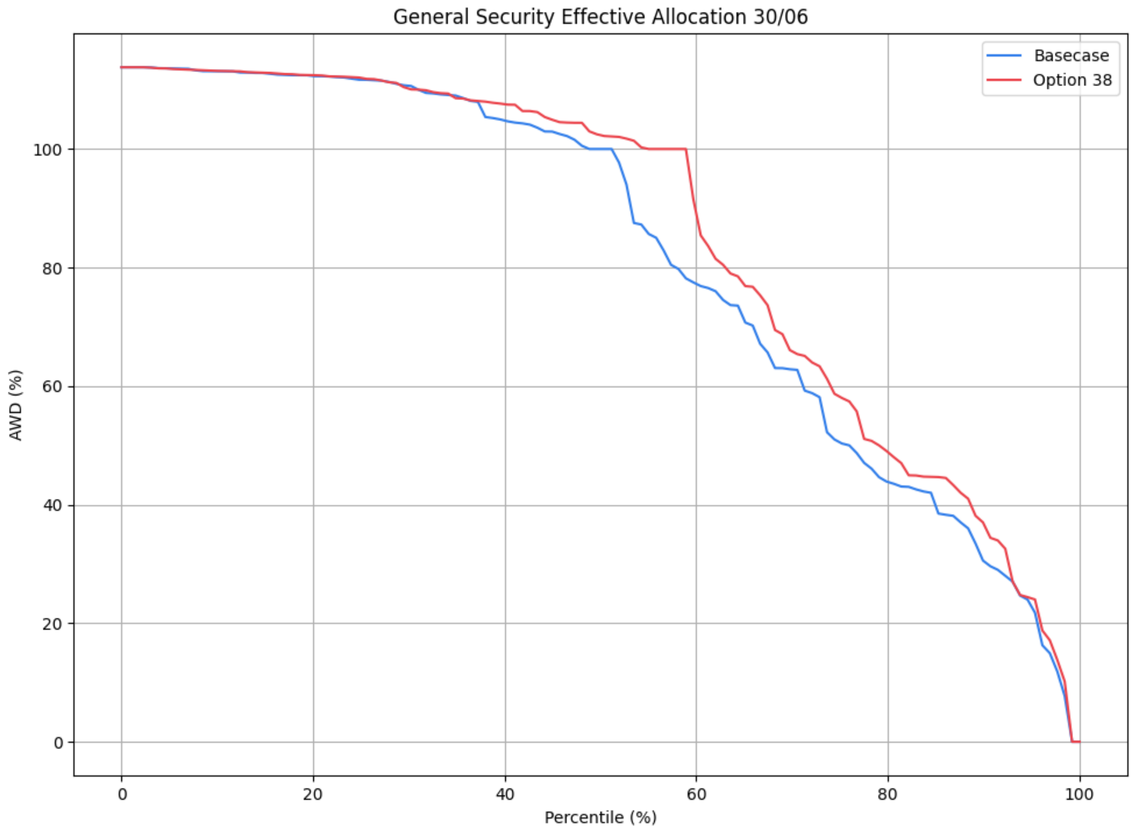


Figure 56. End of water year (30/6) effective general security allocation reliability for general security for the Base Case and Option 38 (Enlarged Bundidgerry off-river storage)



Alterations in storage behaviour

Storage behaviour of Blowering and Burrinjuck reservoirs for 1/7/1891 to 30/6/2020 for the Base Case and Enlarged Bundidgerry Off-river storage option 38 is shown in Table 62. The table shows that the enlargement of the Bundidgerry Off-river storage would have negligible impact on Blowering Dam and average storage response. Burrinjuck Dam however spends notably less time less than 50% full.

Table 62. Blowering and Burrinjuck spill behaviour for the Base Case and Enlarged Bundidgerry Off-river storage.

Storage Spills (GL/y)	Base Case	Option 38	Change (%)
Blowering Dam	313.3	328.4	5%
Burrinjuck Dam	365.6	385.4	5%

Table 63. Blowering and Burrinjuck storage behaviour for the Base Case and Enlarged Bundidgerry Off-river storage.

% of time below	Base Case	Option 38	Difference (%)
Blowering Dam			
1631.4 GL (FSV)	86%	85%	-1%
1531.4 GL	79%	79%	0%
50%	27%	26%	-1%
25%	7%	6%	-1%
10%	3%	2%	-1%
5%	2%	1%	-1%
Burrinjuck Dam			
1026 GL (FSV)	97%	96%	-1%
80%	70%	68%	-2%
50%	16%	9%	-7%
25%	1%	0%	-1%
10%	0%	0%	0%
5%	0%	0%	0%

Comparison of Blowering and Burrinjuck storage behaviour from 1/7/1891 to 30/6/2020 are shown in Figure 57 and Figure 58. The figures show some improvement to system security, at Burrinjuck Dam. This arises from the additional capacity at Bundidgerry Off-river storage being available to regulate surplus flows into the MIA.

Figure 57. Blowering Dam storage behaviour for the Base Case and Option 38 (Enlarged Bundidgerry off-river storage)

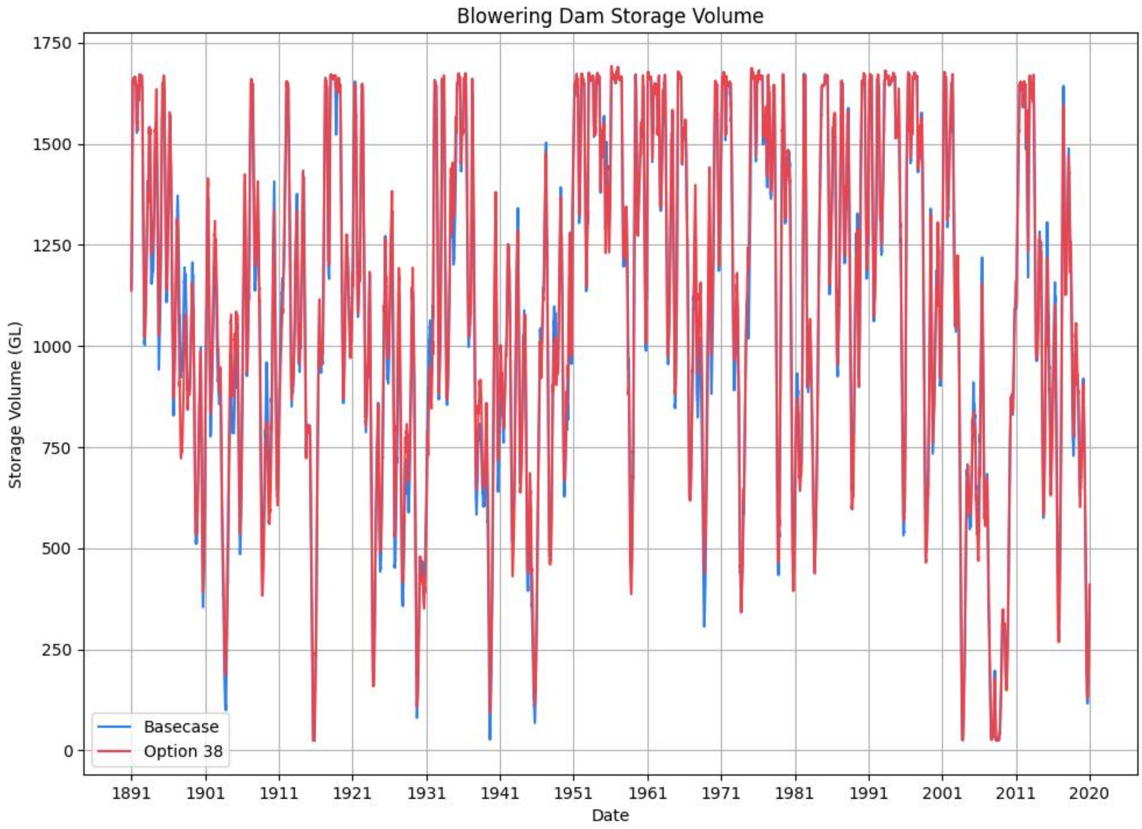
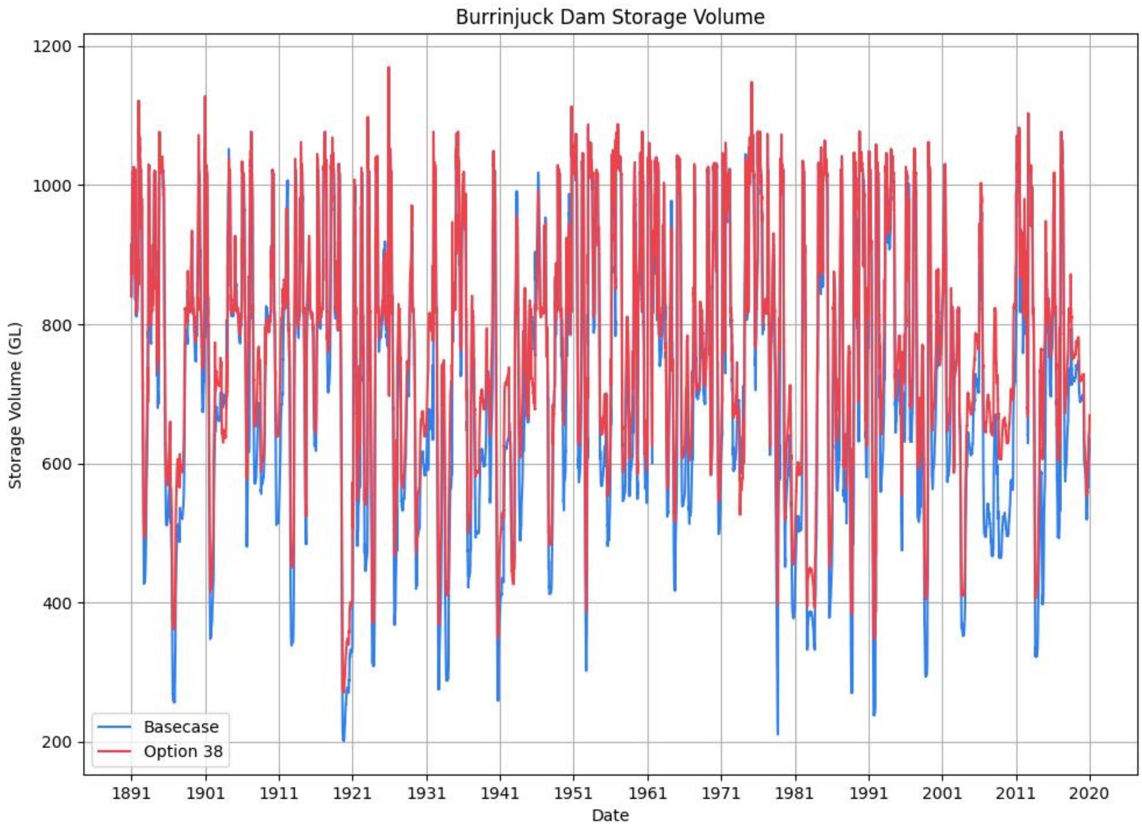


Figure 58. Burrinjuck storage behaviour for the Base Case and Option 38 (Enlarged Bundidgerry off-river storage)



Alterations in river flows

Mean annual flow for 1/7/1891 to 30/6/2020 for the Base Case and enlarged Bundidgerry Off-river storage option 38 are shown in Table 64. The results show negligible change to total mid river and end of system flows, driven by the management of average consumptive take to baseline levels.

Table 64. Comparison of the mean annual flow for the Base Case and Option 38 (Enlarged Bundidgerry off-river storage)

Gauging sites (GL/y)	Base Case	Option 38	Change (%)
Murrumbidgee River at Gundagai	3,432.2	3,431.0	0%
Murrumbidgee River at Wagga Wagga	3,799.1	3,797.8	0%
Murrumbidgee River at Balranald	1,188.6	1,177.8	-1%
Billabong Creek at Darlot	227.5	230.4	1%

12. Option 39. Changes at Tombullen storage

Option description

Option 39 was originally presented in two parts:

- Enlarge the off-river storage to assist with harvesting surplus flows.
- Make operational changes to increase through flow, thus improving water quality.

This analysis only examined the latter part. The results for the Enlarged Bundidgerry option above, provide an indication as to the potential hydrological benefits/impacts of enlarging Tombullen storage.

Model configuration and assumptions

The baseline model has a representation of the Tombullen storage, supplied with Supplementary Access water. The operating rule change aimed at increasing flushing flows was implemented by adding a target regulated supply volume of 8,000 ML for October through April. The target volume for unregulated flows remained at the higher 11,580 ML used in the Baseline model. The regulated supply demand was given a lower priority than all other demands in the system, so supply to Tombullen was only made when there was spare capacity in the system. As with the Baseline model, downstream demands were drawn from Tombullen in preference to the Murrumbidgee River. The intention of the operating rule was that Tombullen would be drawn down by downstream demands prior to the off season.

Murray Darling Basin Plan Compliance

It was assumed that per MDB Basin Planning principles, long term extractive use would stay the same as the baseline case. It was found that setting supplementary use entitlements to 90% of baseline entitlements would achieve this. As the storage is off river, supplementary water use was reduced by additional evaporation losses in addition to increases in other extractive use.

Modelling results

In this section, modelling results are shown for the operational changes at Tombullen storage, option 39, as modelled.

Alterations in water diversions

Table 65 shows the average annual water diversions from 1/7/1895 to 30/6/2010 for consumptive water users under the Base Case, and the Tombullen option 39. The annual distribution of total general and high security diversions is shown in Figure 59 and Figure 60, respectively. It should be noted that this option, as analysed, did not seek to improve water supply volumes, rather to provide flushing flows to improve water quality in Tombullen. Consequently, there was little impact on most water supply categories. Reduction in Supplementary use required to offset additional evaporation from Tombullen was also considered, but this was small.

Table 65 Mean annual water diversions for the Base Case and Option 39 (Enlarged Tombullen off-river storage).

Water diversions (GL/y)	Base Case	Option 39	Change (%)
General Security	674.8	680.9	1%
High Security	294.1	294.7	0%
Murrumbidgee Irrigation Conveyance	161.6	162.8	1%
Coleambally Irrigation Conveyance	103.8	103.9	0%
Premium High Security	18.1	18.0	-1%
Stock and Domestic	19.4	19.6	1%
Local Water Utility	10.1	10.1	0%
Supplementary	116.0	107.6	-7%
Lowbidgee consumptive	48.6	49.0	1%
Inter-valley transfer	105.5	105.8	0%
Total diversions	1,552.0	1,552.4	0%

Figure 59. Total General security annual diversions for the Base Case and Option 39 (Enlarged Tombullen off-river storage).

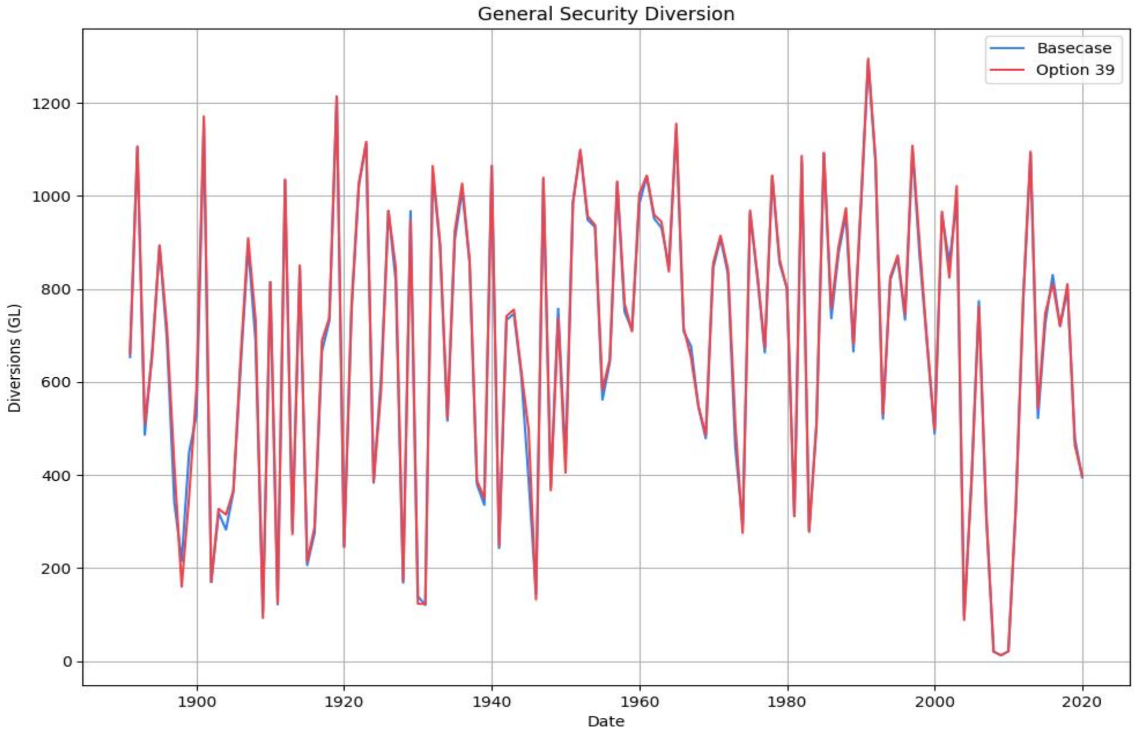
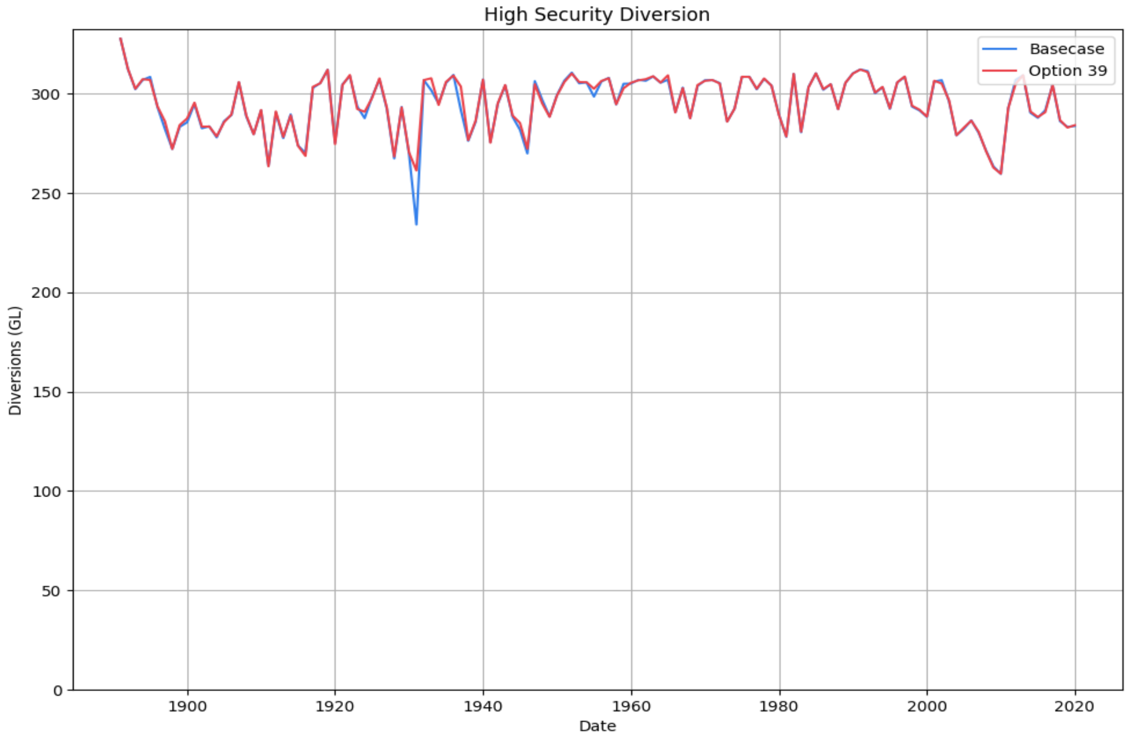


Figure 60. Total High security annual diversions for the Base Case and Option 39 (Enlarged Tombullen off-river storage).



Alterations in environmental water delivery

Table 66 shows the average annual held, Lowbidgee supplementary and planned environmental water deliveries from 1/7/1891 to 30/6/2020. As this option was not designed to alter management of water storage or allocations there was little overall impact on environmental water delivery.

Table 66. Mean annual environmental water delivery for the Base Case and Option 39 (Enlarged Tombullen off-river storage).

Water delivery (GL/y)	Base Case	Option 39	Change (%)
Held environmental water	144.6	142.4	-2%
Lowbidgee environment	70.0	73.2	5%
Planned environmental water	133.4	131.9	-1%
Total environmental water	348.0	347.5	0%

Alterations in allocation reliability

30 September, start and end of water year allocations from 1/7/1891 to 30/6/2020 are shown in Table 67 for the Base Case and the Tombullen storage option 39. The effective general security reliability on the 30 September and at the end of the water year are shown respectively in These show that this option has little impact on allocations, which is to be expected given the nature of the option as discussed above.

Table 67. Allocations for the Base Case and Option 39 (Enlarged Tombullen off-river storage).

Average allocations (%)	Base Case	Option 39	Difference (%)
General security effective allocation on 1 July	39%	40%	1%
General security effective allocation on 30 September	61%	61%	0%
General Security effective allocation on 30 June	80%	81%	1%
General security allocation on 1 July	31%	32%	1%
General security allocation 30 September	53%	53%	0%
General Security allocation on 30 June	72%	73%	1%
High security allocation on 1 July	93%	93%	0%
High security allocation 30 September	96%	96%	0%
High security allocation on 30 June	98%	98%	0%

Average allocations (%)	Base Case	Option 39	Difference (%)
Coleambally Irrigation conveyance allocation on 1 July	88%	88%	0%
Coleambally Irrigation conveyance allocation 30 September	92%	92%	0%
Coleambally Irrigation conveyance allocation on 30 June	95%	95%	0%
Murrumbidgee Irrigation conveyance allocation on 1 July	76%	76%	0%
Murrumbidgee Irrigation conveyance allocation 30 September	85%	85%	0%
Murrumbidgee Irrigation conveyance allocation on 30 June	92%	92%	0%

Figure 61. 30 September effective general security allocation reliability for the Base Case and Option 39 (Enlarged Tombullen off-river storage).

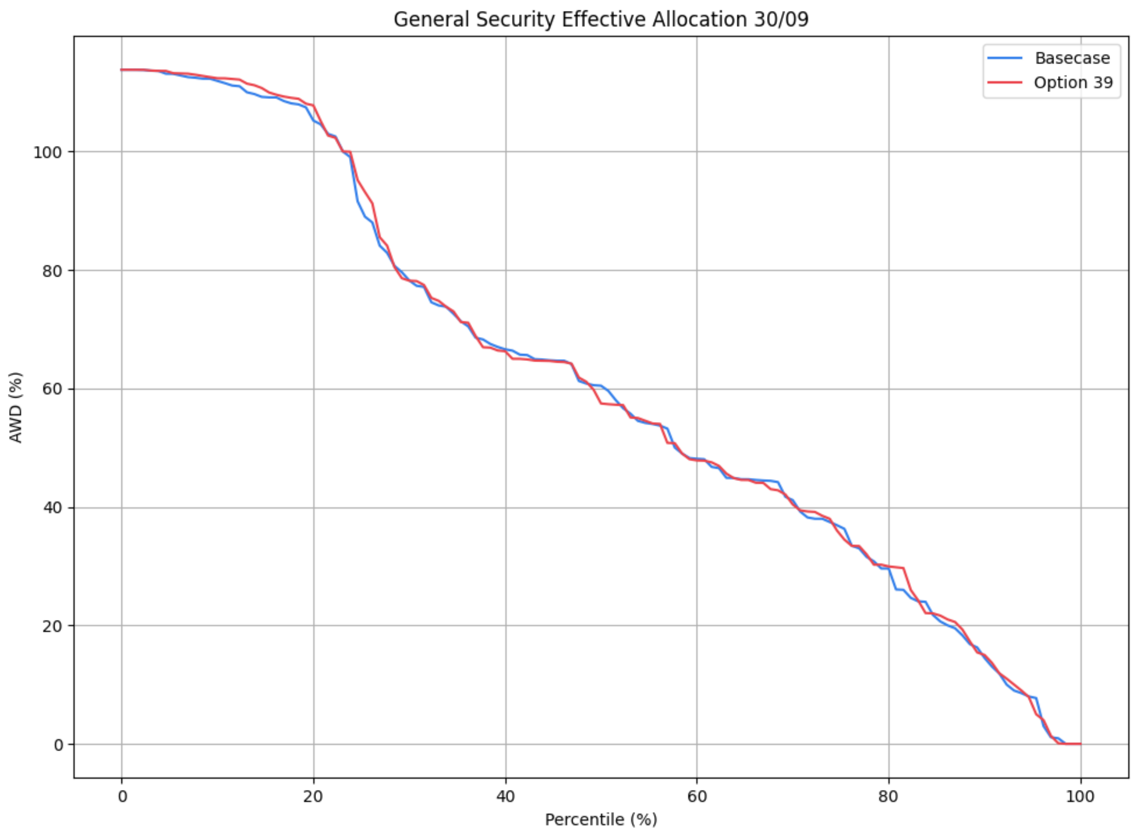
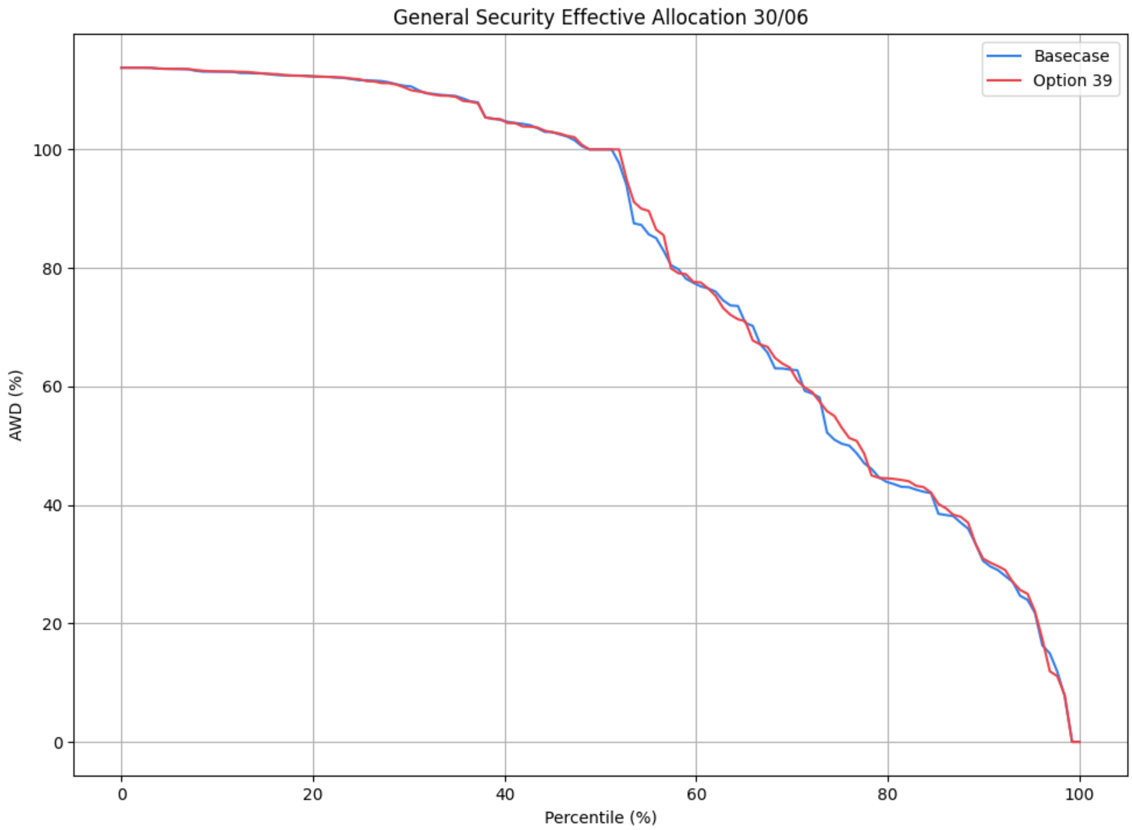


Figure 62. End of water year (30/6) effective general security allocation reliability for general security for the Base Case and Option 39 (Enlarged Tombullen off-river storage).



Alterations in storage behaviour

Mean annual flow for 1/7/1891 to 30/6/2020 for the Base Case and Tombullen storage option 39 are shown in Table 68 and Table 69. Table 69 shows that the option has little impact on average storage levels, for the reasons discussed above. There was a slight reduction in spills from Burrinjuck and Blowering as Tombullen was reconfigured to re-regulate flows.

Table 68. Blowering and Burrinjuck spills behaviour for the Base Case and changed Tombullen storage operations.

Storage Spills (GL/y)	Base Case	Option 39	Change (%)
Blowering Dam	313.3	317.7	1%
Burrinjuck Dam	365.6	368.6	1%

Table 69. Blowering and Burrinjuck storage behaviour for the Base Case and changed Tombullen storage operations.

% of time below	Base Case	Option 39	Difference (%)	Option 36a(ii)	Difference (%)
Blowering Dam					
1631.4 GL (FSV)	86%	85%	-1%	80%	-6%
1531.4 GL	79%	79%	0%	74%	-5%
50%	27%	28%	1%	31%	4%

% of time below	Base Case	Option 39	Difference (%)	Option 36a(ii)	Difference (%)
25%	7%	7%	0%	9%	2%
10%	3%	3%	0%	4%	1%
5%	2%	2%	0%	2%	0%
Burrinjuck Dam					
1026 GL (FSV)	97%	97%	0%	97%	0%
80%	70%	70%	0%	74%	4%
50%	16%	14%	-2%	9%	-7%
25%	1%	0%	-1%	0%	-1%
10%	0%	0%	0%	0%	0%
5%	0%	0%	0%	0%	0%

Comparison of Blowering and Burrinjuck storage behaviour from 1/7/1891 to 30/6/2020 are shown respectively in Figure 63 and Figure 64. These figures show that the option leads to both increases and decreases in storage levels. This is due to complex interactions between re-regulating flows in the lower system, and capping consumptive take at Baseline levels.

Figure 63. Blowering Dam storage behaviour for the Base Case and Option 39 (Enlarged Tombullen off-river storage).

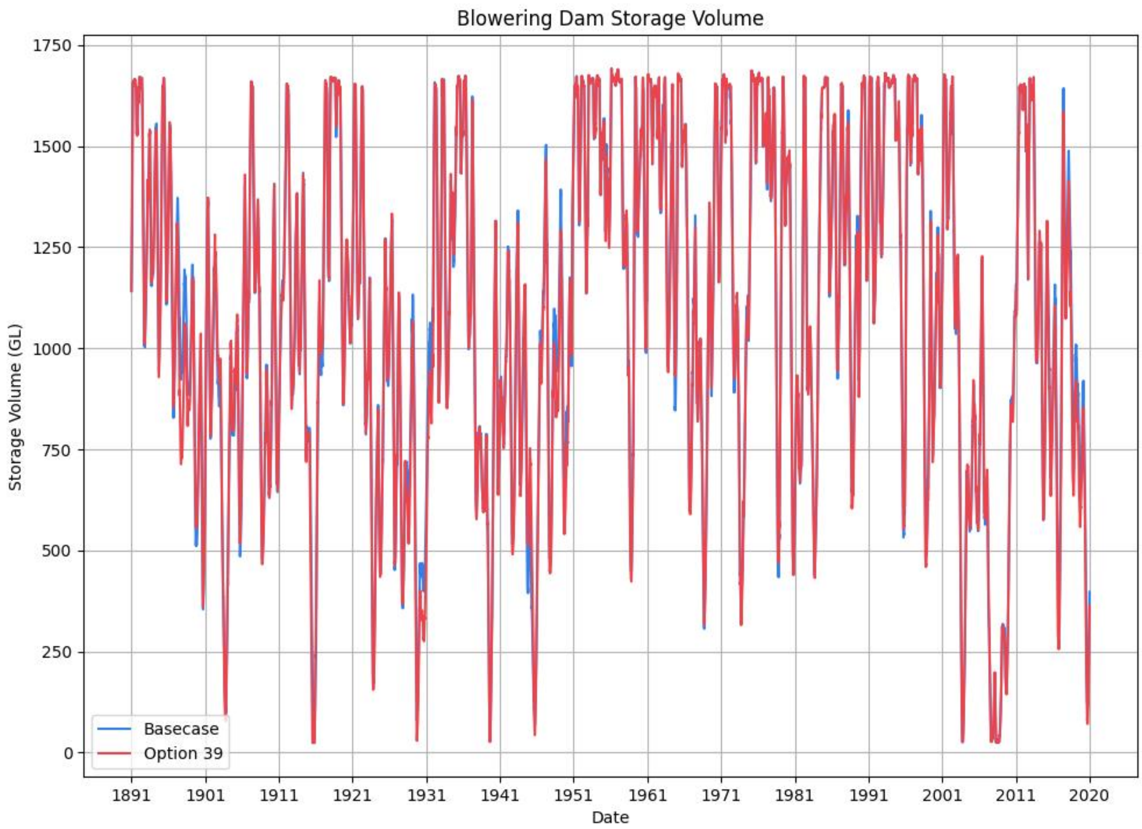
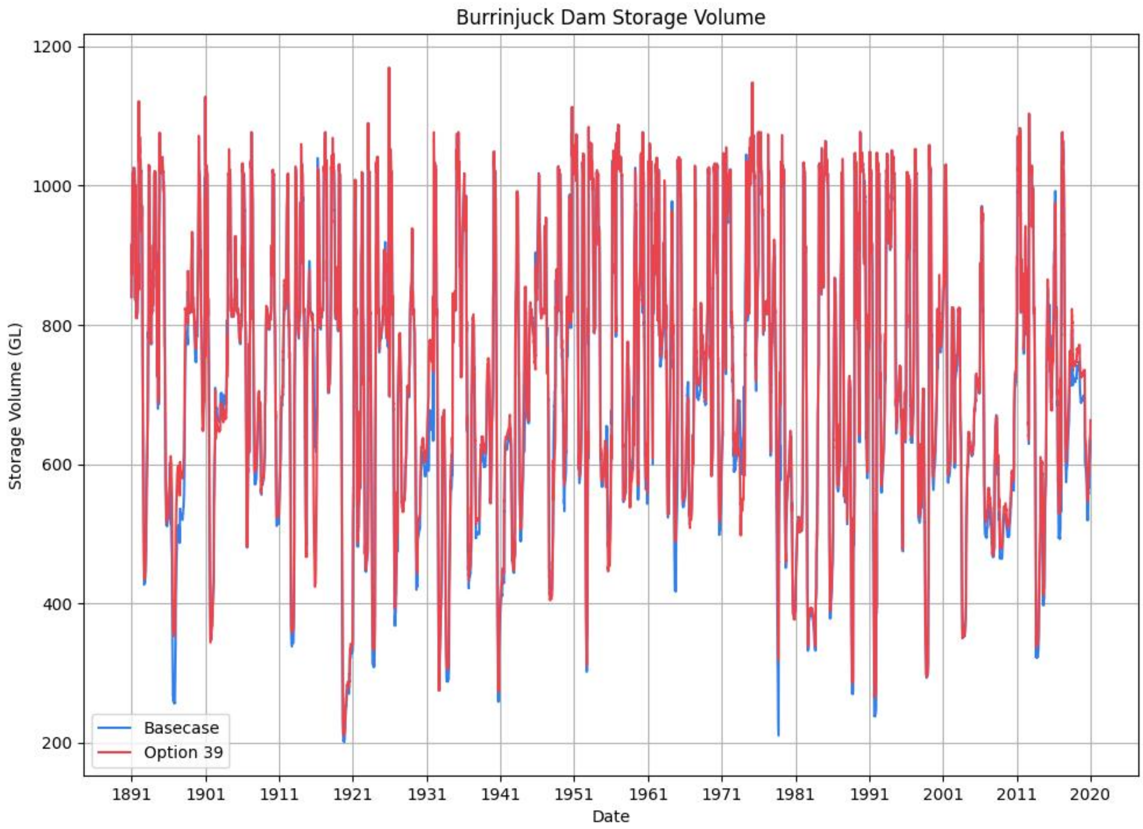


Figure 64. Burrinjuck storage behaviour for the Base Case and Option 39 (Enlarged Tombullen off-river storage).



Alterations in river flows

Mean annual flow for 1/7/1891 to 30/6/2020 for the Base Case and Tombullen storage option 39 are shown in Table 70. The table shows a slight reduction in total end of system flows due to the extra re-regulation of the storage.

Table 70. Comparison of the mean annual flow for the Base Case and Tombullen storage

Gauging sites (GL/y)	Base Case	Option 39	Change (%)
Murrumbidgee River at Gundagai	3,432.2	3,432.5	0%
Murrumbidgee River at Wagga Wagga	3,799.1	3,799.3	0%
Murrumbidgee River at Balranald	1,188.6	1,174.3	-1%
Billabong Creek at Darlot	227.5	231.0	2%

13. Assessment of Historical, Long-Term, and Dry future climate scenarios

The Base Case model was run for historical, long-term historical and dry future climate scenarios and results are presented in Table 71.

The table shows averages over respective modelling periods (the 132-year historical record , and a long-term historical and dry future climate of 10,000 years each).

- The historical and long-term historical scenario results are within 10% suggesting that the historical period is sufficiently long enough to understand average conditions. The long-term historical scenario provides better insights into extreme periods.
- Environmental deliveries of both HEW and PEW are better in the long-term period suggesting that the environment benefits from increased frequency of extreme wet events.
- Climate change shows a 27% reduction in total diversions. The reductions are less significant for higher security entitlements such as High Security (-7%), and Premium High Security (-1%).
- Under climate change Domestic and Stock and Local Water Utilities see a respective 4% increase in diversions. This reflects greater use in a drier climate. It also indicates that reserves held to maintain the security of these entitlements are sufficient to maintain security in a drier climate.
- The percentage of time Blowering is below FSV is the 3% more in the long-term scenario and significantly more under climate change (11%)
- Flows are less in the long-term particularly at Balranald where they are 10% less than historical. The impact of climate change (dry future climate scenario) with a significant reduction in averages, 29% in diversions and approximately 48% in end of system flows. Moreover, a much greater impact on lower allocation reliabilities and diversions.

Table 71 Base Case metrics for historical, Long-term historical and Dry future climate scenarios

Metric	Base Case				
Water diversions (GL/y)	Historical	Long-term	Change (%)	Dry Future	Change (%)
General Security	674.8	647.3	-4%	388.5	-42%
High Security	294.1	291.2	-1%	274.6	-7%
Murrumbidgee Irrigation Conveyance	161.6	158.4	-2%	115.1	-29%
Coleambally Irrigation Conveyance	103.8	104.2	0%	96.8	-7%
Premium High Security	18.1	17.8	-2%	17.9	-1%
Stock and Domestic	19.4	19.7	2%	20.2	4%
Local Water Utility	10.1	9.9	-2%	10.5	4%
Supplementary	116.0	120.9	4%	94.6	-18%
Lowbidgee consumptive	48.6	46.7	-4%	21.5	-56%
Inter-valley transfer	105.5	105.5	0%	97.9	-7%
Total diversions	1,552.0	874.3	-44%	1,137.6	-27%
Water delivery (GL/y)					
Held environmental water	144.6	156.6	8%	118.6	-18%
Lowbidgee environment	70.0	66.6	-5%	42.2	-40%
Planned environmental water	133.4	138.5	4%	86.9	-35%
Total environmental water	348.0	361.7	4%	247.7	-29%
Average allocations (%)					
General security effective allocation on 1 July	39%	40%	1%	21%	-18%
General security effective allocation on 30 September	61%	58%	-3%	28%	-33%
General Security effective allocation on 30 June	80%	85%	5%	43%	-37%
General security allocation on 1 July	31%	30%	-1%	16%	-15%
General security allocation 30 September	53%	48%	-5%	23%	-30%
General Security allocation on 30 June	72%	75%	3%	38%	-34%
High security allocation on 1 July	93%	93%	0%	87%	-6%
High security allocation 30 September	96%	95%	-1%	92%	-4%

Metric	Base Case				
Water diversions (GL/y)	Historical	Long-term	Change (%)	Dry Future	Change (%)
High security allocation on 30 June	98%	97%	-1%	94%	-4%
Coleambally Irrigation conveyance allocation on 1 July	88%	88%	0%	86%	-2%
Coleambally Irrigation conveyance allocation 30 September	92%	91%	-1%	87%	-5%
Coleambally Irrigation conveyance allocation on 30 June	95%	95%	0%	89%	-6%
Murrumbidgee Irrigation conveyance allocation on 1 July	76%	75%	-1%	66%	-10%
Murrumbidgee Irrigation conveyance allocation 30 September	85%	84%	-1%	70%	-15%
Murrumbidgee Irrigation conveyance allocation on 30 June	92%	93%	1%	78%	-14%
Spills (GL/y)					
Blowering Dam	313.3	178.5	-43%	39.2	-87%
Burrinjuck Dam	365.6	300.2	-18%	115.9	-68%
% of time below					
Blowering Dam					
1831.4 GL	100%	100%	0%	100%	0%
1731.4 GL	100%	100%	0%	100%	0%
1631.4 GL (FSV)	86%	89%	3%	97%	11%
1531.4 GL	79%	82%	3%	94%	15%
50%	27%	24%	-3%	46%	19%
25%	7%	6%	-1%	19%	12%
10%	3%	2%	-1%	8%	5%
5%	2%	1%	-1%	6%	4%
Burrinjuck Dam					
1700 GL	100%	100%	0%	100%	0%
1026 GL (FSV)	97%	97%	0%	99%	2%
80%	70%	68%	-2%	74%	4%
50%	16%	11%	-5%	11%	-5%
25%	1%	2%	1%	4%	3%
10%	0%	2%	2%	3%	3%
5%	0%	2%	2%	3%	3%
Gauging sites (GL/y)					
Murrumbidgee River at Gundagai	3,432.2	3,255.3	-5%	2,203.3	-36%

Metric	Base Case				
Water diversions (GL/y)	Historical	Long-term	Change (%)	Dry Future	Change (%)
Murrumbidgee River at Wagga Wagga	3,799.1	3,594.7	-5%	2,393.2	-37%
Murrumbidgee River at Balranald	1,188.6	1,073.3	-10%	601.0	-49%
Billabong Creek at Darlot	227.5	224.9	-1%	133.7	-41%

The end of water year (30/6) effective general and high security allocations for the Historical, Long-term historical, and Dry future climate scenarios are shown in Figure 65 and

Figure 66. These figures show:

- Similar results for Historical and Long-term historical scenarios General Security end of water year allocations, with long-term being slightly more reliable.
- Effective general security allocations are significantly reduced under the dry future climate. Full general security allocations are available only 10%, rather than 55% of the time.
- High security allocations are less reliable in the dry future climate, with 97% or more of the full allocation available more than 10% of the time. However, allocations below this are maintained for the dry future climate scenario which is a good outcome for perennial crops, Domestic and Stock and local water utilities that require a high level of security.

Figure 65 End of water year effective general security allocation reliability in Historical, Long-term historical, and Dry future climate scenarios

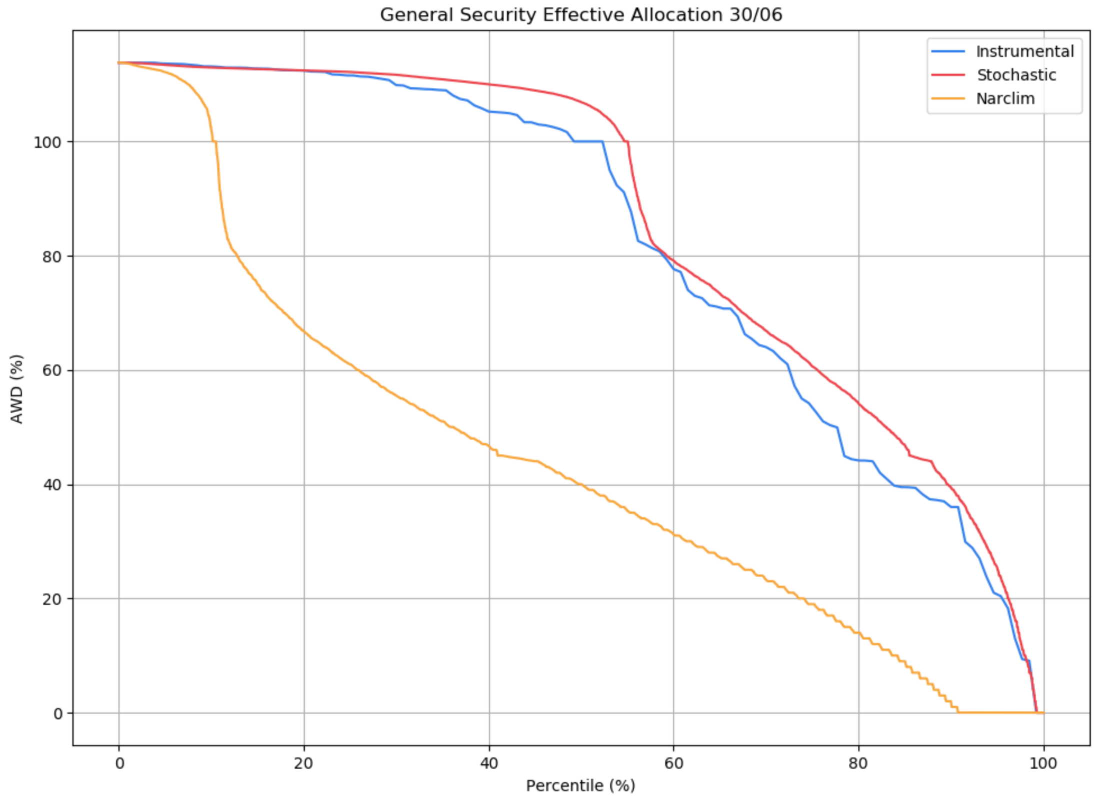
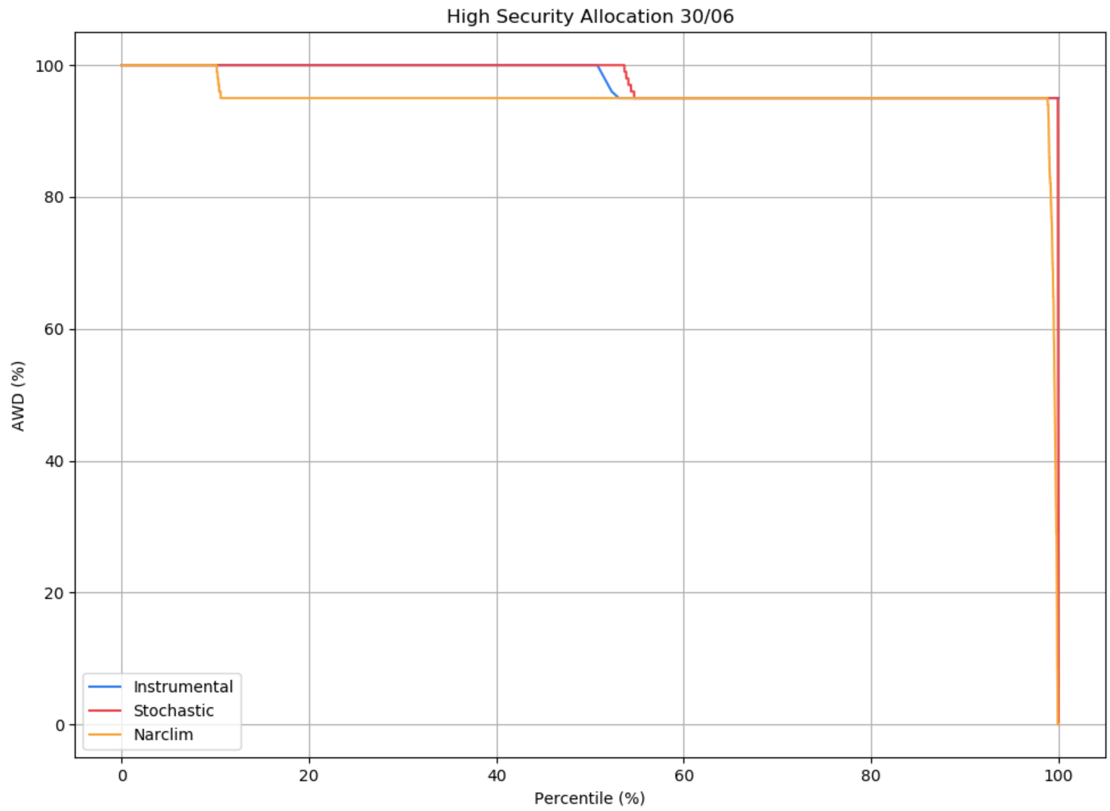
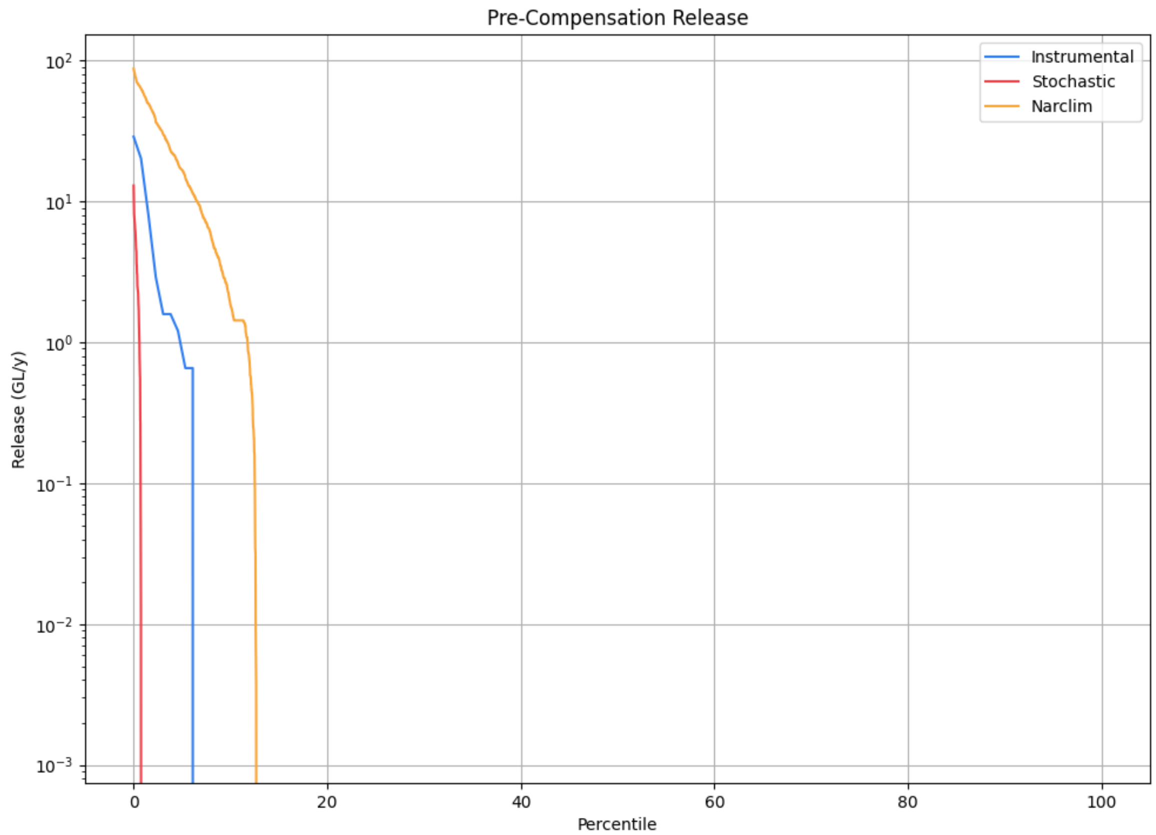


Figure 66 End of water year high security allocation reliability in Historical, Long-term historical, and Dry future climate scenarios



The drought and Pre-release Compensation Reserve (PCR) call outs occur during dry conditions to support high security supplies. The drought call out is rare in all climate scenarios as it requires sufficient reserves to ensure high security requirements are met and the need to call out drought reserves is not required. PCR call outs are also rare as they require a combination of water in the PCR account and Blowering Dam below 160 GL which is rare. Figure 67 shows the PCR call out is influenced by the amount of time Blowering Dam is below 160 GL (approximately 10% storage volume). Table 71 shows this is 3% of the time in the Historical scenario and 2% of the time in the Long-term historical scenario and is reflected in the PCR callouts. Under the Dry future climate scenario Blowering Dam is below 160 GL for 78% of the time and consequently PCR call outs are more frequent. This shows in the Historical scenario Blowering is below 160 GL 1% more frequently than what would happen over the much longer term (without considering a dry future climate change scenario) and consequently more PCR callouts.

Figure 67 Base Case PCR call out in Historical, Long-term historical and Dry future climate scenarios.



Options

The preferred options considered for modelling assessment using the Long-term historical and Dry future climate scenarios are presented in Table 72. In total 8 options have been evaluated.

These are discussed in the next section.

Table 72. Murrumbidgee Regional Water Strategy portfolio options

RWS option	Scenario description
Option 13 - Investigate Water Access Licence conversion	(i) 10% of GS entitlement converted to HS entitlement. (ii) 50% of GS entitlement converted to HS entitlement.
Option 33 - Investigate alternatives for increased storage capacity	a) An on-river storage of 47 GL capacity on the Tumut River near the Murrumbidgee River confluence. b) An on-river dam of 20 GL capacity on the Murrumbidgee River near Gundagai c) An on-river dam of 1,000 GL capacity on the Murrumbidgee River near Gundagai
Option 35- Install gravity pipeline along Tumut River	Scenario 7 — A 2000 ML/day capacity gravity pipeline from Blowering Dam to the Tumut and Murrumbidgee rivers' confluence
Option 36 – Enlarged Blowering Dam	Increase Blowering Dam capacity by 200 GL to 1831 GL (i) 100 GL airspace reserved for SHL releases. (ii) 200 GL airspace reserved for SHL releases
Option 36a – Enlarged Blowering Dam and Tumut gravity pipeline	Combination of option 36 and 35 (i) 100 GL airspace reserved for SHL releases. (ii) 200 GL airspace reserved for SHL releases
Option 37 – Enlarged Burrinjuck Storage Reservoir	Increase Burrinjuck Dam capacity by 672 GL to 1700 GL.
Option 38 – Enlarged Bundidgerry off-river storage and a new transfer canal	Increase Bundidgerry Creek storage by 5490 ML.

RWS option	Scenario description
Option 39 – Augment Tombullen Storage and modify operational changes	Pass flushing flows through Tombullen when system capacity allows, and the water can be used for downstream consumptive purposes.

Option Modelling Results

The results for each scenario are presented for three climatic periods:

- Historical record — the past 132 years climate with all inflows simulated under recent levels of development.
- Long-term — 10,000 years stochastically generated period
- Dry future — 10,000 years stochastically generated period adjusted for dry future climate.
- The results are compared against the respective base case scenarios. This shows how sensitive an option is to both a longer-term climate sequence and climate change. Significant differences between historical and long-term suggest a sensitivity to climate sequences. Significant differences in the dry future scenario suggests a sensitivity to the extreme sequences of a dry future climate.

Option 13

Table 73 shows Option13(i) impacts relative to corresponding base case climate scenarios:

- Historical and long-term overall diversion impacts are similar (0%) and Dry future is slightly improved (1%).
- Overall environmental impacts are slightly improved for historical and long-term climate and similar for the dry future climate.
- Historical and long-term allocation impacts are slightly improved and dry future impacts are similar.
- Spilling is more for all climate scenarios. Storage behaviour impacts are similar for each of the climate scenarios.
- Flow impacts are similar for each of the climate scenarios.

Table 73. Murrumbidgee Regional Water Strategy scenario results (Historical, Long-term historical and Dry future climate scenarios) for Option 13(i)

Metric	Option 13(i)					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
General Security	618.0	-8%	595.7	-8%	347.9	-10%
High Security	352.1	20%	347.2	19%	327.4	19%
Murrumbidgee Irrigation Conveyance	163.0	1%	156.5	-1%	112.1	-3%
Coleambally Irrigation Conveyance	103.7	0%	104.2	0%	96.7	0%
Premium High Security	18.0	-1%	17.7	-1%	17.9	0%
Stock and Domestic	19.4	0%	19.7	0%	20.0	-1%
Local Water Utility	10.1	0%	9.9	0%	10.5	0%
Supplementary	115.8	0%	121.2	0%	94.8	0%
Lowbidgee consumptive	48.8	0%	47.0	1%	21.6	0%
Inter-valley transfer	104.2	-1%	105.3	0%	97.5	0%
Total diversions	1,553.1	0%	1,524.4	0%	1,146.4	1%
Held environmental water	151.6	5%	158.7	1%	117.5	-1%
Lowbidgee environment	69.3	-1%	67.3	1%	42.6	1%
Planned environmental water	132.7	-1%	138.9	0%	86.7	0%
Total environmental water	353.6	2%	364.9	1%	246.8	0%
General security effective allocation on 1 July	41%	2%	42%	2%	22%	1%
General security effective allocation on 30 September	62%	1%	60%	2%	29%	1%
General Security effective allocation on 30 June	81%	1%	86%	1%	43%	0%
General security allocation on 1 July	34%	3%	32%	2%	16%	0%
General security allocation 30 September	55%	2%	51%	3%	24%	1%
General Security allocation on 30 June	74%	2%	77%	2%	38%	0%
High security allocation on 1 July	93%	0%	93%	0%	86%	-1%

Metric	Option 13(i)					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
High security allocation 30 September	96%	0%	95%	0%	91%	-1%
High security allocation on 30 June	98%	0%	97%	0%	94%	0%
Coleambally Irrigation conveyance allocation on 1 July	88%	0%	88%	0%	86%	0%
Coleambally Irrigation conveyance allocation 30 September	92%	0%	91%	0%	87%	0%
Coleambally Irrigation conveyance allocation on 30 June	95%	0%	96%	1%	89%	0%
Murrumbidgee Irrigation conveyance allocation on 1 July	77%	1%	76%	1%	66%	0%
Murrumbidgee Irrigation conveyance allocation 30 September	86%	1%	85%	1%	71%	1%
Murrumbidgee Irrigation conveyance allocation on 30 June	92%	0%	93%	0%	78%	0%
Blowering Dam	313.4	0%	182.2	2%	40.9	4%
Burrinjuck Dam	368.7	1%	302.6	1%	116.8	1%
Blowering Dam						
1831.4 GL	100%	0%	100%	0%	100%	0%
1731.4 GL	100%	0%	100%	0%	100%	0%
1631.4 GL (FSV)	86%	0%	89%	0%	97%	0%
1531.4 GL	79%	0%	82%	0%	94%	0%
50%	27%	0%	23%	-1%	45%	-1%
25%	7%	0%	5%	-1%	19%	0%
10%	3%	0%	2%	0%	9%	1%
5%	2%	0%	1%	0%	6%	0%
Burrinjuck Dam						
1700 GL	100%	0%	100%	0%	100%	0%
1026 GL (FSV)	97%	0%	97%	0%	99%	0%
80%	70%	0%	67%	-1%	73%	-1%
50%	15%	-1%	10%	-1%	12%	1%
25%	0%	-1%	2%	0%	4%	0%
10%	0%	0%	2%	0%	3%	0%

Metric	Option 13(i)					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
5%	0%	0%	2%	0%	3%	0%
Murrumbidgee River at Gundagai	3,433.0	0%	3,255.1	0%	2,203.2	0%
Murrumbidgee River at Wagga Wagga	3,799.9	0%	3,594.5	0%	2,393.2	0%
Murrumbidgee River at Balranald	1,183.5	0%	1,066.8	-1%	592.8	-1%
Billabong Creek at Darlot	227.8	0%	225.4	0%	134.2	0%

Table 74 shows Option13(ii) impacts relative to corresponding base case climate scenarios:

- Historical and long-term impacts are similar and dry future impacts are improved (4%). This mostly driven by High Security diversions.
- Historical and long-term environmental impacts are similar (5%) and dry future impacts are significantly worse (-6%).
- Historical and long-term allocation impacts are improved for most licence classes for historical and long-term climate. Dry future impacts are worse for most licence types.
- Spilling of both storages increases in all scenarios and increases for Blowering in the long term and dry future climate. Storage behaviour is improved for historical and long-term and similar for dry future climate.
- All climate scenario impacts are improved for Billabong Creek and are worse for Balranald.

Table 74. Murrumbidgee Regional Water Strategy scenario results (Historical, Long-term, and Dry future) for Option 13(ii)

Metric	Option 13(ii)					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
General Security	358.9	-47%	345.0	-47%	168.0	-57%
High Security	620.5	111%	609.9	109%	565.4	106%
Murrumbidgee Irrigation Conveyance	148.5	-8%	140.2	-11%	94.3	-18%
Coleambally Irrigation Conveyance	103.8	0%	103.7	0%	95.9	-1%
Premium High Security	17.9	-1%	17.3	-3%	17.7	-1%

Metric	Option 13(ii)					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
Stock and Domestic	19.5	1%	19.2	-3%	19.2	-5%
Local Water Utility	10.1	0%	10.0	1%	10.5	0%
Supplementary	116.8	1%	122.8	2%	95.5	1%
Lowbidgee consumptive	50.2	3%	49.4	6%	22.0	2%
Inter-valley transfer	96.2	-9%	103.2	-2%	93.9	-4%
Total diversions	1,542.4	-1%	1,520.7	0%	1,182.4	4%
Held environmental water	158.8	10%	165.8	6%	106.4	-10%
Lowbidgee environment	72.3	3%	72.2	8%	44.5	5%
Planned environmental water	133.1	0%	140.1	1%	82.8	-5%
Total environmental water	364.2	5%	378.1	5%	233.7	-6%
General security effective allocation on 1 July	51%	12%	52%	12%	23%	2%
General security effective allocation on 30 September	67%	6%	68%	10%	29%	1%
General Security effective allocation on 30 June	81%	1%	87%	2%	39%	-4%
General security allocation on 1 July	45%	14%	44%	14%	19%	3%
General security allocation 30 September	62%	9%	61%	13%	25%	2%
General Security allocation on 30 June	75%	3%	79%	4%	35%	-3%
High security allocation on 1 July	92%	-1%	93%	0%	77%	-10%
High security allocation 30 September	96%	0%	95%	0%	87%	-5%
High security allocation on 30 June	98%	0%	97%	0%	93%	-1%
Coleambally Irrigation conveyance allocation on 1 July	91%	3%	90%	2%	87%	1%
Coleambally Irrigation conveyance allocation 30 September	93%	1%	93%	2%	88%	1%

Metric	Option 13(ii)					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
Coleambally Irrigation conveyance allocation on 30 June	96%	1%	96%	1%	89%	0%
Murrumbidgee Irrigation conveyance allocation on 1 July	81%	5%	82%	7%	66%	0%
Murrumbidgee Irrigation conveyance allocation 30 September	87%	2%	88%	4%	71%	1%
Murrumbidgee Irrigation conveyance allocation on 30 June	92%	0%	93%	0%	76%	-2%
Blowering Dam	341.1	9%	212.2	19%	49.8	27%
Burrinjuck Dam	395.6	8%	320.4	7%	121.9	5%
Blowering Dam						
1831.4 GL	100%	0%	100%	0%	100%	0%
1731.4 GL	100%	0%	100%	0%	100%	0%
1631.4 GL (FSV)	84%	-2%	87%	-2%	96%	-1%
1531.4 GL	77%	-2%	79%	-3%	93%	-1%
50%	23%	-4%	18%	-6%	46%	0%
25%	6%	-1%	4%	-2%	23%	4%
10%	3%	0%	2%	0%	12%	4%
5%	2%	0%	2%	1%	9%	3%
Burrinjuck Dam						
1700 GL	100%	0%	100%	0%	100%	0%
1026 GL (FSV)	96%	-1%	97%	0%	99%	0%
80%	65%	-5%	63%	-5%	72%	-2%
50%	9%	-7%	6%	-5%	14%	3%
25%	0%	-1%	2%	0%	7%	3%
10%	0%	0%	2%	0%	4%	1%
5%	0%	0%	2%	0%	3%	0%
Murrumbidgee River at Gundagai	3,436.5	0%	3,253.3	0%	2,204.4	0%
Murrumbidgee River at Wagga Wagga	3,803.8	0%	3,593.1	0%	2,395.0	0%
Murrumbidgee River at Balranald	1,160.2	-2%	1,040.8	-3%	560.8	-7%

Metric	Option 13(ii)					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
Billabong Creek at Darlot	235.6	4%	232.6	3%	139.6	4%

Options 33a

Table 75 shows Option33a impacts relative to corresponding base case climate scenarios:

- Diversion impacts are similar for each of the climate scenarios.
- Environmental delivery impacts are similar for each of the climate scenarios, with long-term being slightly worse and dry future slightly better.
- Allocation impacts are similar for each of the climate scenarios.
- Burrinjuck spill more in all scenarios. Storage behaviour impacts are different between Burrinjuck and Blowering which suggest harmony operations are different between scenarios. Overall Burrinjuck is improved in all scenarios.
- Flow impacts are similar for each of the climate scenarios.

Table 75. Murrumbidgee Regional Water Strategy scenario results (Historical, Long-term, and Dry future) for Option 33a

Metric	Option 33a					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
General Security	680.1	1%	654.6	1%	400.8	3%
High Security	295.0	0%	291.8	0%	277.2	1%
Murrumbidgee Irrigation Conveyance	164.1	2%	160.2	1%	116.2	1%
Coleambally Irrigation Conveyance	104.0	0%	104.5	0%	96.9	0%
Premium High Security	18.1	0%	17.8	0%	18.1	1%
Stock and Domestic	19.8	2%	20.1	2%	20.6	2%
Local Water Utility	9.9	-2%	9.7	-2%	10.2	-3%
Supplementary	105.6	-9%	109.9	-9%	84.7	-10%
Lowbidgee consumptive	47.6	-2%	45.9	-2%	21.1	-2%
Inter-valley transfer	104.9	-1%	105.4	0%	97.2	-1%
Total diversions	1,549.1	0%	1,519.9	0%	1,143.0	0%
Held environmental water	149.4	3%	157.3	0%	119.9	1%
Lowbidgee environment	66.7	-5%	64.8	-3%	41.1	-3%

Metric	Option 33a					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
Planned environmental water	132.1	-1%	136.5	-1%	88.2	1%
Total environmental water	348.2	0%	358.6	-1%	249.2	1%
General security effective allocation on 1 July	40%	1%	41%	1%	22%	1%
General security effective allocation on 30 September	61%	0%	59%	1%	29%	1%
General Security effective allocation on 30 June	81%	1%	86%	1%	45%	2%
General security allocation on 1 July	32%	1%	31%	1%	16%	0%
General security allocation 30 September	53%	0%	49%	1%	24%	1%
General Security allocation on 30 June	73%	1%	76%	1%	39%	1%
High security allocation on 1 July	94%	1%	94%	1%	89%	2%
High security allocation 30 September	96%	0%	95%	0%	93%	1%
High security allocation on 30 June	98%	0%	97%	0%	95%	1%
Coleambally Irrigation conveyance allocation on 1 July	88%	0%	88%	0%	86%	0%
Coleambally Irrigation conveyance allocation 30 September	92%	0%	91%	0%	87%	0%
Coleambally Irrigation conveyance allocation on 30 June	95%	0%	96%	1%	89%	0%
Murrumbidgee Irrigation conveyance allocation on 1 July	76%	0%	75%	0%	66%	0%
Murrumbidgee Irrigation conveyance allocation 30 September	85%	0%	84%	0%	71%	1%

Metric	Option 33a					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
Murrumbidgee Irrigation conveyance allocation on 30 June	92%	0%	93%	0%	79%	1%
Blowering Dam	296.0	-6%	176.9	-1%	39.2	0%
Burrinjuck Dam	403.6	10%	336.4	12%	135.1	17%
Blowering Dam						
1831.4 GL	100%	0%	100%	0%	100%	0%
1731.4 GL	100%	0%	100%	0%	100%	0%
1631.4 GL (FSV)	86%	0%	90%	1%	97%	0%
1531.4 GL	80%	1%	83%	1%	94%	0%
50%	32%	5%	27%	3%	47%	1%
25%	9%	2%	7%	1%	19%	0%
10%	3%	0%	2%	0%	9%	1%
5%	2%	0%	2%	1%	6%	0%
Burrinjuck Dam						
1700 GL	100%	0%	100%	0%	100%	0%
1026 GL (FSV)	96%	-1%	96%	-1%	99%	0%
80%	64%	-6%	61%	-7%	67%	-7%
50%	8%	-8%	5%	-6%	4%	-7%
25%	0%	-1%	2%	0%	2%	-2%
10%	0%	0%	2%	0%	2%	-1%
5%	0%	0%	2%	0%	2%	-1%
Murrumbidgee River at Gundagai	3,432.4	0%	3,255.1	0%	2,202.1	0%
Murrumbidgee River at Wagga Wagga	3,799.3	0%	3,594.5	0%	2,392.0	0%
Murrumbidgee River at Balranald	1,187.6	0%	1,068.2	0%	591.7	-2%
Billabong Creek at Darlot	228.3	0%	225.8	0%	133.9	0%

Options 33b

Table 76 shows Option33b impacts relative to corresponding base case climate scenarios:

- Diversion impacts are similar for each of the climate scenarios.
- Environmental delivery impacts are slightly improved across all climate scenarios.
- Allocation impacts are improved for General Security for each of the climate scenarios.
- There is more spilling of both storages under all scenarios. Storage impacts are improved for lower storage volume frequencies for all climate scenarios.
- Flow impacts are similar for each of the climate scenarios except for Balranald which is slightly worse.

Table 76. Murrumbidgee Regional Water Strategy scenario results (Historical, Long-term, and Dry future) for Option 33b

Metric	Option 33b					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
General Security	695.7	3%	677.3	5%	411.0	6%
High Security	295.6	1%	293.3	1%	276.2	1%
Murrumbidgee Irrigation Conveyance	167.0	3%	164.5	4%	119.5	4%
Coleambally Irrigation Conveyance	104.3	0%	105.2	1%	97.4	1%
Premium High Security	18.0	-1%	17.8	0%	18.1	1%
Stock and Domestic	20.5	6%	20.8	6%	20.7	2%
Local Water Utility	10.0	-1%	9.9	0%	10.4	-1%
Supplementary	89.0	-23%	92.1	-24%	73.0	-23%
Lowbidgee consumptive	45.1	-7%	43.3	-7%	20.5	-5%
Inter-valley transfer	103.7	-2%	104.4	-1%	97.5	0%
Total diversions	1,548.9	0%	1,528.6	0%	1,144.3	1%
Held environmental water	157.1	9%	166.6	6%	121.9	3%
Lowbidgee environment	60.9	-13%	58.7	-12%	38.8	-8%
Planned environmental water	132.6	-1%	139.5	1%	89.3	3%
Total environmental water	350.6	1%	364.8	1%	250.0	1%

Metric	Option 33b					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
General security effective allocation on 1 July	43%	4%	45%	5%	23%	2%
General security effective allocation on 30 September	64%	3%	62%	4%	30%	2%
General Security effective allocation on 30 June	83%	3%	89%	4%	47%	4%
General security allocation on 1 July	35%	4%	35%	5%	17%	1%
General security allocation 30 September	55%	2%	53%	5%	25%	2%
General Security allocation on 30 June	75%	3%	79%	4%	41%	3%
High security allocation on 1 July	93%	0%	93%	0%	87%	0%
High security allocation 30 September	96%	0%	95%	0%	92%	0%
High security allocation on 30 June	98%	0%	97%	0%	94%	0%
Coleambally Irrigation conveyance allocation on 1 July	89%	1%	88%	0%	86%	0%
Coleambally Irrigation conveyance allocation 30 September	92%	0%	91%	0%	87%	0%
Coleambally Irrigation conveyance allocation on 30 June	95%	0%	96%	1%	90%	1%
Murrumbidgee Irrigation conveyance allocation on 1 July	78%	2%	78%	3%	66%	0%
Murrumbidgee Irrigation conveyance allocation 30 September	86%	1%	86%	2%	71%	1%
Murrumbidgee Irrigation conveyance allocation on 30 June	92%	0%	94%	1%	79%	1%
Blowering Dam	354.8	13%	257.7	44%	58.4	49%

Metric	Option 33b					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
Burrinjuck Dam	445.4	22%	377.5	26%	148.2	28%
Blowering Dam						
1831.4 GL	100%	0%	100%	0%	100%	0%
1731.4 GL	100%	0%	100%	0%	100%	0%
1631.4 GL (FSV)	84%	-2%	84%	-5%	96%	-1%
1531.4 GL	77%	-2%	77%	-5%	92%	-2%
50%	27%	0%	21%	-3%	44%	-2%
25%	8%	1%	5%	-1%	18%	-1%
10%	3%	0%	2%	0%	8%	0%
5%	2%	0%	1%	0%	6%	0%
Burrinjuck Dam						
1700 GL	100%	0%	100%	0%	100%	0%
1026 GL (FSV)	96%	-1%	96%	-1%	99%	0%
80%	62%	-8%	58%	-10%	67%	-7%
50%	6%	-10%	4%	-7%	8%	-3%
25%	0%	-1%	2%	0%	4%	0%
10%	0%	0%	2%	0%	3%	0%
5%	0%	0%	2%	0%	3%	0%
Murrumbidgee River at Gundagai	3,428.6	0%	3,250.0	0%	2,198.0	0%
Murrumbidgee River at Wagga Wagga	3,795.5	0%	3,589.5	0%	2,387.9	0%
Murrumbidgee River at Balranald	1,173.2	-1%	1,050.1	-2%	586.4	-2%
Billabong Creek at Darlot	228.2	0%	226.3	1%	134.4	1%

Options 33c

Table 77 shows Option33c impacts relative to corresponding base case climate scenarios:

- Diversion impacts are similar for historical and long-term. Dry future impacts are improved by 7% across most regulated licence classes.
- Environmental delivery impacts are significantly improved across all climate scenarios. This is mostly caused by Lowbidgee access increasing due to removing consumptive supplementary access to be SDL compliant.
- Allocation impacts are improved for General Security for all climate scenarios.
- There is more spilling of both storages under all historical and long-term scenarios. Spilling for Burrinjuck has more than doubled for historical, 141% for long-term and 184% for the dry future climate. Storage impacts are improved for lower storage volume frequencies for all climate scenarios.
- Flow impacts are worse for each of the climate scenarios especially for Balranald which is significantly worse under the dry future climate.

Table 77. Murrumbidgee Regional Water Strategy scenario results (Historical, Long-term, and Dry future) for Option 33c

Metric	Option 33c					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
General Security	792.7	17%	755.2	17%	525.8	35%
High Security	301.8	3%	300.0	3%	285.5	4%
Murrumbidgee Irrigation Conveyance	184.6	14%	183.8	16%	147.2	28%
Coleambally Irrigation Conveyance	107.5	4%	108.2	4%	101.7	5%
Premium High Security	19.1	6%	19.4	9%	19.8	11%
Stock and Domestic	24.5	26%	24.6	25%	23.7	17%
Local Water Utility	10.2	1%	10.1	2%	10.4	-1%
Supplementary	0.0	-100%	0.0	-100%	0.0	-100%
Lowbidgee consumptive	0.0	-100%	0.0	-100%	0.0	-100%
Inter-valley transfer	105.3	0%	106.3	1%	100.2	2%

Metric	Option 33c					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
Total diversions	1,545.7	0%	1,507.6	-1%	1,214.3	7%
Held environmental water	139.8	-3%	146.9	-6%	124.6	5%
Lowbidgee environment	238.1	240%	247.8	272%	163.1	286%
Planned environmental water	148.5	11%	151.6	9%	107.7	24%
Total environmental water	526.4	51%	546.3	51%	395.4	60%
General security effective allocation on 1 July	78%	39%	82%	42%	41%	20%
General security effective allocation on 30 September	88%	27%	90%	32%	51%	23%
General Security effective allocation on 30 June	98%	18%	101%	16%	69%	26%
General security allocation on 1 July	72%	41%	74%	44%	35%	19%
General security allocation 30 September	82%	29%	83%	35%	44%	21%
General Security allocation on 30 June	92%	20%	93%	18%	62%	24%
High security allocation on 1 July	97%	4%	96%	3%	90%	3%
High security allocation 30 September	98%	2%	98%	3%	94%	2%
High security allocation on 30 June	99%	1%	99%	2%	96%	2%

Metric	Option 33c					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
Coleambally Irrigation conveyance allocation on 1 July	95%	7%	95%	7%	89%	3%
Coleambally Irrigation conveyance allocation 30 September	97%	5%	97%	6%	90%	3%
Coleambally Irrigation conveyance allocation on 30 June	98%	3%	99%	4%	93%	4%
Murrumbidgee Irrigation conveyance allocation on 1 July	92%	16%	93%	18%	76%	10%
Murrumbidgee Irrigation conveyance allocation 30 September	95%	10%	95%	11%	81%	11%
Murrumbidgee Irrigation conveyance allocation on 30 June	98%	6%	98%	5%	88%	10%
Blowering Dam	404.7	29%	283.9	59%	37.8	-4%
Burrinjuck Dam	736.0	101%	722.6	141%	329.0	184%
Blowering Dam						
1831.4 GL	100%	0%	100%	0%	100%	0%
1731.4 GL	100%	0%	100%	0%	100%	0%
1631.4 GL (FSV)	81%	-5%	84%	-5%	98%	1%
1531.4 GL	73%	-6%	76%	-6%	96%	2%
50%	29%	2%	27%	3%	70%	24%
25%	9%	2%	10%	4%	41%	22%
10%	4%	1%	4%	2%	22%	14%

Metric	Option 33c					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
5%	2%	0%	3%	2%	15%	9%
Burrinjuck Dam						
1700 GL	100%	0%	100%	0%	100%	0%
1026 GL (FSV)	95%	-2%	94%	-3%	98%	-1%
80%	16%	-54%	9%	-59%	24%	-50%
50%	3%	-13%	3%	-8%	8%	-3%
25%	0%	-1%	2%	0%	5%	1%
10%	0%	0%	2%	0%	3%	0%
5%	0%	0%	2%	0%	3%	0%
Murrumbidgee River at Gundagai	3,401.8	-1%	3,215.1	-1%	2,163.0	-2%
Murrumbidgee River at Wagga Wagga	3,768.6	-1%	3,554.4	-1%	2,352.6	-2%
Murrumbidgee River at Balranald	1,156.5	-3%	1,034.9	-4%	522.1	-13%
Billabong Creek at Darlot	227.4	0%	225.5	0%	132.3	-1%

Option 35

Table 78 shows Option35 impacts relative to corresponding base case climate scenarios:

- Diversion and environmental impacts are similar for each of the climate scenarios.
- Allocation impacts are similar for each of the climate scenarios.
- Blowering and Burrinjuck spilling volumes are similar for historical and increased for Blowering in the long-term and dry future. For the dry future climate Blowering spills increase and Burrinjuck decrease which suggest harmony issues. Storage behaviour is similar across all scenarios.
- Flow impacts are similar for each of the climate scenarios.

Table 78. Murrumbidgee Regional Water Strategy scenario results (Historical, Long-term, and Dry future) for Option 35

Metric	Option 35					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
General Security	665.7	-1%	644.7	0%	390.2	0%
High Security	294.2	0%	291.0	0%	274.7	0%

Metric	Option 35					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
Murrumbidgee Irrigation Conveyance	161.5	0%	157.9	0%	115.1	0%
Coleambally Irrigation Conveyance	103.7	0%	104.1	0%	96.8	0%
Premium High Security	18.0	-1%	17.8	0%	17.9	0%
Stock and Domestic	19.3	-1%	19.7	0%	20.2	0%
Local Water Utility	10.1	0%	9.9	0%	10.5	0%
Supplementary	116.4	0%	121.0	0%	94.8	0%
Lowbidgee consumptive	48.8	0%	47.7	2%	21.8	1%
Inter-valley transfer	105.3	0%	105.4	0%	98.1	0%
Total diversions	1,543.0	-1%	1,519.2	0%	1,140.1	0%
Held environmental water	148.9	3%	158.1	1%	119.4	1%
Lowbidgee environment	70.8	1%	70.6	6%	43.3	3%
Planned environmental water	132.6	-1%	137.5	-1%	87.0	0%
Total environmental water	352.3	1%	366.2	1%	249.7	1%
General security effective allocation on 1 July	38%	-1%	40%	0%	21%	0%
General security effective allocation on 30 September	60%	-1%	58%	0%	29%	1%
General Security effective allocation on 30 June	80%	0%	85%	0%	43%	0%
General security allocation on 1 July	30%	-1%	30%	0%	16%	0%
General security allocation 30 September	52%	-1%	48%	0%	23%	0%
General Security allocation on 30 June	71%	-1%	75%	0%	38%	0%
High security allocation on 1 July	94%	1%	93%	0%	87%	0%
High security allocation 30 September	96%	0%	95%	0%	92%	0%

Metric	Option 35					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
High security allocation on 30 June	97%	-1%	97%	0%	94%	0%
Coleambally Irrigation conveyance allocation on 1 July	88%	0%	88%	0%	86%	0%
Coleambally Irrigation conveyance allocation 30 September	91%	-1%	91%	0%	87%	0%
Coleambally Irrigation conveyance allocation on 30 June	95%	0%	95%	0%	89%	0%
Murrumbidgee Irrigation conveyance allocation on 1 July	75%	-1%	74%	-1%	66%	0%
Murrumbidgee Irrigation conveyance allocation 30 September	85%	0%	84%	0%	71%	1%
Murrumbidgee Irrigation conveyance allocation on 30 June	91%	-1%	93%	0%	78%	0%
Blowering Dam	311.4	-1%	189.0	6%	46.5	19%
Burrinjuck Dam	371.1	2%	296.3	-1%	105.5	-9%
Blowering Dam						
1831.4 GL	100%	0%	100%	0%	100%	0%
1731.4 GL	100%	0%	100%	0%	100%	0%
1631.4 GL (FSV)	86%	0%	89%	0%	96%	-1%
1531.4 GL	80%	1%	83%	1%	93%	-1%
50%	32%	5%	26%	2%	43%	-3%
25%	9%	2%	6%	0%	17%	-2%
10%	3%	0%	2%	0%	8%	0%
5%	2%	0%	1%	0%	5%	-1%
Burrinjuck Dam						
1700 GL	100%	0%	100%	0%	100%	0%
1026 GL (FSV)	96%	-1%	97%	0%	99%	0%
80%	73%	3%	72%	4%	82%	8%
50%	7%	-9%	5%	-6%	8%	-3%
25%	0%	-1%	2%	0%	4%	0%
10%	0%	0%	2%	0%	3%	0%
5%	0%	0%	2%	0%	2%	-1%

Metric	Option 35					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
Murrumbidgee River at Gundagai	3,432.2	0%	3,256.2	0%	2,204.1	0%
Murrumbidgee River at Wagga Wagga	3,799.0	0%	3,595.6	0%	2,394.0	0%
Murrumbidgee River at Balranald	1,196.6	1%	1,076.0	0%	601.3	0%
Billabong Creek at Darlot	227.8	0%	224.8	0%	133.6	0%

Option 36

Table 79 and Table 80 shows similar respective impacts for Option36(i) 100 GL and 36(ii) 200 GL relative to the corresponding base case climate scenarios:

- Diversion impacts are similar for each of the climate scenarios with Dry future being slightly worse.
- Environmental delivery impacts are slightly improved for all climate scenarios.
- Allocation impacts are improved for general security for all the climate scenarios.
- Spilling of both dams is reduced in all scenarios with a 27% reduction for Blowering in the future dry climate. The portion of time Blowering is near full supply volume is improved for all scenarios. There is no significant change to Burrinjuck storage behaviour across all scenarios.
- Flow impacts are similar for each of the climate scenarios.

Table 79. Murrumbidgee Regional Water Strategy scenario results (Historical, Long-term, and Dry future) for Option 36(i) (100 GL)

Metric	Option 36(i)					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
General Security	707.7	5%	682.1	5%	407.2	5%
High Security	295.8	1%	292.6	0%	275.7	0%
Murrumbidgee Irrigation Conveyance	165.0	2%	162.4	3%	118.3	3%
Coleambally Irrigation Conveyance	104.0	0%	104.6	0%	97.2	0%
Premium High Security	17.9	-1%	17.9	1%	18.1	1%
Stock and Domestic	21.3	10%	21.6	10%	21.1	4%
Local Water Utility	10.1	0%	9.9	0%	10.5	0%

Metric	Option 36(i)					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
Supplementary	62.8	-46%	63.9	-47%	51.9	-45%
Lowbidgee consumptive	47.5	-2%	45.9	-2%	21.1	-2%
Inter-valley transfer	106.4	1%	105.6	0%	98.2	0%
Total diversions	1,538.5	-1%	1,506.5	-1%	1,119.3	-2%
Held environmental water	156.8	8%	160.9	3%	120.0	1%
Lowbidgee environment	67.8	-3%	65.3	-2%	41.0	-3%
Planned environmental water	132.1	-1%	140.4	1%	89.4	3%
Total environmental water	356.7	3%	366.6	1%	250.4	1%
General security effective allocation on 1 July	44%	5%	44%	4%	23%	2%
General security effective allocation on 30 September	65%	4%	63%	5%	30%	2%
General Security effective allocation on 30 June	83%	3%	87%	2%	46%	3%
General security allocation on 1 July	37%	6%	35%	5%	17%	1%
General security allocation 30 September	57%	4%	54%	6%	25%	2%
General Security allocation on 30 June	75%	3%	78%	3%	40%	2%
High security allocation on 1 July	94%	1%	94%	1%	87%	0%
High security allocation 30 September	96%	0%	95%	0%	92%	0%
High security allocation on 30 June	98%	0%	97%	0%	94%	0%
Coleambally Irrigation conveyance allocation on 1 July	89%	1%	88%	0%	86%	0%
Coleambally Irrigation conveyance allocation 30 September	92%	0%	92%	1%	87%	0%
Coleambally Irrigation conveyance allocation on 30 June	95%	0%	96%	1%	90%	1%

Metric	Option 36(i)					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
Murrumbidgee Irrigation conveyance allocation on 1 July	78%	2%	77%	2%	66%	0%
Murrumbidgee Irrigation conveyance allocation 30 September	87%	2%	85%	1%	71%	1%
Murrumbidgee Irrigation conveyance allocation on 30 June	92%	0%	94%	1%	79%	1%
Blowering Dam	289.4	-8%	164.7	-8%	28.7	-27%
Burrinjuck Dam	361.7	-1%	297.2	-1%	113.5	-2%
Blowering Dam						
1831.4 GL	87%	-13%	90%	-10%	98%	-2%
1731.4 GL	81%	-19%	84%	-16%	96%	-4%
1631.4 GL (FSV)	74%	-12%	78%	-11%	94%	-3%
1531.4 GL	69%	-10%	72%	-10%	91%	-3%
50%	23%	-4%	21%	-3%	44%	-2%
25%	7%	0%	5%	-1%	18%	-1%
10%	3%	0%	2%	0%	8%	0%
5%	1%	-1%	1%	0%	5%	-1%
Burrinjuck Dam						
1700 GL	100%	0%	100%	0%	100%	0%
1026 GL (FSV)	97%	0%	97%	0%	99%	0%
80%	71%	1%	68%	0%	74%	0%
50%	16%	0%	11%	0%	11%	0%
25%	0%	-1%	2%	0%	4%	0%
10%	0%	0%	2%	0%	3%	0%
5%	0%	0%	2%	0%	3%	0%
Murrumbidgee River at Gundagai	3,429.7	0%	3,254.5	0%	2,202.4	0%
Murrumbidgee River at Wagga Wagga	3,796.5	0%	3,593.8	0%	2,392.3	0%
Murrumbidgee River at Balranald	1,190.9	0%	1,074.5	0%	602.8	0%
Billabong Creek at Darlot	228.6	0%	226.3	1%	134.6	1%

Table 80. Murrumbidgee Regional Water Strategy scenario results (Historical, Long-term, and Dry future) for Option 36(ii) (200 GL)

Metric	Option 36(ii)					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
General Security	705.8	5%	682.3	5%	407.6	5%
High Security	295.4	0%	292.5	0%	275.8	0%
Murrumbidgee Irrigation Conveyance	165.4	2%	162.5	3%	118.8	3%
Coleambally Irrigation Conveyance	104.1	0%	104.6	0%	97.1	0%
Premium High Security	17.9	-1%	17.8	0%	18.1	1%
Stock and Domestic	21.4	10%	21.6	10%	21.1	4%
Local Water Utility	10.1	0%	9.9	0%	10.5	0%
Supplementary	62.4	-46%	64.2	-47%	52.0	-45%
Lowbidgee consumptive	48.3	-1%	46.3	-1%	21.2	-1%
Inter-valley transfer	105.9	0%	105.7	0%	98.3	0%
Total diversions	1,536.7	-1%	1,507.4	-1%	1,120.5	-2%
Held environmental water	152.8	6%	161.7	3%	120.7	2%
Lowbidgee environment	68.4	-2%	67.2	1%	41.2	-2%
Planned environmental water	135.1	1%	140.4	1%	89.3	3%
Total environmental water	356.3	2%	369.3	2%	251.2	1%
General security effective allocation on 1 July	43%	4%	44%	4%	23%	2%
General security effective allocation on 30 September	64%	3%	63%	5%	30%	2%
General Security effective allocation on 30 June	83%	3%	87%	2%	45%	2%
General security allocation on 1 July	36%	5%	35%	5%	17%	1%
General security allocation 30 September	57%	4%	54%	6%	25%	2%
General Security allocation on 30 June	75%	3%	78%	3%	40%	2%

Metric	Option 36(ii)					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
High security allocation on 1 July	94%	1%	93%	0%	87%	0%
High security allocation 30 September	96%	0%	95%	0%	92%	0%
High security allocation on 30 June	98%	0%	97%	0%	94%	0%
Coleambally Irrigation conveyance allocation on 1 July	89%	1%	88%	0%	86%	0%
Coleambally Irrigation conveyance allocation 30 September	92%	0%	92%	1%	87%	0%
Coleambally Irrigation conveyance allocation on 30 June	95%	0%	96%	1%	89%	0%
Murrumbidgee Irrigation conveyance allocation on 1 July	78%	2%	77%	2%	66%	0%
Murrumbidgee Irrigation conveyance allocation 30 September	87%	2%	85%	1%	71%	1%
Murrumbidgee Irrigation conveyance allocation on 30 June	92%	0%	94%	1%	79%	1%
Blowering Dam	272.4	-13%	144.0	-19%	23.3	-41%
Burrinjuck Dam	357.9	-2%	296.9	-1%	113.0	-3%
Blowering Dam						
1831.4 GL	88%	-12%	92%	-8%	98%	-2%
1731.4 GL	84%	-16%	87%	-13%	97%	-3%
1631.4 GL (FSV)	78%	-8%	81%	-8%	95%	-2%
1531.4 GL	72%	-7%	74%	-8%	92%	-2%
50%	24%	-3%	24%	0%	46%	0%
25%	7%	0%	6%	0%	19%	0%
10%	3%	0%	2%	0%	8%	0%
5%	1%	-1%	1%	0%	5%	-1%
Burrinjuck Dam						
1700 GL	100%	0%	100%	0%	100%	0%
1026 GL (FSV)	97%	0%	97%	0%	99%	0%
80%	71%	1%	68%	0%	74%	0%

Metric	Option 36(ii)					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
50%	16%	0%	11%	0%	11%	0%
25%	0%	-1%	2%	0%	4%	0%
10%	0%	0%	2%	0%	3%	0%
5%	0%	0%	2%	0%	2%	-1%
Murrumbidgee River at Gundagai	3,432.8	0%	3,255.6	0%	2,205.5	0%
Murrumbidgee River at Wagga Wagga	3,799.6	0%	3,595.0	0%	2,395.3	0%
Murrumbidgee River at Balranald	1,192.7	0%	1,073.7	0%	604.2	1%
Billabong Creek at Darlot	228.6	0%	226.1	1%	134.5	1%

Option 36a

Table 81 and Table 82 shows similar respective impacts for Option36a(i) 100 GL and 36a(ii) 200 GL relative to corresponding base case climate scenarios:

- Diversion impacts are similar for each of the climate scenarios with Dry future being slightly worse.
- Environmental delivery impacts are slightly improved for all climate scenarios.
- Allocation impacts are improved for general security for all of the climate scenarios.
- Storage spill behaviour is reduced for all climate scenarios except for Burrinjuck in the historical scenario where it increases by 1%.
- The portion of time Blowering is near full supply volume is improved across all climate scenarios.
- Flow impacts are similar for each of the climate scenarios.

Table 81. Murrumbidgee Regional Water Strategy scenario results (Historical, Long-term, and Dry future) for Option 36a(i) (100 GL)

Metric	Option 36a(i)					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
General Security	681.1	1%	666.8	3%	404.5	4%
High Security	294.6	0%	292.1	0%	275.4	0%
Murrumbidgee Irrigation Conveyance	162.9	1%	160.8	2%	117.3	2%

Metric	Option 36a(i)					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
Coleambally Irrigation Conveyance	103.8	0%	104.5	0%	97.1	0%
Premium High Security	18.1	0%	17.8	0%	18.0	1%
Stock and Domestic	19.7	2%	20.2	3%	20.5	1%
Local Water Utility	10.1	0%	9.9	0%	10.5	0%
Supplementary	104.2	-10%	109.3	-10%	85.6	-10%
Lowbidgee consumptive	47.8	-2%	45.8	-2%	20.6	-4%
Inter-valley transfer	105.6	0%	105.6	0%	98.3	0%
Total diversions	1,547.9	0%	1,532.8	1%	1,147.8	1%
Held environmental water	152.0	5%	160.4	2%	120.5	2%
Lowbidgee environment	68.7	-2%	67.1	1%	40.5	-4%
Planned environmental water	131.3	-2%	139.4	1%	89.4	3%
Total environmental water	352.0	1%	366.9	1%	250.4	1%
General security effective allocation on 1 July	42%	3%	43%	3%	22%	1%
General security effective allocation on 30 September	62%	1%	62%	4%	30%	2%
General Security effective allocation on 30 June	81%	1%	86%	1%	45%	2%
General security allocation on 1 July	34%	3%	33%	3%	17%	1%
General security allocation 30 September	54%	1%	52%	4%	25%	2%
General Security allocation on 30 June	73%	1%	77%	2%	39%	1%
High security allocation on 1 July	93%	0%	93%	0%	87%	0%
High security allocation 30 September	96%	0%	95%	0%	92%	0%
High security allocation on 30 June	98%	0%	97%	0%	94%	0%

Metric	Option 36a(i)					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
Coleambally Irrigation conveyance allocation on 1 July	89%	1%	88%	0%	86%	0%
Coleambally Irrigation conveyance allocation 30 September	92%	0%	91%	0%	87%	0%
Coleambally Irrigation conveyance allocation on 30 June	95%	0%	96%	1%	89%	0%
Murrumbidgee Irrigation conveyance allocation on 1 July	77%	1%	77%	2%	66%	0%
Murrumbidgee Irrigation conveyance allocation 30 September	85%	0%	85%	1%	71%	1%
Murrumbidgee Irrigation conveyance allocation on 30 June	92%	0%	93%	0%	79%	1%
Blowering Dam	285.9	-9%	168.3	-6%	31.9	-19%
Burrinjuck Dam	368.6	1%	292.4	-3%	103.6	-11%
Blowering Dam						
1831.4 GL	88%	-12%	90%	-10%	98%	-2%
1731.4 GL	83%	-17%	85%	-15%	96%	-4%
1631.4 GL (FSV)	78%	-8%	80%	-9%	93%	-4%
1531.4 GL	74%	-5%	74%	-8%	90%	-4%
50%	29%	2%	23%	-1%	41%	-5%
25%	8%	1%	5%	-1%	17%	-2%
10%	3%	0%	2%	0%	7%	-1%
5%	2%	0%	1%	0%	5%	-1%
Burrinjuck Dam						
1700 GL	100%	0%	100%	0%	100%	0%
1026 GL (FSV)	97%	0%	97%	0%	99%	0%
80%	74%	4%	73%	5%	82%	8%
50%	9%	-7%	6%	-5%	8%	-3%
25%	0%	-1%	2%	0%	4%	0%
10%	0%	0%	2%	0%	3%	0%
5%	0%	0%	2%	0%	2%	-1%

Metric	Option 36a(i)					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
Murrumbidgee River at Gundagai	3,439.1	0%	3,255.2	0%	2,203.4	0%
Murrumbidgee River at Wagga Wagga	3,805.9	0%	3,594.6	0%	2,393.2	0%
Murrumbidgee River at Balranald	1,194.0	0%	1,064.7	-1%	594.3	-1%
Billabong Creek at Darlot	228.0	0%	224.4	0%	133.5	0%

Table 82. Murrumbidgee Regional Water Strategy scenario results (Historical, Long-term, and Dry future) for Option 36a(ii) (200 GL)

Metric	Option 36a(ii)					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
General Security	681.1	1%	666.8	3%	405.2	4%
High Security	294.9	0%	292.0	0%	275.5	0%
Murrumbidgee Irrigation Conveyance	163.9	1%	160.9	2%	117.7	2%
Coleambally Irrigation Conveyance	103.9	0%	104.5	0%	97.1	0%
Premium High Security	18.0	-1%	17.8	0%	18.0	1%
Stock and Domestic	19.7	2%	20.2	3%	20.5	1%
Local Water Utility	10.1	0%	9.9	0%	10.5	0%
Supplementary	104.9	-10%	109.7	-9%	85.8	-9%
Lowbidgee consumptive	48.4	0%	46.0	-1%	20.6	-4%
Inter-valley transfer	106.2	1%	105.6	0%	98.3	0%
Total diversions	1,551.1	0%	1,533.4	1%	1,149.2	1%
Held environmental water	152.6	6%	160.8	3%	121.5	2%
Lowbidgee environment	69.8	0%	68.3	3%	40.6	-4%
Planned environmental water	131.0	-2%	139.5	1%	89.2	3%
Total environmental water	353.4	2%	368.6	2%	251.3	1%
General security effective allocation on 1 July	41%	2%	43%	3%	22%	1%

Metric	Option 36a(ii)					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
General security effective allocation on 30 September	62%	1%	62%	4%	30%	2%
General Security effective allocation on 30 June	81%	1%	86%	1%	45%	2%
General security allocation on 1 July	33%	2%	33%	3%	17%	1%
General security allocation 30 September	54%	1%	52%	4%	25%	2%
General Security allocation on 30 June	73%	1%	77%	2%	39%	1%
High security allocation on 1 July	93%	0%	93%	0%	87%	0%
High security allocation 30 September	96%	0%	95%	0%	92%	0%
High security allocation on 30 June	98%	0%	97%	0%	94%	0%
Coleambally Irrigation conveyance allocation on 1 July	89%	1%	88%	0%	86%	0%
Coleambally Irrigation conveyance allocation 30 September	92%	0%	91%	0%	87%	0%
Coleambally Irrigation conveyance allocation on 30 June	95%	0%	96%	1%	89%	0%
Murrumbidgee Irrigation conveyance allocation on 1 July	77%	1%	77%	2%	66%	0%
Murrumbidgee Irrigation conveyance allocation 30 September	86%	1%	85%	1%	71%	1%
Murrumbidgee Irrigation conveyance allocation on 30 June	92%	0%	93%	0%	79%	1%
Blowering Dam	271.7	-13%	146.4	-18%	25.8	-34%
Burrinjuck Dam	369.6	1%	292.1	-3%	103.3	-11%
Blowering Dam						
1831.4 GL	89%	-11%	92%	-8%	98%	-2%

Metric	Option 36a(ii)					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
1731.4 GL	86%	-14%	88%	-12%	97%	-3%
1631.4 GL (FSV)	80%	-6%	82%	-7%	95%	-2%
1531.4 GL	74%	-5%	76%	-6%	91%	-3%
50%	31%	4%	26%	2%	45%	-1%
25%	9%	2%	6%	0%	18%	-1%
10%	4%	1%	2%	0%	8%	0%
5%	2%	0%	2%	1%	5%	-1%
Burrinjuck Dam						
1700 GL	100%	0%	100%	0%	100%	0%
1026 GL (FSV)	97%	0%	97%	0%	99%	0%
80%	74%	4%	73%	5%	82%	8%
50%	9%	-7%	6%	-5%	8%	-3%
25%	0%	-1%	2%	0%	4%	0%
10%	0%	0%	2%	0%	3%	0%
5%	0%	0%	2%	0%	2%	-1%
Murrumbidgee River at Gundagai	3,442.6	0%	3,256.6	0%	2,207.1	0%
Murrumbidgee River at Wagga Wagga	3,809.4	0%	3,596.0	0%	2,396.9	0%
Murrumbidgee River at Balranald	1,192.4	0%	1,065.1	-1%	595.3	-1%
Billabong Creek at Darlot	227.6	0%	224.3	0%	133.5	0%

Option 37

Table 83 shows Option37 impacts relative to corresponding base case climate scenarios:

- Diversion impacts are similar for each of the climate scenarios.
- Environmental delivery impacts are significantly improved in all climate scenarios.
- Allocation impacts are improved for general security for each of the climate scenarios.
- Spills are reduced across all scenarios. The frequency of lower storage volumes is worsened for Blowering and improved for Burrinjuck across all scenarios which suggests a harmony issue.
- Flow impacts are similar for each of the climate scenarios.

Table 83. Murrumbidgee Regional Water Strategy scenario results (Historical, Long-term, and Dry future) for Option 37

Metric	Option 37					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
General Security	765.2	13%	735.4	14%	447.3	15%
High Security	297.8	1%	294.6	1%	277.8	1%
Murrumbidgee Irrigation Conveyance	170.5	6%	168.6	6%	125.3	9%
Coleambally Irrigation Conveyance	104.7	1%	105.4	1%	98.0	1%
Premium High Security	18.6	3%	18.6	4%	18.9	6%
Stock and Domestic	23.7	22%	23.7	20%	22.9	13%
Local Water Utility	10.1	0%	9.9	0%	10.5	0%
Supplementary	4.9	-96%	4.9	-96%	4.5	-95%
Lowbidgee consumptive	49.9	3%	48.3	3%	22.0	2%
Inter-valley transfer	105.8	0%	105.9	0%	99.1	1%
Total diversions	1,551.2	0%	1,515.3	0%	1,126.3	-1%
Held environmental water	163.8	13%	172.5	10%	127.5	8%
Lowbidgee environment	75.0	7%	72.6	9%	43.4	3%
Planned environmental water	140.8	6%	143.7	4%	95.1	9%
Total environmental water	379.6	9%	388.8	7%	266.0	7%
General security effective allocation on 1 July	53%	14%	54%	14%	26%	5%
General security effective allocation on 30 September	73%	12%	72%	14%	35%	7%
General Security effective allocation on 30 June	86%	6%	91%	6%	51%	8%
General security allocation on 1 July	46%	15%	45%	15%	20%	4%
General security allocation 30 September	66%	13%	63%	15%	29%	6%
General Security allocation on 30 June	79%	7%	82%	7%	45%	7%
High security allocation on 1 July	95%	2%	94%	1%	87%	0%
High security allocation 30 September	97%	1%	96%	1%	92%	0%
High security allocation on 30 June	98%	0%	97%	0%	95%	1%

Metric	Option 37					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
Coleambally Irrigation conveyance allocation on 1 July	91%	3%	90%	2%	87%	1%
Coleambally Irrigation conveyance allocation 30 September	94%	2%	93%	2%	88%	1%
Coleambally Irrigation conveyance allocation on 30 June	96%	1%	97%	2%	90%	1%
Murrumbidgee Irrigation conveyance allocation on 1 July	82%	6%	81%	6%	68%	2%
Murrumbidgee Irrigation conveyance allocation 30 September	89%	4%	88%	4%	73%	3%
Murrumbidgee Irrigation conveyance allocation on 30 June	94%	2%	95%	2%	81%	3%
Blowering Dam	301.6	-4%	177.1	-1%	26.3	-33%
Burrinjuck Dam	293.7	-20%	228.0	-24%	68.4	-41%
Blowering Dam						
1831.4 GL	100%	0%	100%	0%	100%	0%
1731.4 GL	100%	0%	100%	0%	100%	0%
1631.4 GL (FSV)	86%	0%	90%	1%	98%	1%
1531.4 GL	80%	1%	84%	2%	97%	3%
50%	44%	17%	43%	19%	72%	26%
25%	19%	12%	19%	13%	40%	21%
10%	9%	6%	7%	5%	20%	12%
5%	5%	3%	5%	4%	13%	7%
Burrinjuck Dam						
1700 GL	97%	-3%	98%	-2%	99%	-1%
1026 GL (FSV)	28%	-69%	16%	-81%	27%	-72%
80%	9%	-61%	5%	-63%	14%	-60%
50%	0%	-16%	2%	-9%	6%	-5%
25%	0%	-1%	2%	0%	4%	0%
10%	0%	0%	2%	0%	3%	0%
5%	0%	0%	2%	0%	3%	0%
Murrumbidgee River at Gundagai	3,427.9	0%	3,246.7	0%	2,194.3	0%

Metric	Option 37					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
Murrumbidgee River at Wagga Wagga	3,794.7	0%	3,586.1	0%	2,384.1	0%
Murrumbidgee River at Balranald	1,189.7	0%	1,068.0	0%	602.5	0%
Billabong Creek at Darlot	226.9	0%	224.9	0%	134.5	1%

Option 38

Table 84 shows Option 38 impacts relative to corresponding base case climate scenarios:

- Diversion impacts are similar for each of the climate scenarios.
- Environmental delivery impacts are slightly improved in all climate scenarios.
- Allocation impacts are improved for general security for each of the climate scenarios.
- Spills are increased across all climate scenarios. The frequency of lower storage volumes is improved across all scenarios.
- Flows are reduced at Balranald for each of the climate scenarios.

Table 84. Murrumbidgee Regional Water Strategy scenario results (Historical, Long-term, and Dry future) for Option 38

Metric	Option 38					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
General Security	710.1	5%	692.4	7%	425.7	10%
High Security	295.6	1%	292.5	0%	277.5	1%
Murrumbidgee Irrigation Conveyance	168.3	4%	166.3	5%	124.9	9%
Coleambally Irrigation Conveyance	104.1	0%	104.8	1%	97.2	0%
Premium High Security	18.7	3%	18.8	6%	19.3	8%
Stock and Domestic	22.3	15%	22.5	14%	21.7	7%
Local Water Utility	10.1	0%	9.9	0%	10.5	0%
Supplementary	67.1	-42%	66.8	-45%	56.1	-41%
Lowbidgee consumptive	50.4	4%	49.2	5%	22.9	7%
Inter-valley transfer	104.3	-1%	105.3	0%	98.3	0%
Total diversions	1,551.0	0%	1,528.5	0%	1,154.1	1%
Held environmental water	148.3	3%	158.2	1%	119.1	0%
Lowbidgee environment	74.2	6%	72.5	9%	46.0	9%

Metric	Option 38					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
Planned environmental water	135.4	1%	140.6	2%	90.5	4%
Total environmental water	357.9	3%	371.3	3%	255.6	3%
General security effective allocation on 1 July	42%	3%	43%	3%	23%	2%
General security effective allocation on 30 September	63%	2%	61%	3%	31%	3%
General Security effective allocation on 30 June	83%	3%	89%	4%	48%	5%
General security allocation on 1 July	34%	3%	33%	3%	17%	1%
General security allocation 30 September	55%	2%	52%	4%	25%	2%
General Security allocation on 30 June	75%	3%	79%	4%	42%	4%
High security allocation on 1 July	94%	1%	94%	1%	88%	1%
High security allocation 30 September	96%	0%	95%	0%	92%	0%
High security allocation on 30 June	98%	0%	97%	0%	94%	0%
Coleambally Irrigation conveyance allocation on 1 July	88%	0%	88%	0%	86%	0%
Coleambally Irrigation conveyance allocation 30 September	92%	0%	91%	0%	87%	0%
Coleambally Irrigation conveyance allocation on 30 June	96%	1%	96%	1%	90%	1%
Murrumbidgee Irrigation conveyance allocation on 1 July	78%	2%	77%	2%	66%	0%
Murrumbidgee Irrigation conveyance allocation 30 September	86%	1%	85%	1%	71%	1%
Murrumbidgee Irrigation conveyance allocation on 30 June	93%	1%	94%	1%	80%	2%

Metric	Option 38					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
Blowering Dam	328.4	5%	201.1	13%	45.9	17%
Burrinjuck Dam	385.4	5%	314.7	5%	118.6	2%
Blowering Dam						
1831.4 GL	100%	0%	100%	0%	100%	0%
1731.4 GL	100%	0%	100%	0%	100%	0%
1631.4 GL (FSV)	85%	-1%	88%	-1%	96%	-1%
1531.4 GL	79%	0%	80%	-2%	93%	-1%
50%	26%	-1%	22%	-2%	43%	-3%
25%	6%	-1%	5%	-1%	17%	-2%
10%	2%	-1%	2%	0%	8%	0%
5%	1%	-1%	1%	0%	5%	-1%
Burrinjuck Dam						
1700 GL	100%	0%	100%	0%	100%	0%
1026 GL (FSV)	96%	-1%	97%	0%	99%	0%
80%	68%	-2%	64%	-4%	71%	-3%
50%	9%	-7%	6%	-5%	8%	-3%
25%	0%	-1%	2%	0%	4%	0%
10%	0%	0%	2%	0%	3%	0%
5%	0%	0%	2%	0%	2%	-1%
Murrumbidgee River at Gundagai	3,431.0	0%	3,254.6	0%	2,202.4	0%
Murrumbidgee River at Wagga Wagga	3,797.8	0%	3,593.9	0%	2,392.3	0%
Murrumbidgee River at Balranald	1,177.8	-1%	1,050.2	-2%	585.2	-3%
Billabong Creek at Darlot	230.4	1%	227.7	1%	135.9	2%

Option 39

Table 85 shows Option 39 impacts relative to corresponding base case climate scenarios:

- Diversion impacts are similar for each of the climate scenarios.
- Environmental delivery impacts are similar for each of the climate scenarios.
- Allocation impacts are similar for each of the climate scenarios.
- Storage spill and behaviour are similar for each of the climate scenarios.
- Flows are reduced at Balranald and increased at Darlot for each of the climate scenarios.

Table 85. Murrumbidgee Regional Water Strategy scenario results (Historical, Long-term, and Dry future) for Option 39

Metric	Option 39					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
General Security	680.9	1%	656.5	1%	394.3	1%
High Security	294.7	0%	291.6	0%	275.0	0%
Murrumbidgee Irrigation Conveyance	162.8	1%	159.8	1%	116.4	1%
Coleambally Irrigation Conveyance	103.9	0%	104.4	0%	97.0	0%
Premium High Security	18.0	-1%	17.8	0%	18.0	1%
Stock and Domestic	19.6	1%	20.0	2%	20.3	0%
Local Water Utility	10.1	0%	9.9	0%	10.5	0%
Supplementary	107.6	-7%	111.6	-8%	87.7	-7%
Lowbidgee consumptive	49.0	1%	47.0	1%	21.6	0%
Inter-valley transfer	105.8	0%	105.4	0%	97.9	0%
Total diversions	1,552.4	0%	1,524.0	0%	1,138.7	0%
Held environmental water	142.4	-2%	156.4	0%	118.0	-1%
Lowbidgee environment	73.2	5%	67.2	1%	42.2	0%
Planned environmental water	131.9	-1%	138.7	0%	87.4	1%
Total environmental water	347.5	0%	362.3	0%	247.6	0%
General security effective allocation on 1 July	40%	1%	41%	1%	21%	0%
General security effective allocation on 30 September	61%	0%	59%	1%	29%	1%
General Security effective allocation on 30 June	81%	1%	86%	1%	44%	1%
General security allocation on 1 July	32%	1%	31%	1%	16%	0%
General security allocation 30 September	53%	0%	49%	1%	23%	0%

Metric	Option 39					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
General Security allocation on 30 June	73%	1%	76%	1%	38%	0%
High security allocation on 1 July	93%	0%	93%	0%	87%	0%
High security allocation 30 September	96%	0%	95%	0%	92%	0%
High security allocation on 30 June	98%	0%	97%	0%	94%	0%
Coleambally Irrigation conveyance allocation on 1 July	88%	0%	88%	0%	86%	0%
Coleambally Irrigation conveyance allocation 30 September	92%	0%	91%	0%	87%	0%
Coleambally Irrigation conveyance allocation on 30 June	95%	0%	96%	1%	89%	0%
Murrumbidgee Irrigation conveyance allocation on 1 July	76%	0%	75%	0%	66%	0%
Murrumbidgee Irrigation conveyance allocation 30 September	85%	0%	84%	0%	71%	1%
Murrumbidgee Irrigation conveyance allocation on 30 June	92%	0%	93%	0%	78%	0%
Blowering Dam	317.7	1%	180.9	1%	40.1	2%
Burrinjuck Dam	368.6	1%	302.1	1%	116.3	0%
Blowering Dam						
1831.4 GL	100%	0%	100%	0%	100%	0%
1731.4 GL	100%	0%	100%	0%	100%	0%
1631.4 GL (FSV)	85%	-1%	89%	0%	97%	0%
1531.4 GL	79%	0%	82%	0%	94%	0%
50%	28%	1%	24%	0%	45%	-1%
25%	7%	0%	5%	-1%	18%	-1%
10%	3%	0%	2%	0%	8%	0%
5%	2%	0%	1%	0%	5%	-1%
Burrinjuck Dam						
1700 GL	100%	0%	100%	0%	100%	0%

Metric	Option 39					
Water diversions (GL/y)	Historical	Change (%)	Long-term	Change (%)	Dry Future	Change(%)
1026 GL (FSV)	97%	0%	97%	0%	99%	0%
80%	70%	0%	67%	-1%	73%	-1%
50%	14%	-2%	10%	-1%	11%	0%
25%	0%	-1%	2%	0%	4%	0%
10%	0%	0%	2%	0%	3%	0%
5%	0%	0%	2%	0%	2%	-1%
Murrumbidgee River at Gundagai	3,432.5	0%	3,255.3	0%	2,203.3	0%
Murrumbidgee River at Wagga Wagga	3,799.3	0%	3,594.7	0%	2,393.2	0%
Murrumbidgee River at Balranald	1,174.3	-1%	1,060.0	-1%	591.0	-2%
Billabong Creek at Darlot	231.0	2%	229.1	2%	136.6	2%

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Attachment 1 Model versions

The models are uploaded to Confluence at https://nswwmmi.atlassian.net/wiki/spaces/SCSRWS/pages/2588180481/Model+Index+Page+RWS+Southern+System+modelling

Instructions for running models and locating results are at:

https://nswwmmi.atlassian.net/wiki/spaces/SCSRWS/pages/2882732069/Murrumbidgee+Options+Summary

Option	Source Project File	Input Set
Baseline	murrumbidgee-rev113-v19_ins.rsproj	Baseline. Instrumental
Option13(i) (10%)	murrumbidgee-rev113-v19_ins.rsproj	Option13.GSHS_10.Instrumental
Option13(ii) (20%)	murrumbidgee-rev113-v19_ins.rsproj	Option13.GSHS_50.Instrumental
Option33a	murrumbidgee-113-ins_option33a_factored 0.90_supp_v1.2b.rsproj	Option33a.90perc_Supp.Instrumental
Option33b	murrumbidgee-113-ins_options_GP_23_1_23_O37_O33b_v0.8a_for_O33b_0.73_Supp.rsproj	Option33b.0_73_Sup.Instrumental
Option33c	murrumbidgee-113-ins_options_O37_O33c_087_prop_GS_08_Harmony_Tmt_order_LB_RAS5.rsproj	Option33c.0_Supp_087_GS.Instrumental
Option35	murrumbidgee-rev113-v19_ins.rsproj	Option35.Instrumental
Option36(i) (100GL)	murrumbidgee-rev113-v19_ins.rsproj	Option36.ReduceOffCap.Instrumental
Option36(ii) (200GL)	murrumbidgee-rev113-v19_ins_200gl.rsproj	Option36.ReduceOffCap.Instrumental
Option36a(i) (100GL)	murrumbidgee-rev113-v19_ins.rsproj	Option36a.ReduceOffCap.Instrumental
Option36a(ii) (200GL)	murrumbidgee-rev113-v19_ins_200gl.rsproj	Option36a.ReduceOffCap.Instrumental
Option37	murrumbidgee-rev113-v19_ins_op37_revised.rsproj	Option37.04Supp.Instrumental
Option38_Bundidgery	murrumbidgee-rev113-v15a_ins_O38_Bundidgery_v4.3_0.62_Supp2.rsproj	Option38_Bundidgery.0_38_Supp_reduction.Instrumental
Option_39_Tombullen	murrumbidgee-rev113-v15a_ins_O39_Tombullen_a2.rsproj	Option_39_Tombullen.090_Supp.Instrumental