Department of Climate Change, Energy, the Environment and Water

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Economic base case assessment for the NSW Murray and Murrumbidgee regions

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

This report details the economic base case used for the hydrologic and economic modelling undertaken to support the assessment of the long list of options for the draft NSW Murray and Murrumbidgee regional water strategies.

This economic base case analysis has been undertaken at a strategic, regional level rather than at the level of detail required for a business case. However, it is the first step in strategically analysing alternate options being considered for the NSW Murray and Murrumbidgee regions. The analysis still needs to be robust and sufficiently specific to compare the merits of different options. The approach outlined in this document aims to strike the right balance between a high level, strategic assessment and region-specific information. It aims to determine an economic base case that represents robust estimates of future surface water availability and the economic value of that availability.

The first step in any economic analysis is to understand what the future could look like and the potential consequences of doing nothing. This is known as the 'base case'. The economic base case used for the regional water strategies represents what the future could look like for towns and water-based industries if nothing is done to address issues related to the supply, demand or allocation of water over the next four decades.

For the purposes of the regional water strategies, three plausible futures have been examined. All of these futures are referred to as part of the base case. Portfolios of options considered in the NSW Murray and Murrumbidgee regional water strategies that can be hydrologically modelled will be assessed against these three plausible futures:

1. historical climate — this scenario assumes that future climate will be similar to the climate data that has been recorded over the last 130 years.
2. long-term historical climate — this scenario assumes our future climate will be similar to what the science indicates our long-term paleoclimate was like and is based on a 10,000-year stochastic (long-term historical) dataset.
3. dry future climate — this scenario assumes a dry, worst-case climate change in the future. It is based on the 10,000-year stochastic dataset of the long-term historical climate scenario, adjusted for NARCliM 1.0[1] climate change projections.

[1] NARCliM (NSW and ACT Regional Climate Modelling) is a partnership between the NSW, ACT and South Australan governments and the Climate Change Research Centre at the University of NSW. NARCliM produces robust regional climate projections that can be used to plan for the range of likely climate futures. Further information about NARCliM modelling can be found at: climatechange.environment.nsw.gov.au/Climate-projections-for-NSW/About-NARCliM.

In the past, water infrastructure and policy changes in the region have only been assessed against historical data (records of rainfall, temperature and other climate conditions going back to the 1890s). However, the long-term historical and dry future climate scenarios give a much better understanding of the water risks that could be faced by the region.

The economic base case presented in this report assumes existing infrastructure and policy settings but includes median population growth projections for the region from the NSW Government's Common Planning Assumptions.[2]

To understand the economic consequences for the NSW Murray and the Murrumbidgee regions of 'doing nothing', we have modelled the three most relevant surface water user groups, that take surface water from the two regulated river systems of these region:

- town water supply (as water shortfall)
  - NSW Murray region: Albury, Berrigan Shire, Corowa, Deniliquin, Euston, Murray River Council, and Wentworth.
  - Murrumbidgee region: Balranald, Gundagai, Hay, Jerilderie, Jugiong, Morundah to Coonong, and Tumut.
- annual crop producers (as water supplied) — assumed to be cotton for both regions
- permanent crop producers (as water supplied and as shortfalls) — assumed to be almonds for both regions.

It should be noted that the modelling initially incorporated mining activity as well as stock and domestic activities and the regional water function estimated an economic cost associated with shortfalls in supply for both. However, deficiencies in both the hydrologic modelling of shortfalls and economic estimates as to the value of water for mining activities and the implications of shortfalls for stock and domestic has led to it not being incorporated in the options assessment process. The reason being is that it is difficult to estimate the value of water shortfalls for mining activity in that it is dependent on two factors that would vary for each mine:

- the value of water in the production process for the mine, which depends on the technology used in mining, and
- the options to replace shortfalls in surface water.

In addition, stock and domestic use of water is not adequately reflected in the hydrologic modelling. While surface water shortfalls for mining and stock and domestic activity were modelled, the results

[2] NSW Department of Climate Change, Energy, the Environment and Water, Common Planning Assumptions, 2022, available from pp.planningportal.nsw.gov.au/populations

were not realistic and not sufficiently robust to use in evaluating the regional water strategy options.

The first step in developing the economic base case is to understand how water availability changes from that currently experienced for these water users under the future scenarios, and this is done through quantitative hydrologic modelling. The modelling results show that towns and agricultural producers in the NSW Murray and the Murrumbidgee are, on average, likely to access water less often (or have reduced water supply reliability) under the dry future climate scenario. A summary of the average amount of water available for each aggregated water user group under the three plausible futures is shown in Table A1 and Table A2.

Table A1. Average yearly water taken by different water user groups, NSW Murray region

Water users	**Long-term historical climate scenario**	**Dry future climate scenario**	**Difference between both climate scenarios**
Town water supply (shortfall, ML/year)	5759.0	7178.8	1419.8
Annual crops (supplied, GL/year)	1542.8	1001.8	-541.0
Permanent crops (supplied, GL/year)	209.2	181.3	-27.9

Table A2. Average yearly water provided to different water user groups, Murrumbidgee region

Water users	Long-term historical climate scenario	Dry future climate scenario	Difference between both climate scenarios
Town water supply (shortfall, ML/year)	0.3	10.3	10.0
Annual crops (supplied, GL/year)	774.9	501.7	-273.3
Permanent crops (supplied, GL/year)	327.9	303.1	-24.8

The second step in developing the economic base case is to undertake an economic analysis to understand how this change in water availability translates into dollar values and impacts on the economy. Economic analysis was undertaken in accordance with the framework set out in *Regional Water Value Function.*[3] The evaluation period for each analysis was 40 years with a discount rate of 5%. Economic valuations per megalitre of water for each water user group were:

- towns water supply — escalating cost is dependent on the size of the town and the length of the shortfall as this value is applied to the volume of water not supplied — that is, the shortfall
- annual crop producers (assumed to be the highest value crop — cotton as detailed in the Regional Water Value Function report) — $225/ML in both regions
- permanent crop producers (assumed to be almonds) — $1,100/ML in NSW Murray and $1,000 /ML in Murrumbidgee; $1,300/ML in shortfall for both regions.

As shown in Table B1 and Table B2, the economic impacts, on average, are higher under the dry future climate scenario than under the long-term historical scenario, reflecting the lower availability of water between the two estimates in both regions.

Table B1. Average total (over 40 years) economic outcomes per water user group, NSW Murray region

Water users	Long-term historical climate scenario ($m)	Dry future climate scenario ($m)	Difference between both climate scenarios ($m)
Town water supply (impact of shortfalls) ($m)	-887.5	-1136.4	-248.9
Annual crops ($m)	7013.1	4626.2	-2386.9
Permanent crops ($m)	4661.9	3958.6	-703.3

[3] Marsden Jacobs Associates. 2020. *Regional Water Value Function.*

Table B2. Average total (over 40 years) economic outcomes per water user group, Murrumbidgee region

Water users	Long-term historical climate scenario ($m)	Dry future climate scenario ($m)	Difference between both climate scenarios ($m)
Town water supply (cost to) ($m)	0.0	-0.3	-0.3
Annual crops ($m)	3538.4	2369.3	-1169.1
Permanent crops ($m)	6992.6	6421.9	-570.7

In the NSW Murray region, town water users are predicted to experience decreases in economic outcomes (increases in the economic costs of maintaining water supplies) under the long-term historical and the dry future climate scenarios. Whereas this increased cost is minimal for the Murrumbidgee region, shortfalls are negligible under both scenarios. Agricultural producers in both regions would also experience reduced economic outcomes under the dry future climate scenario compared to the long-term historical scenario, reflecting a reduction in agricultural production due to decreased water supply. Annual crop producers would be worse off due to the less secure nature of the water allocation required to grow these crops, with flow-on economic impacts for regional economies.

Introduction

Context

This report details the Economic Base Case used for the hydrologic and economic modelling undertaken to support the assessment of the long list options presented in the Draft Regional Water Strategy NSW Murray: Long list of options, April 2022[4] and Draft Regional Water Strategy Murrumbidgee: Long list of options, April 2022[5].

This report has been prepared to document the process used and support decision-making for the draft NSW Murray and Murrumbidgee Regional Water Strategies about options that may impact the supply, demand or allocation of water and that can be represented adequately within catchment-level hydrologic modelling. A range of other options in the regional water strategies do not impact on the supply, demand or allocation of water in the region. A separate assessment process has been undertaken for those options and detailed in the Options Assessment Process report. However, the information documented in this report may also support analysis of those other options.

The economic base case has been prepared in accordance with the requirements outlined in:

- NSW Treasury, NSW Government Business Case Guidelines[6]
- NSW Treasury, NSW Guide to Cost–Benefit Analysis.[7]

The economic base case and why it is important

The economic base case represents what the future could look like for towns and water-based industries if nothing over the next four decades to address the issues related to supply, demand and allocation of water. The economic base case is generated by combining the value different extractive water users place on water against the water availability forecasts for the region. It assumes current infrastructure and water policy settings but includes changes to population

[4] More information about the Draft Regional Water Strategy NSW Murray: Long list of options, April 2022 at https://www.dpie.nsw.gov.au/water/our-work/plans-and-strategies/regional-water-strategies/public-exhibition/murray/murray-regional-water-strategy

[5] More information about the Draft Regional Water Strategy Murrumbidgee: Long list of options, April 2022 at https://www.dpie.nsw.gov.au/water/our-work/plans-and-strategies/regional-water-strategies/public-exhibition/murrumbidgee/murrumbidgee-regional-water-strategy

[6] NSW Treasury. 2023. *TPG23-08: NSW Government Policy and Guidelines: Submission of Business Cases.*

[7] NSW Treasury. 2023. *TPG23-08 NSW Government Guide to Cost-Benefit Analysis*

projections. The water demands of users are generally set as fixed, with some exceptions where population growth in towns is projected. This approach allows all potential options to be compared consistently and any benefits, costs or other effects from an individual option to be assessed against their impact to the economic base case. The economic base case will be used as the central scenario in the cost–benefit analysis for the hydrologic modelling of portfolios of solutions developed for the regional water strategies.

The Regional Water Value function

The Regional Water Value function[8] places a value on the amount of water forecast to be available. The forecasts are developed through hydrologic modelling. These estimated values:

- focus on key water user groups — not every water user in a region is analysed because the hydrologic modelling only captures changes in water availability for key water users in each region
- reflect how users make decisions and how they use water in practice — this water user behaviour has been studied and included in the NSW Department of Climate Change, Energy, the Environment and Water 's water models.

The values produced in the Regional Water Value function are for key water users. In the NSW Murray and Murrumbidgee regions, these users are:

- town water supply
- annual crop producers — assumed to be cotton (as per the methodology outlined in the Regional Water Value Function report, which uses a profitable crop to assess options)
- permanent crop producers — assumed to be almonds.

The Regional Water Value function values reflect how water is used in practice by the key water user groups. For example, irrigators of annual crops scale their operations each year depending on water availability, whereas irrigators of permanent crops change their operations following a sustained change in high reliability of water. As a result, producers with permanent plantings are more vulnerable in periods of supply shortfalls. This reflects how the economic value of water adjusts as forecast availability changes.

Deficiencies in both the hydrologic modelling of shortfalls and economic estimates as to the value of water for mining activity has led to it not being incorporated in the options assessment process.

The reason being is that it is difficult to estimate the value of water shortfalls for mining activity in that it is dependent on two factors that would vary for each mine:

[8] Marsden Jacob Associates. 2020. *Regional Water Value Function*

- the value of water in the production process for the mine, which depends on the technology used in mining, and
- the options to replace shortfalls in surface water.

In addition, stock and domestic use of water is not adequately reflected in the hydrologic modelling. While surface water shortfalls for mining and stock and domestic activity were modelled, the results were not realistic and not sufficiently robust to use in evaluating the regional water strategy options.

Using climate change modelling to create expectations of the amount of future water available

The NSW Government has invested in new climate datasets and improved hydrologic modelling that provide a more sophisticated understanding of historic climate variability, as well as likely future climate risks. The regional water strategies' reliability assessments for towns and communities in the region are based on this new climate data, scaled down to the regional level and used in the modelling of surface water. This data and modelling include consideration of long-term historic paleoclimate data, where available, and climate change impacts to develop scenarios of plausible extreme climate events.

Using the IQQM and SOURCE streamflow modelling platform, the rainfall runoff — recorded at gauging stations across the catchment — is calibrated with historical streamflow data. The calibrated hydrologic model is then used to generate two series of streamflow sequences: one incorporating historic paleoclimate data (long-term historical scenario) and the other adding climate change scenario (dry future climate scenario) impacts.

These two scenarios are used to create expectations about the amount of water available in the future. The hydrologic modelling creates 1,000 replicates of 40-year duration daily climate inputs — sampled with a moving window of 10 years from the 10,000-year historic estimates — to create a broad range of feasible possibilities for the next four decades.[9]

[9] See NSW Department of Climate Change, Energy, the Environment and Water. 2020. *New climate analysis informs NSW's regional water strategies*, available at: industry.nsw.gov.au/__data/assets/pdf_file/0018/321093/nsw-climate-model-report.pdf

Translating hydrologic modelling to user group outcomes

The hydrologic modelling estimates town surface water availability over the next 40 years. Town water availability was estimated by the duration/depth of shortfalls in surface water entitlement availability.

Water availability for high-security water entitlements was calculated with restriction curves, similar to town and community water supply, to infer shortfalls in water supplied to those licences. This provides the data for the economic analysis.

Water availability for general security entitlements is estimated according to the amount of water that is supplied to users based on the level of modelled water availability in the region. It is assumed that general security entitlement holders decide on an annual basis how they will use the water and what crops they will grow.[10]

For the purposes of the regional water strategies (which involve broad, region-wide and strategic studies), the economic base case only captures the main water uses of a region, it does not capture every user. It also does not include quantitative analysis of groundwater. Rather, it provides an indication of surface water risks. Future business cases and detailed studies, associated with regional water strategy actions may need to conduct further analyses if groundwater or other alternative water sources are to be associated with any such proposals. However, the economic base case represents a robust estimate of future surface water availability and the economic value of that availability.

[10] Marsden Jacob Associates. 2020. *Regional Water Value Function*

NSW Murray and Murrumbidgee regions — key details

The NSW Murray and Murrumbidgee regions

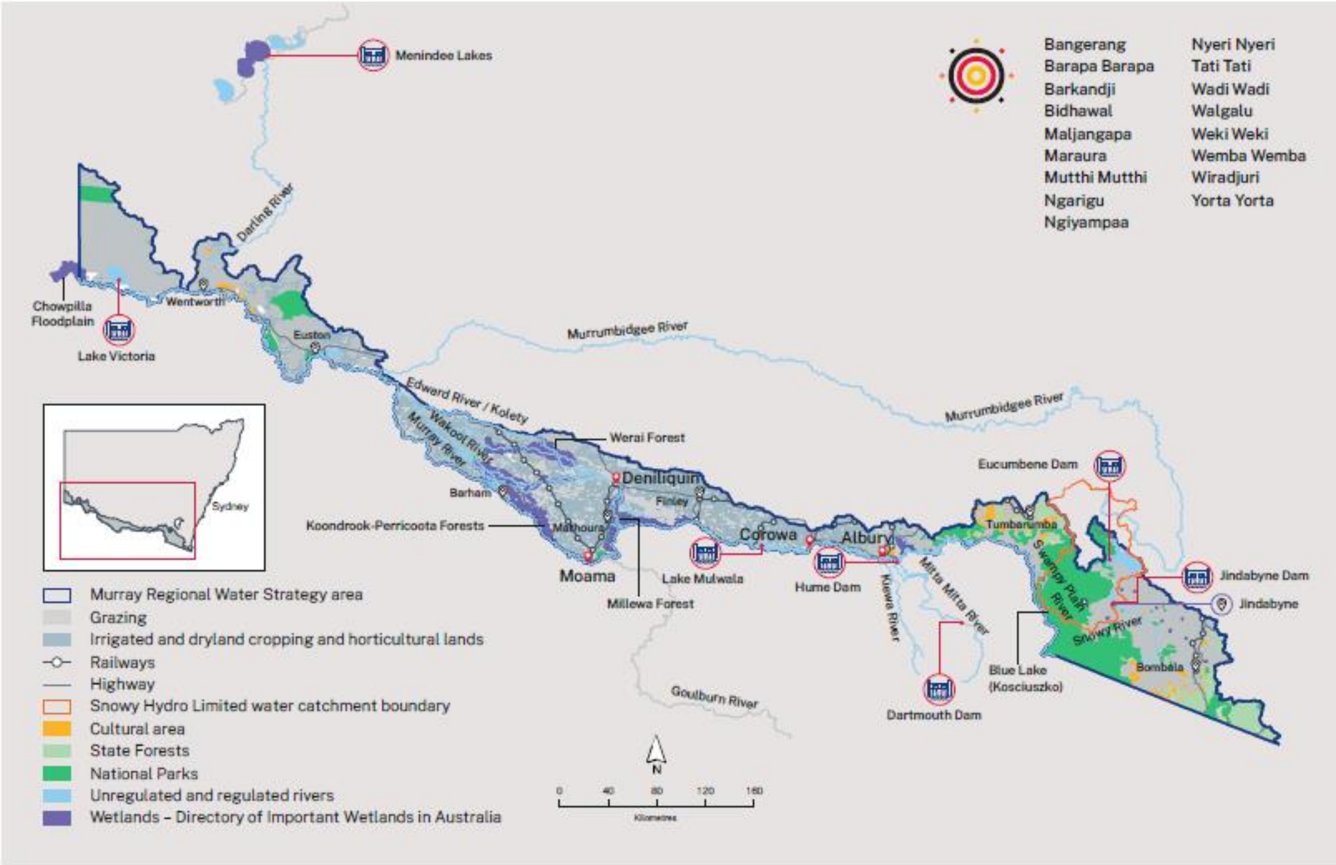
NSW Murray region

The NSW Murray Regional Water Strategy region (Figure 1) lies in southern NSW and includes varying natural landscapes that change from mountainous terrain in the east to flat alluvial plains in the west. The region is home to many thriving regional centres and communities, productive agricultural industries and nationally important wetlands, including 2 that are Ramsar listed.

The region is located within the traditional lands of the Bangerang, Barapa Barapa, Barkandji, Bidhawal, Maljangapa, Maraura, Mutthi Mutthi, Ngarigu, Ngiyampaa, Nyeri Nyeri, Tati Tati, Wadi Wadi, Walgaulu, Wemba Wemba, Weki Weki, Wiradjuri and Yorta Yorta Nations. These Nations have been caretakers of the NSW Murray region for over 60,000 years.

The NSW Murray region is part of the broader southern connected Basin, linked hydrologically and through water management arrangements to the Darling and Murrumbidgee rivers and, by extension, to Victoria, Queensland and South Australia. The region also receives inflows from the Snowy Scheme under the rules of the Snowy Water Licence.

Figure 1. Map of the NSW Murray region



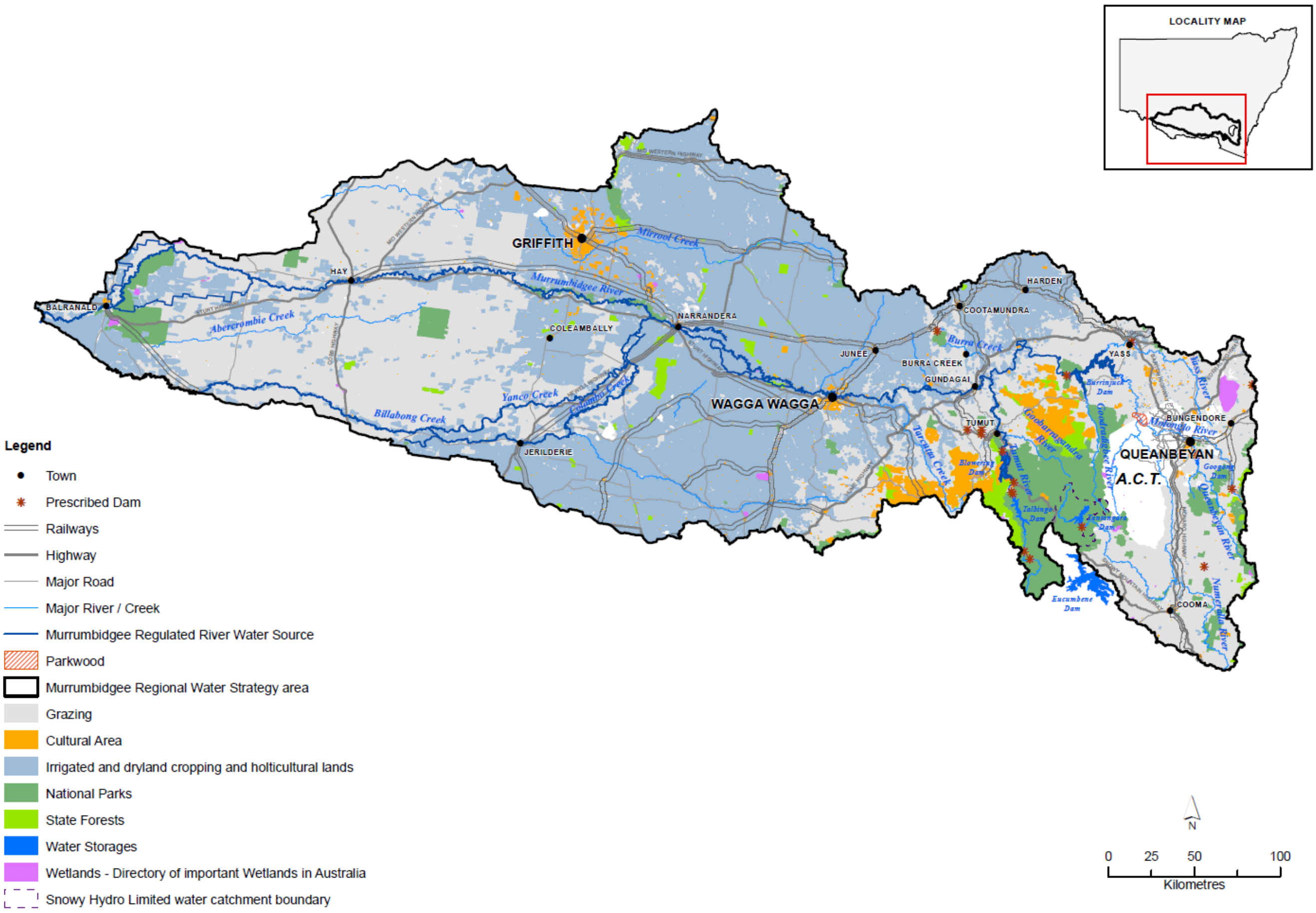
The Murrumbidgee region

The Murrumbidgee Regional Water Strategy region (Figure 2) lies towards the geographic bottom of NSW and has the third longest river in Australia. It includes stunning natural landscapes that change from alpine terrain in the east to riverine plains in the west. The region is home to many thriving regional centres and communities, productive agricultural land, hydroelectricity, and nationally important wetlands such as Fivebough and Tuckerbil wetlands.

The region is located within the traditional lands of the Nari Nari, Ngambri, Ngarigu, Ngunnawal/Ngunawal, Nyeri Nyeri, Mutthi Mutthi, Wadi Wadi, Wemba Wemba, Wiradjuri, Wolgalu and Yita Yita Nations. These Nations have been caretakers of the Murrumbidgee for over 60,000 years.

The Murrumbidgee region is part of the broader 'southern connected Basin', linked hydrologically and through water management arrangements to the Murray River and, by extension, to Victoria and South Australia. The region also receives inflows from the Snowy Scheme in accordance with the Snowy Water Licence.

Figure 2. Map of the Murrumbidgee region



Extractive users of water

The hydrologic outcomes and subsequent economic impacts have been considered in the context of the region's major extractive user groups. The key water user groups considered in this economic assessment are:

- town water supplies
- agricultural users
    - annual crop producers
    - permanent crop producers

In each base case scenario, the economic benefit or cost of water supplied or not supplied has been quantified in $/ML for each user.[11]

[11] Detailed information on the development of the value of water for different extractive users can be found in *Regional Water Value Functions* (Marsden Jacob Associates, 2020).

Town and community water supplies

The economic base case for towns and communities was developed for the following communities:

- NSW Murray Region: Albury, Berrigan Shire, Corowa, Deniliquin, Euston, Murray River Council, and Wentworth
- Murrumbidgee Region: Balranald, Gundagai, Hay, Jerilderie, Jugiong, Morundah to Coonong, and Tumut.

The economic base case assigns different values for the costs of replacing surface water for towns and communities when surface water supply shortfalls are modelled. The cost of a shortfall is dependent on the size of the town or community and the length/depth of shortfall being experienced. For example, for small towns it is assumed that local water utilities can manage brief periods of shortfalls through water carting. The management response to longer shortfall periods is assumed to require a more permanent, costlier solution. For larger towns, carting may not be a feasible option under any circumstances. Details of towns considered within this document and their associated shortfall costs are shown in Table 1.

Table 1. Economic cost ($ per ML) of town water supply shortages in the NSW Murray and Murrumbidgee regions

NSW Murray Region

Time in water shortage	Albury	Berrigan Shire	Corowa	Deniliquin	Euston	Murray River Council	Wentworth
Population*	52,603	4,499	10,420	7,862	839	6,558	4,673
System type	Regulated	Regulated	Regulated	Regulated	Regulated	Regulated	Regulated
0– 6 months (restrictions)	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500
6–12 months (restrictions)	$3,500	$3,500	$3,500	$3,500	$3,500	$3,500	$3,500
Greater than 12 months	$16,000*	$16,000*	$16,000*	$16,000*	$16,000**	$16,000*	$16,000*
Continued shortages (greater than 24 months)	$16,000*	$16,000*	$16,000*	$16,000*	$10,000 (water carting)	$16,000*	$16,000*

* Alternative water source. * *Alternative water supply.

Murrumbidgee region

Time in water shortage	Balranald	Gundagai	Hay	Jerilderie	Jugiong	Morundah To Coonong	Tumut
Population*	1,158	2,229	2,298	3,895	17,558	12,594	6,086
System type	Regulated	Regulated	Regulated	Regulated	Regulated	Regulated	Regulated
0– 6 months (restrictions)	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500
6–12 months (restrictions)	$3,500	$3,500	$3,500	$3,500	$3,500	$3,500	$3,500
Greater than 12 months	$16,000*	$16,000*	$16,000*	$16,000**	$16,000**	$16,000*	$16,000*
Continued shortages (greater than 24 months)	$16,000*	$16,000*	$16,000*	$10,000 (water carting)	$10,000 (water carting)	$16,000*	$16,000*

* Alternative water source. * *Alternative water supply.

Population projections are based on the medium growth projections included in the NSW Government's Common Planning Assumptions.

Water supply is either based on LGA drought response plans or assumed to be restricted (shortfall created against unrestricted supply) within the regulated system when the level of water in key storages falls below certain storage levels. These assumptions are based on how the dams have been operated in previous droughts, with restrictions imposed on different users. Where there are no past precedents,[12] professional assessments were about the storage levels that would trigger restrictions and thus result in shortfalls.

[12] For instance, at extremely low levels of storage that have not occurred in the historic record, but that do occur in either the long-term historical or dry future climate scenarios

Agricultural, stock and domestic users

The economic benefit of water for agriculture varies depending on the crop. The marginal economic benefit per megalitre of water supplied for an annual crop will not change with a shortfall in supply, as the area cropped is adjusted to match the amount of water available. For permanent crops, a shortfall in supply will increase the marginal economic benefit per megalitre of water, which recognises the replacement cost of establishing the crop. Table 2 highlights the majority of the agricultural crops grown in the NSW Murray and Murrumbidgee regions, water licences and the economic value of water (for permanent crops, values during shortfall are represented in parentheses).

Table 2. NSW Murray and Murrumbidgee agricultural water supply economic benefit[13]

Region	Crop	Cropping	Water licence	Marginal economic benefit (of water) ($/ML)
NSW Murray	Cotton	Annual	• General security • Supplementary • Rainfall run off	225
	Rice	Annual		175
	Potatoes	Annual		150
	Wheat	Annual		150
	Oats	Annual		150
	Barley	Annual		150
	Lucerne (Hay)	Annual		150
	Almonds	Permanent	• High security	1100 (1,300)
	Olives	Permanent		1,000 (2,600)
	Viticulture	Permanent		475 (825)
	Nectarines/Peaches	Permanent		450 (2,100)
	Oranges	Permanent		450 (2,100)
Murrumbidgee	Cotton	Annual	• General security • Supplementary • Rainfall run off	225
	Rice	Annual		175
	Potatoes	Annual		150
	Wheat	Annual		150
	Oats	Annual		150

[13] These were derived from the *Regional Water Value Functions* (MJA, 2020).

Region	Crop	Cropping	Water licence	Marginal economic benefit (of water) ($/ML)
	Barley	Annual		150
	Lucerne (Hay)	Annual		150
	Almonds	Permanent	• High security	1,000 (1,300)
	Olives	Permanent		975 (2,500)
	Viticulture	Permanent		500 (850)
	Nectarines/Peaches	Permanent		450 (2,100)
	Oranges	Permanent		450 (2,100)

The highest economic values for annual and permanent crops in the NSW Murray and Murrumbidgee region are:

- NSW Murray region: cotton (annual); almond (permanent)
- Murrumbidgee region: cotton (annual); almond (permanent).

Both crops have sensitivities associated with their producer surplus, estimated at the long-run profitability derived from a megalitre of water, as detailed in the *Regional Water Value Function* report.[14] Annual crops grown in both regions include cotton, rice, potatoes, wheat, oats, barley, and lucerne (hay) with a producer surplus ranging from $150/ML to $225/ML. However, cotton was deemed as the dominate crop in the region and was used as the basis of the calculations in the economic base case. Permanent crops in both regions include almonds, olives, viticulture, nectarines/peaches, and oranges.[15] For this economic base case, it is assumed almonds are grown as the permanent crops. These crops generate producer surpluses of $1,100/ML in NSW Murray region and $1,000/ML in Murrumbidgee region for the water supplied but $1,300 /ML when shortfalls occur in both regions.

[14] Marsden Jacobs Associates (2020). *Regional Water Value Function*

[15] While the region supports a range of viticulture, they tend not to source their water from the regulated system.

Hydrologic and economic base case outcomes

This section outlines the estimated hydrologic and economic outcomes from the economic base case hydrologic modelling for the key extractive users in the NSW Murray and Murrumbidgee region the historical, long-term historical and dry future climate scenarios.

There are 10,000 years of data in the long-term historical and dry future climate scenario datasets. This data has been split into 1,000 40-year realisations or 'windows' for each major water user.[16]

All economic calculations use a discount rate of 5%, as recommended by the NSW Treasury.[17]

Town and community hydrologic base case outcomes

The hydrologic modelling indicates that communities within the NSW Murray region are likely to experience some levels of surface water supply shortfalls under the long-term historical scenario, with moderate increases in both the magnitude and length under the dry future climate scenario. For the Murrumbidgee region, while there is only negligible level of surface water shortfall in the long-term historical scenario, given the dry future climate scenario, the magnitude is predicted to slightly increase. The average length and magnitude of each town's expected annual shortfall for the 1,000 40-year windows under the long-term historical and dry future climate scenarios are shown from Table 3 to Table 6 for both the NSW Murray and Murrumbidgee regions.

Table 7 and Table 8 summarises the difference between results in the two datasets for both regions. All values are rounded to 1 decimal places. On average, all towns and communities in NSW Murray, other than Berrigan shire, experience at least mild shortfalls with more than 0.1 MLs in annual average shortfall level in their surface water supplies under the long-term historical scenario. The largest shortfall, both on average and in percentage of demand, occurs for Albury where the average annual shortfall was 5607.3 MLs and more than 39% of the annual demand not being met. It should be acknowledged that this forecasted large shortfall is partially contributed by the fact that the projection methodology assumed the entitlements for each region remain the same

[16] Each realisation or 'window' covers a single 40-year hydrologic simulation. There are 1,000 of these realisations for each of the long-term historical and dry future climate scenario datasets. The windows are drawn from 40-year rolling periods extracted from the 10,000-year generated climatic datasets, with an approximate 9-year overlap between periods.

[17] NSW Treasury (2017) *TPP17-03: NSW Government Guide to Cost–Benefit Analysis.*

value as indicated by the current *Water Sharing Plans* while population growth would continue. The large shortfalls in Albury and Murray River Council represent the consequence of their population growth outstripping *existing* water entitlements.

Under the dry future climate scenario, the average annual shortfalls increase moderately for all towns and communities in the NSW Murray region compared to that under the long-term historical scenario. The town to experience the largest rise in level when comparing the long-term historical and dry future climate scenario was Albury, who has an increase in average annual shortfall around 1,022 MLs. For percentage change in shortfall as demand, Murray River Council experiences the largest increase, with 6.9% in shortfall as percentage of demand and 12.5% in average of the year with shortfall.

The base case outcomes suggest significantly lower overall average annual town water shortfalls in the Murrumbidgee region compared to the NSW Murray region. Jugiong is the only community with an average annual shortfall in town water supply higher than 0.1 MLs under the long-term historical scenario. In the dry future climate scenario, all other towns except for Gundagai, Morundah to Coonong and Wanganella also experience mild shortfalls. The town has largest change in average annual shortfall is Jugiong with 7.3MLs as the increase in volume and 0.2% as increase in shortfall as % of demand.

Table 3. Town water supply hydrologic outcomes—NSW Murray region, long-term historical climate scenario

Town	Average annual shortfall (ML)	Average annual demand (ML)	Shortfall as % of demand	Average months per year with shortfall	Average % of the year with shortfall
Albury	5607.3	14266.8	39.3	8.4	69.7
Berrigan Shire	0.0	644.6	0.0	0.0	0.0
Corowa	8.0	3654.6	0.2	0.1	1.1
Deniliquin	1.8	3164.5	0.1	0.0	0.2
Euston	0.3	274.4	0.1	0.0	0.3
Murray River Council	141.5	1946.2	7.3	3.4	28.6
Wentworth	0.3	1148.7	0.0	0.0	0.0

Table 4. Town water supply hydrologic outcomes — Murrumbidgee region, long-term historical climate scenario

Town	Average annual shortfall (ML)	Average annual demand (ML)	Shortfall as % of demand	Average months per year with shortfall	Average % of the year with shortfall
Balranald	0.0	692.1	0.0	0.0	0.0
Gundagai	0.0	475.6	0.0	0.0	0.0
Hay	0.0	1198.5	0.0	0.0	0.0
Jerilderie	0.0	444.4	0.0	0.0	0.1
Jugiong	0.3	3423.4	0.0	0.0	0.0
Morundah To Coonong	0.0	9.6	0.0	0.0	0.0
Tumut	0.0	1226.6	0.0	0.0	0.0

Table 5. Town water supply hydrologic outcomes — NSW Murray region, dry future climate scenario

Town	Average annual shortfall (ML)	Average annual demand (ML)	Shortfall as % of demand	Average months per year with shortfall	Average % of the year with shortfall
Albury	6629.5	14678.9	45.2	9.1	75.6
Berrigan Shire	3.5	656.0	0.5	0.1	1.1
Corowa	188.3	3783.8	5.0	1.6	13.4
Deniliquin	62.0	3271.4	1.9	0.6	5.0
Euston	5.8	283.2	2.0	0.6	5.0
Murray River Council	283.5	2000.4	14.2	4.9	41.1
Wentworth	6.3	1183.7	0.5	0.1	1.1

Table 6. Town water supply hydrologic outcomes — Murrumbidgee region, dry future climate scenario

Town	Average annual shortfall (ML)	Average annual demand (ML)	Shortfall as % of demand	Average months per year with shortfall	Average % of the year with shortfall
Balranald	0.3	720.3	0.0	0.0	0.2
Gundagai	0.0	497.1	0.0	0.0	0.0
Hay	0.3	1266.0	0.0	0.0	0.1
Jerilderie	2.0	445.8	0.4	0.2	1.5
Jugiong	7.5	3696.1	0.2	0.1	0.6
Morundah To Coonong	0.0	10.0	0.0	0.0	0.0
Tumut	0.3	1283.8	0.0	0.0	0.1

Table 7. Town water supply hydrologic outcomes — difference (long-term historical and dry future climate scenarios), NSW Murray region

Town	Increase in average annual shortfall (ML)	Increase in average annual demand (ML)	Increase in shortfall as % of demand	Increase in average months per year with shortfall	Increase in average % of the year with shortfall
Albury	1022.3	412.1	5.9	0.7	5.9
Berrigan Shire	3.5	11.4	0.5	0.1	1.1
Corowa	180.3	129.2	4.8	1.5	12.3
Deniliquin	60.3	106.9	1.8	0.6	4.8
Euston	5.5	8.8	1.9	0.6	4.7
Murray River Council	142.0	54.2	6.9	1.5	12.5
Wentworth	6.0	35.0	0.5	0.1	1.1

Table 8. Town water supply hydrologic outcomes — difference (long-term historical and dry future climate scenarios), Murrumbidgee region

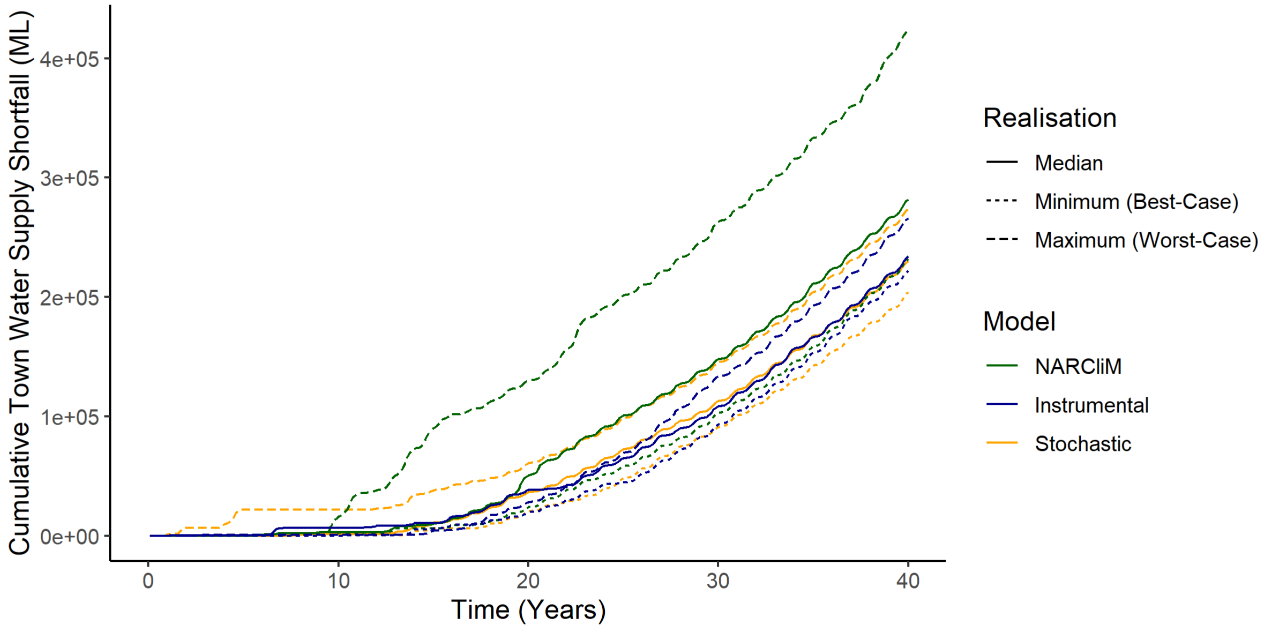
Town	Increase in average annual shortfall (ML)	Increase in average annual demand (ML)	Increase in shortfall as % of demand	Increase in average months per year with shortfall	Increase in average % of the year with shortfall
Balranald	0.3	28.2	0.0	0.0	0.2
Gundagai	0.0	21.5	0.0	0.0	0.0
Hay	0.3	67.5	0.0	0.0	0.1
Jerilderie	2.0	1.4	0.4	0.2	1.4
Jugiong	7.3	272.7	0.2	0.1	0.6
Morundah To Coonong	0.0	0.4	0.0	0.0	0.0
Tumut	0.3	57.2	0.0	0.0	0.1

Figure 3 and Figure 4 illustrates the key town water supply shortfall scenarios of the 1,000 40-year windows for individual towns, and the combined towns, in the instrumental, long-term historical and dry future climate scenario models. These figures show realisations as cumulative totals over the 40-year simulation period. The key realisations are:

- minimum — the best-case realisation
- median — the exact middle realisation
- maximum — the worst-case realisation.

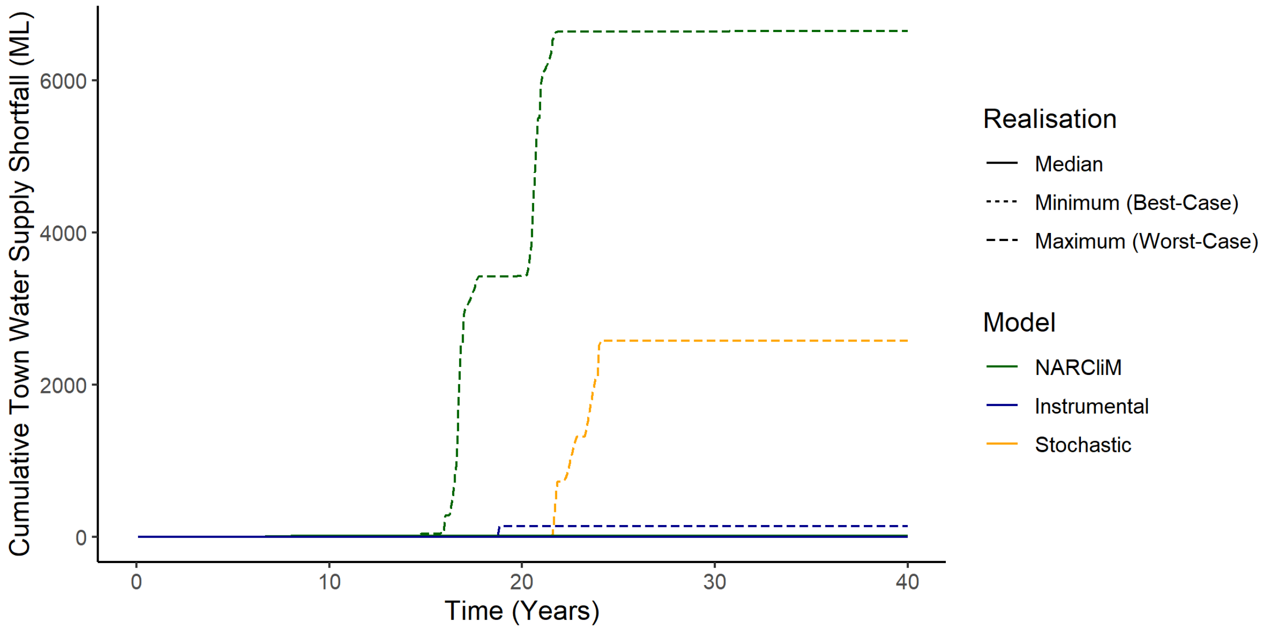
These realisations allow an understanding of the spread of outcomes (what could happen) over all the 40-year windows simulated for the region and how towns might experience the predicted economic outcomes of the climate models over time. In short, it shows that over the next 40 years, the number of times a town might run out of surface water could be anywhere between the dotted lines. In instances where there are no (or very low) shortfalls, lines may overlap. These figures also support the facts that in both regions the dry future climate scenario (here presented as the NARCliM scenario) would increase the uncertainty of town water supply shortfalls.

Figure 3. Town supply cumulative 40-year shortfall series (ML), NSW Murray region.



Note: stochastic is long-term historical climate and NARCliM is dry future climate scenario

Figure 4. Town supply cumulative 40-year shortfall series (ML), Murrumbidgee region.



Note: stochastic is long-term historical climate and NARCliM is dry future climate scenario

Town and community economic base case outcomes

The estimated average economic impact of water supply shortfalls for towns within the NSW Murray and Murrumbidgee region over a 40-year period are shown in Table 9 and Table 10, respectively. The economic consequences of surface water shortfalls are, naturally, based on the hydrologic forecasts. Among all towns within the NSW Murray region, Albury has the largest net present cost of water supply with a value around $-872 million under the long-term historical scenario and $-1,084 million under the dry future climate scenario. Besides Albury, Murray River Council also has a moderate level of net present cost associated with town water supply under both scenarios, while other towns in the NSW Murray region all have relatively trivial economic outcomes. For Murrumbidgee region the economic base outcomes in water shortfall net present cost are negligible under both scenarios, as consistent to the hydrologic base case outcomes.

Table 9. NSW Murray economic base case outcome — town water supply average 40-year shortfall, net present costs

Town	**Long-term historical climate scenario** ($m)	**Dry future climate scenario** ($m)	**Difference between both climate scenarios** ($m)	Difference (%)
Albury	-872.4	-1084.3	-211.9	24.3
Berrigan Shire	0.0	-0.1	-0.1	4532.3
Corowa	-0.5	-15.8	-15.3	3263.3
Deniliquin	-0.1	-3.8	-3.7	4107.8
Euston	0.0	-0.3	-0.3	3426.0
Murray River Council	-14.5	-31.8	-17.3	118.9
Wentworth	0.0	-0.3	-0.3	4151.2
Total	-887.5	-1136.4	-248.9	28.0

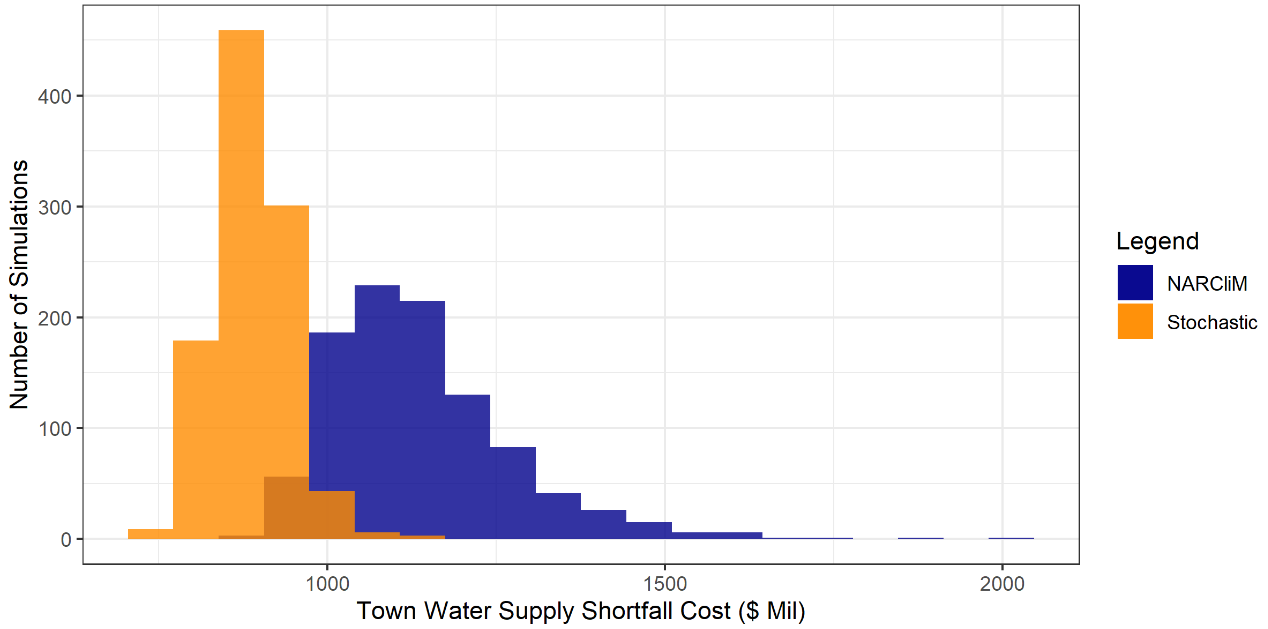
Table 10. Murrumbidgee economic base case outcome — town water supply average 40-year shortfall, net present costs

Town	**Long-term historical climate scenario** ($m)	**Dry future climate scenario** ($m)	**Difference between both climate scenarios** ($m)	Difference (%)
Balranald	0.0	0.0	0.0	6331.5
Gundagai	0.0	0.0	0.0	2393.2
Hay	0.0	0.0	0.0	2096.5
Jerilderie	0.0	-0.1	-0.1	1509.4
Jugiong	0.0	-0.2	-0.2	1996.7
Morundah To Coonong	0.0	0.0	0.0	NA
Tumut	0.0	0.0	0.0	4195.2
Total	0.0	-0.3	-0.3	1934.7

The distributions of the expected economic outcomes for each model are shown in Figure 5 and Figure 6, which condense the economic costs of town water supply shortfalls for all 1,000 40-year windows by grouping results into ranges of values — in this case, 20 ranges per data series. These figures also illustrate that both the magnitude and uncertainty (that is, the spread) of the average cost of town water supply shortfalls increases under the dry future climate scenario. The increase in the spread of town water supply costs under a dry future climate scenario reflects the predicted increase in the number and severity of shortfalls where water supply is required to be supported by a more expensive alternative source.

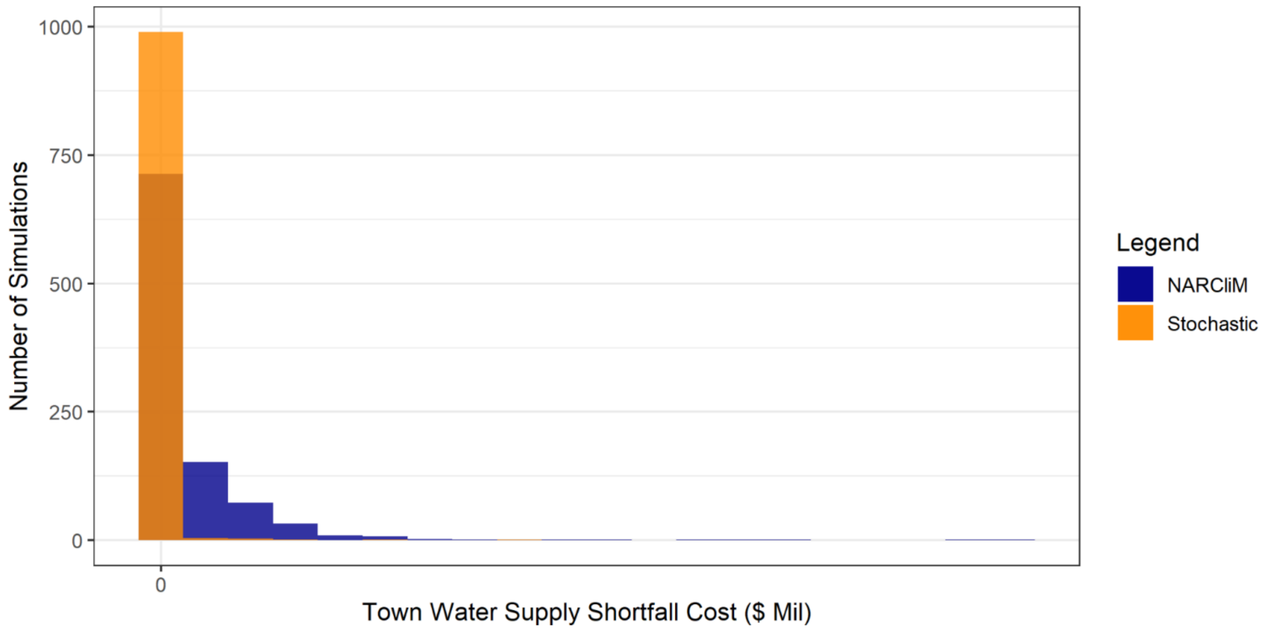
Figure 5 and Figure 6 indicate that the worst economic outcomes for town water supply shortfalls would be approximately $1,170 million for the NSW Murray region in the long-term historical scenario (referred to as stochastic) and $1,750 in the dry future climate scenario (referred to as NARCliM), while the outcomes are much lighter for the Murrumbidgee region such that the shortfall costs under both scenarios cluster around $0 million. In general, for both regions, both the average results in the dry future climate scenario, and the skew of results, are worse than that in the long-term historical scenario.

Figure 5. Total average towns water supply, net present costs, NSW Murray region



Note: stochastic is long-term historical climate and NARCliM is dry future climate scenario

Figure 6. Total average towns water supply, net present costs, Murrumbidgee region



Note: stochastic is long-term historical climate and NARCliM is dry future climate scenario

Agricultural hydrologic base case outcomes

The following section describes the hydrologic impacts on the agricultural industry within the NSW Murray and Murrumbidgee region. Agriculture has been separated into two groups for this region:

- Annual crops (cotton for both regions)
- Permanent crops (almonds for both regions)

The estimated annual average volume of water these producers use under both the long-term historical and dry future climate scenarios are given in Table 11 and Table 12 for the NSW Murray and Murrumbidgee regions, respectively.

Annual agricultural water users are expected to receive less water under the dry future climate scenario than the long-term historical scenario, with an average use difference of approximately -541 GL per year (a 35.1% reduction) for the NSW Murray region and -273 GL per year (a 35.3% reduction) for the Murrumbidgee region. Water for permanent crops is sourced from high-security water access licence shares but are also expected to see a decrease of -27.9 GL per year (a 13.3% reduction) in the NSW Murray region and -24.8 GL (a 7.6% reduction) in the Murrumbidgee region. The tables also show that in both regions and for both annual and permanent crop water users the dry future climate scenario predicts realisations with larger standard deviations, implying more uncertainties in agricultural water use volumes given a drier future climate assumption.

Table 11. Economic base case outcomes—average annual agricultural water use volumes in NSW Murray region

Crop classification	Water Use Metric	Long-term historical scenario	Dry future climate scenario	Difference (Dry future – long-term historical)	Difference (%)
Annual crops (GL/year)	Average	1542.8	1001.8	-541.0	-35.1
	Maximum	1922.9	1646.5	-276.4	-14.4
	Median	1566.5	1008.5	-558.0	-35.6
	Minimum	896.6	394.0	-502.6	-56.1
	Standard deviation	139.8	179.7	39.9	28.5
Permanent crops (GL/year)	Average	209.2	181.3	-27.9	-13.3
	Maximum	211.8	211.7	-0.1	-0.1
	Median	210.7	184.0	-26.6	-12.6
	Minimum	188.5	113.6	-74.9	-39.8

Crop classification	Water Use Metric	Long-term historical scenario	Dry future climate scenario	Difference (Dry future – long-term historical)	Difference (%)
	Standard deviation	3.7	16.5	12.8	341.7

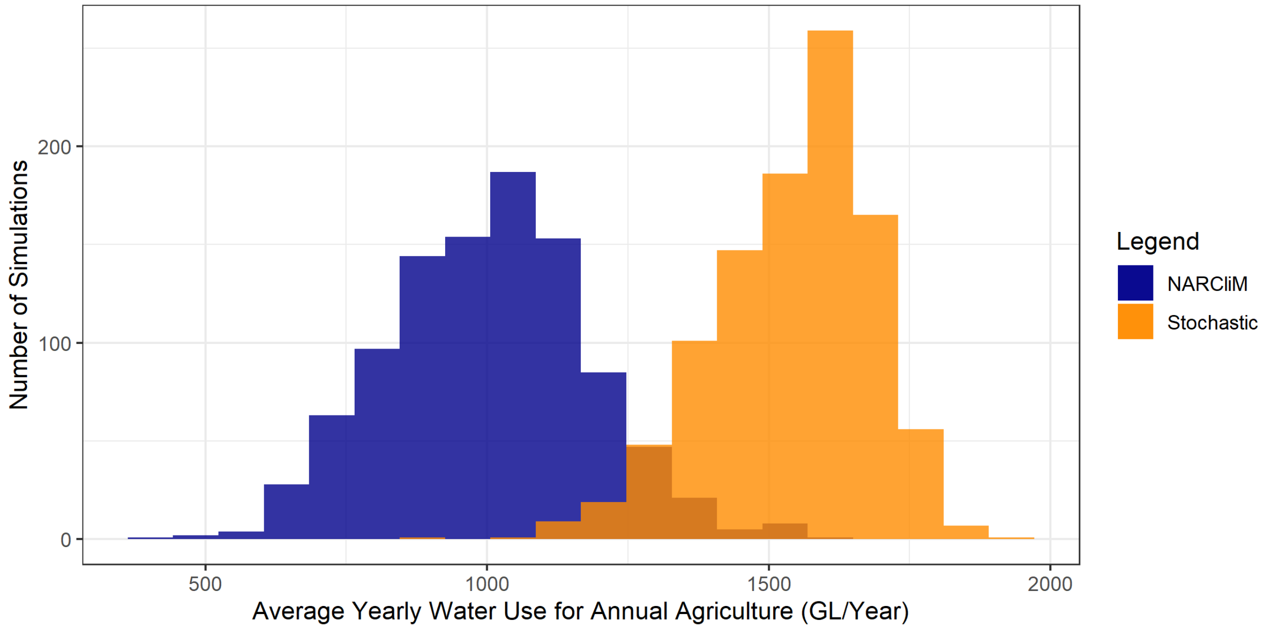
Table 12. Economic base case outcomes — average annual agricultural water use volumes in Murrumbidgee region

Crop classification	Water Use Metric	Lon-term historical scenario	Dry future climate scenario	Difference (Dry future – long-term historical)	Difference (%)
Annual crops (GL/year)	Average	774.9	501.7	-273.3	-35.3
	Maximum	986.5	810.6	-175.9	-17.8
	Median	780.9	501.3	-279.6	-35.8
	Minimum	447.3	225.1	-222.1	-49.7
	Standard deviation	79.5	95.6	16.1	20.3
Permanent crops (GL/year)	Average	327.9	303.1	-24.8	-7.6
	Maximum	330.3	330.3	0.0	0.0
	Median	330.3	307.5	-22.8	-6.9
	Minimum	284.4	185.8	-98.6	-34.7
	Standard deviation	5.2	21.8	16.6	315.9

Graphs of the modelled annual agricultural water use within the NSW Murray and Murrumbidgee region are shown in Figure 7 and Figure 8 for annual crops and Figure 9 and Figure 10 for permanent crops, respectively. The figures group the results of the 40-year realisations into 20 'bins' to provide an overview of the outcomes for the 1,000 realisations of each model.

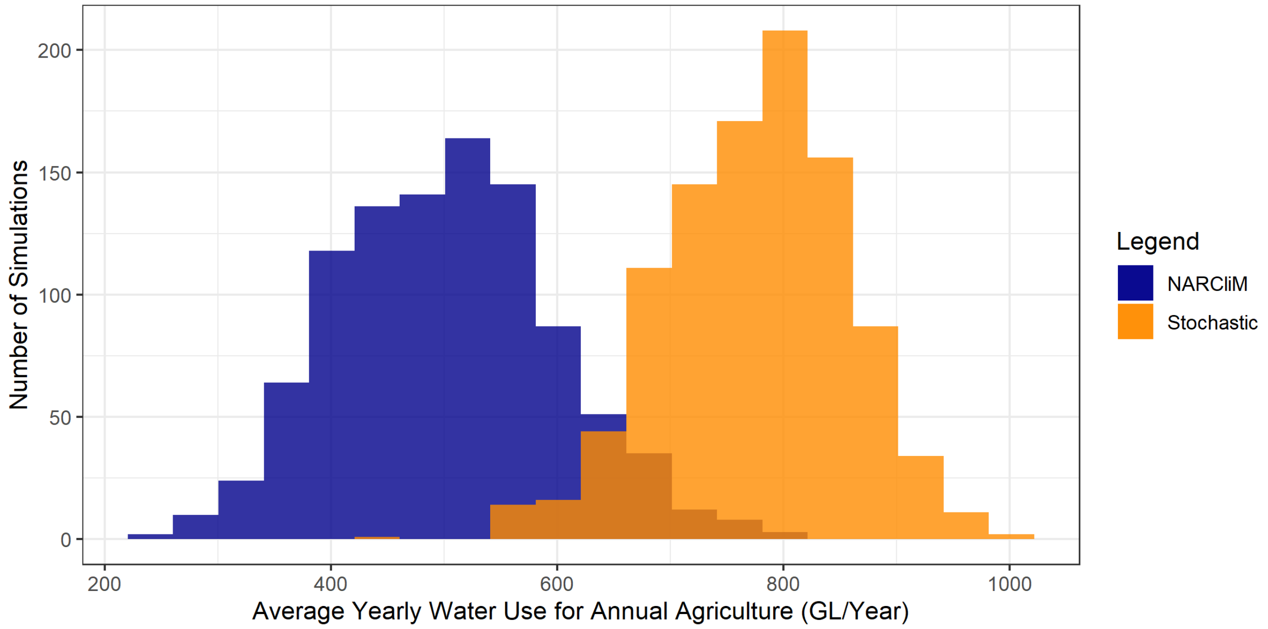
These histograms show that for both agricultural water user groups and in both regions, the average yearly water use would decrease given a climate change assumption. For example, in the NSW Murray region while the peak (i.e., the value of water uses that corresponding to the highest number of simulations) for the annual agricultural water user group is between 1,600 and 1,700 GLs per year in the stochastic model, the maximum amount is almost 2,000 GLs, and the minimum is around 1,000 GLs. The dry future climate results average only around 1,000 GLs, with the maximum being just over 1,600 GLs and the minimum being close to 250 GLs. For the Murrumbidgee region, the maximum value under stochastic scenario is around 1,000 GLs with an average being about 700 GLs. The dry future climate model predicts a maximum around only 800 GLs and a minimum being approximately 250 GLs. These figures also support results from Table 11 and Table 12 such that the dry future climate dataset produces realisations are with slightly higher level of variation.

Figure 7. NSW Murray region — annual crops water uses under the long-term historical and dry future climate scenarios



Note: stochastic is long-term historical climate and NARCliM is dry future climate scenario

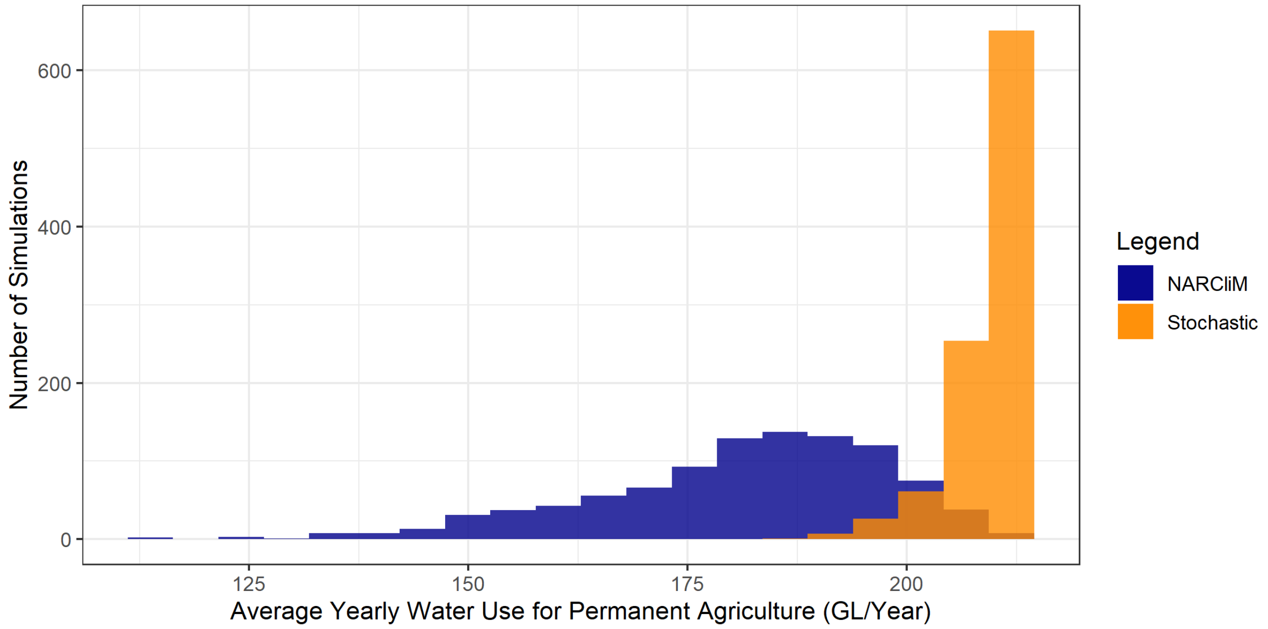
Figure 8. Murrumbidgee region — annual crops water uses under long-term historical and dry future climate scenarios



Note: stochastic is long-term historical climate and NARCliM is dry future climate scenario

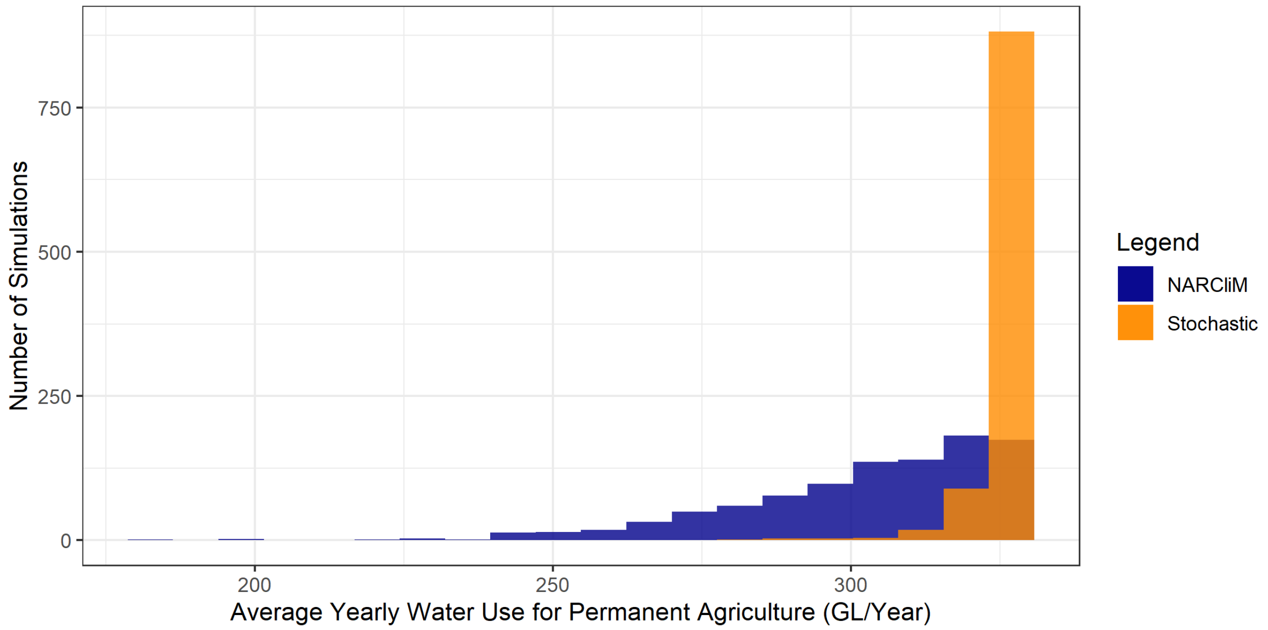
The histograms for permanent crops follow similar pattern to the annual crops group, but the results predicted in the dry future climate datasets shows much higher level of variation compared to that from the long-term historical dataset for both regions. Another pattern to note for the permanent crops groups is that the realisations produced from the long-term historical dataset are highly left-skewed and cluster closely around the maximum. See Figure 9 and Figure 10.

Figure 9. NSW Murray region—permanent crops water uses under the long-term historical and dry future climate scenarios



Note: stochastic is long-term historical climate and NARCliM is dry future climate scenario

Figure 10. Murrumbidgee region—permanent crops water uses under the long-term historical and dry future climate scenarios



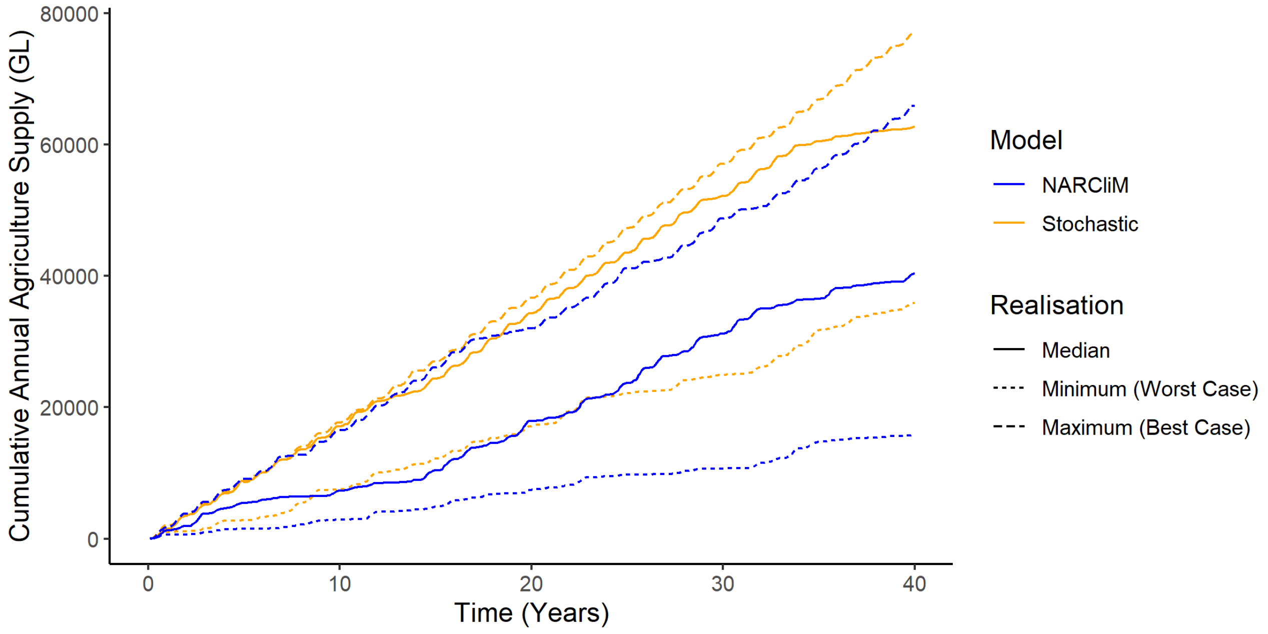
Note: stochastic is long-term historical climate and NARCliM is dry future climate scenario

Figure 11 to Figure 14 illustrate three statistical outcomes of expected cumulative water use for producers of annual and permanent crops under both the long-term historical and dry future climate scenarios for both regions. These outcomes are:

- minimum: the best-case scenario
- median: the exact middle scenario
- maximum: the worst-case scenario.

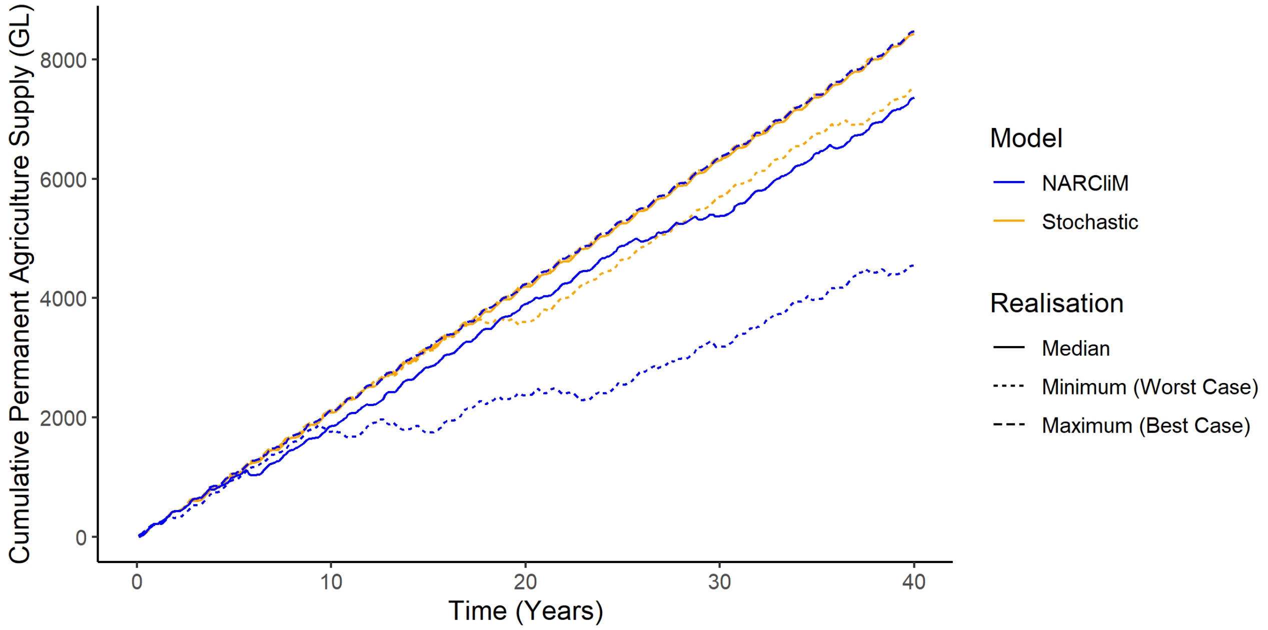
These figures further support results from Figure 7 and Figure 8 such that the dry future climate scenario suggest less water availability to produce annual crops in both the NSW Murray and Murrumbidgee regions. For permanent crops, while the predicted maximum levels of water supply are generally closed under both the scenarios, the dry future climate model predicts significantly lower values in the median and the minimum. These statistical results also show that the cumulative water use of annual crops in both regions are of less variances compared to the case of permanent crops within the 40-year simulation.

Figure 11. NSW Murray region annual crop water use—descriptive statistics



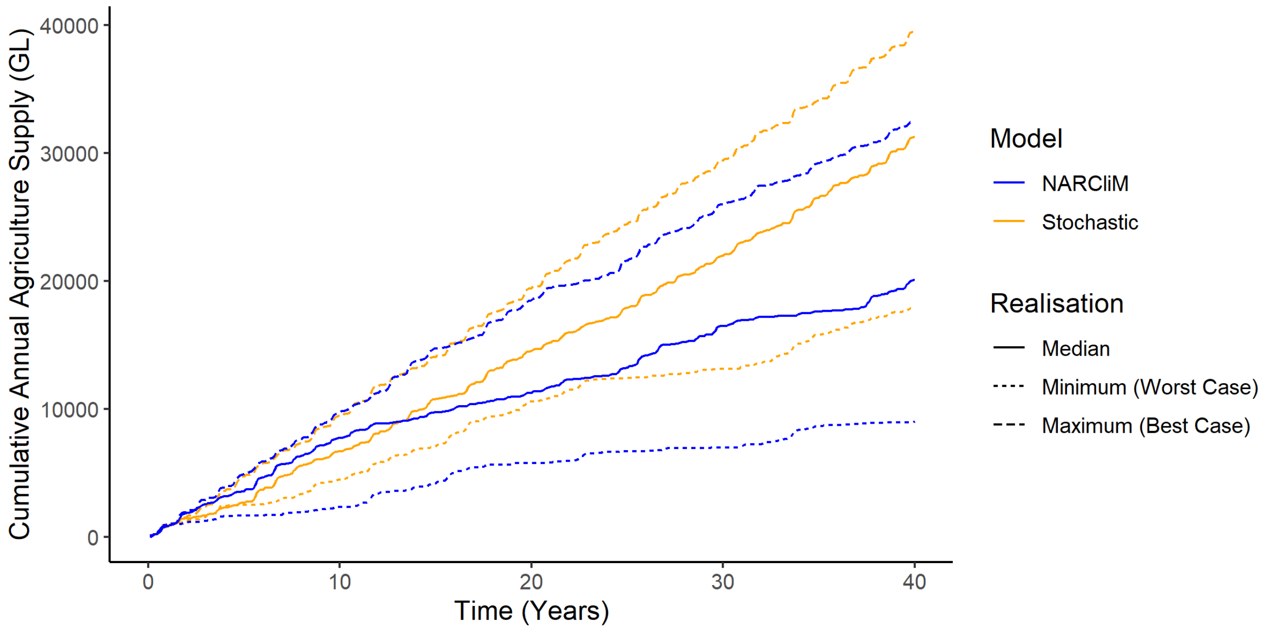
Note: stochastic is long-term historical climate and NARCliM is dry future climate scenario

Figure 12. NSW Murray region permanent crop water use — descriptive statistics



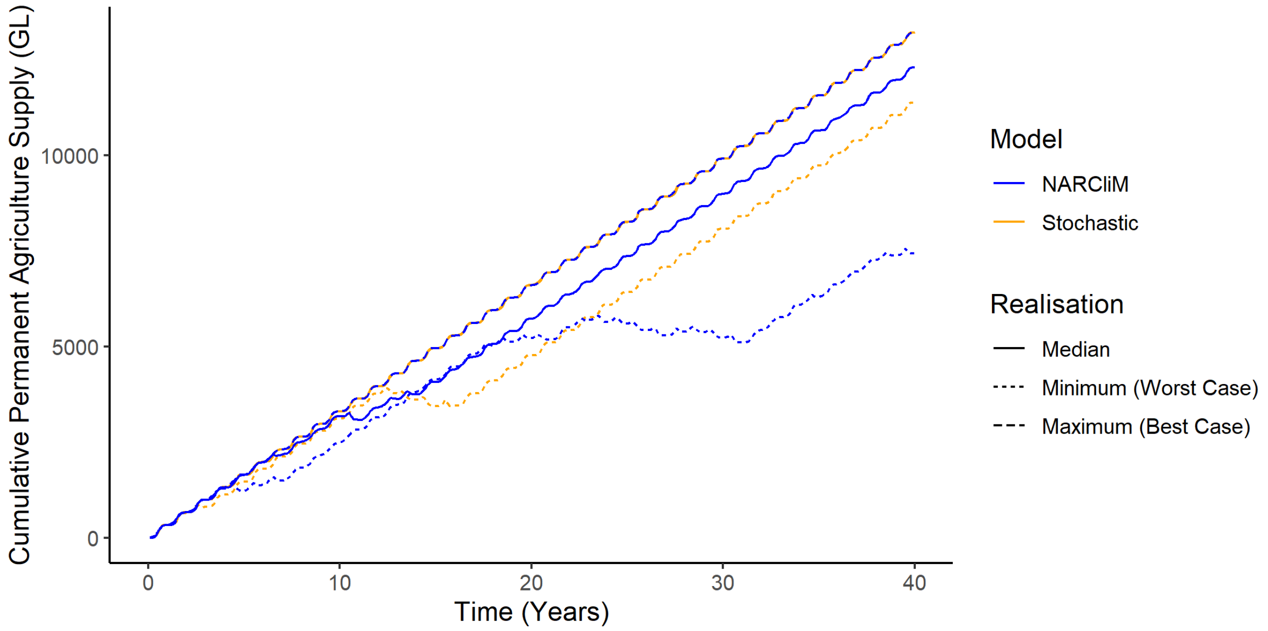
Note: stochastic is long-term historical climate and NARCliM is dry future climate scenario

Figure 13. Murrumbidgee region annual crop water use — descriptive statistics



Note: stochastic is long-term historical climate and NARCliM is dry future climate scenario

Figure 14. Murrumbidgee region permanent crop water use — descriptive statistics



Note: stochastic is long-term historical climate and NARCliM is dry future climate scenario

Agricultural economic base case outcomes

Average economic values of water for agricultural producers on the NSW Murray and Murrumbidgee regions over the 40-year analysis period are shown in Table 13 and Table 14, respectively. Under the dry future climate scenario in the NSW Murray region, a decrease in the average economic value for annual (-34.0%) and permanent crop (-15.1%) producers reflect the reduction of agricultural production due to decreased water supply under a dry future climate scenario. The outcomes of Murrumbidgee region suggest similar results such that there will be a 33.0% decrease in annual crops producer surplus and 8.2% decrease in permanent crops producer surplus given the dry future climate assumption. In total, the difference between dry future climate and long-term historical outcome suggests a decline of around $3090 million in producer surplus for agricultural activity on the NSW Murray region and $1740 million on the Murrumbidgee region because of the future drier climate.

Table 13. NSW Murray economic base case outcomes: agriculture net present producer surplus averages (40 years)

Crop classification	Long-term historical ($m)	dry future climate ($m)	Difference ($m) (dry future climate - Long-term historical)	Difference (%) (dry future climate - Long-term historical)
Annual crops	7013.1	4626.2	-2386.9	-34.0
Permanent crops	4661.9	3958.6	-703.3	-15.1
Total	11675.0	8584.8	-3090.2	-0.3

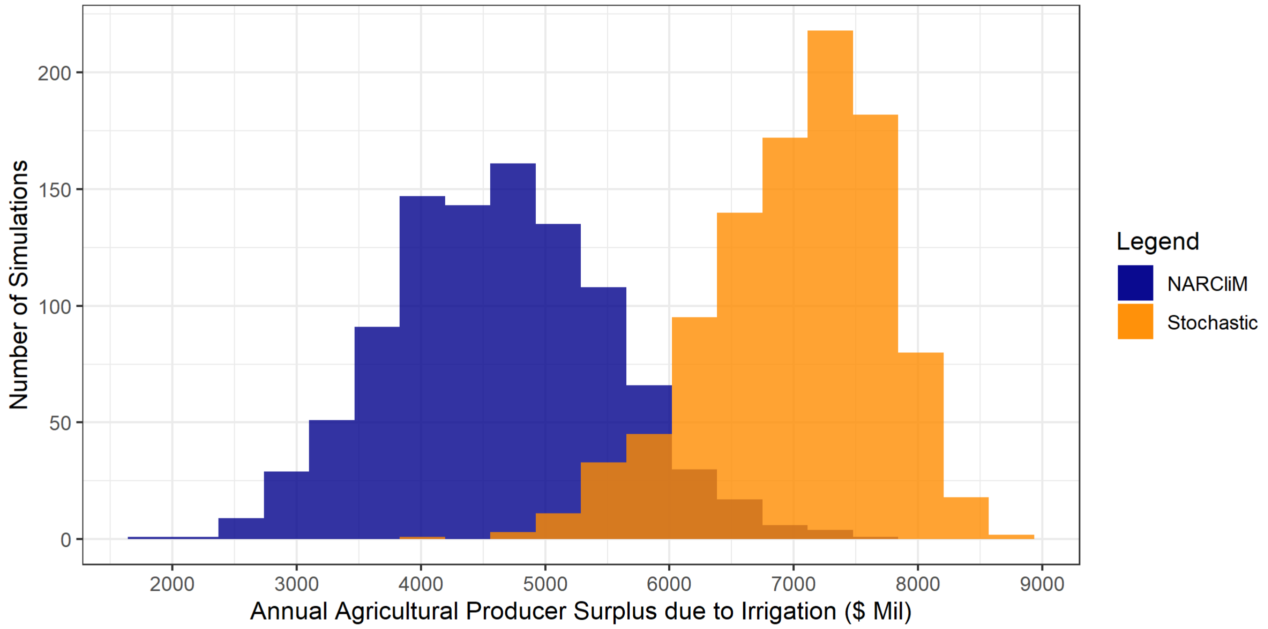
Table 14. Murrumbidgee economic base case outcomes: agriculture net present producer surplus averages (40 years)

Crop classification	Long-term historical ($m)	dry future climate ($m)	Difference ($m) (dry future climate - Long-term historical)	Difference (%) (dry future climate - Long-term historical)
Annual crops	3538.4	2369.3	-1169.1	-33.0
Permanent crops	6992.6	6421.9	-570.7	-8.2
Total	10531.0	8791.2	-1739.8	-0.2

Summaries of the distributions of possible outcomes for crop producers are shown in Figure 15 to Figure 18 for annual and permanent crops in both regions. These figures provide information such as ranges, variation, and central tendency of possible economic outcomes under the long-term historical and dry future climate scenarios. For example, from Figure 15 the predicted economic surplus due to irrigation for producers of annual crops under Long-term historical conditions ranges from approximately $4,000 million to almost $9,000 million in the NSW Murray region, with an average value of around $7,000 million over the forecast 40 years. For the dry future climate results, the possible outcomes of water for producers of annual crops shifts lower, with values ranging from $2,000 million to around $8,000 million and an average value around $4,600 million.

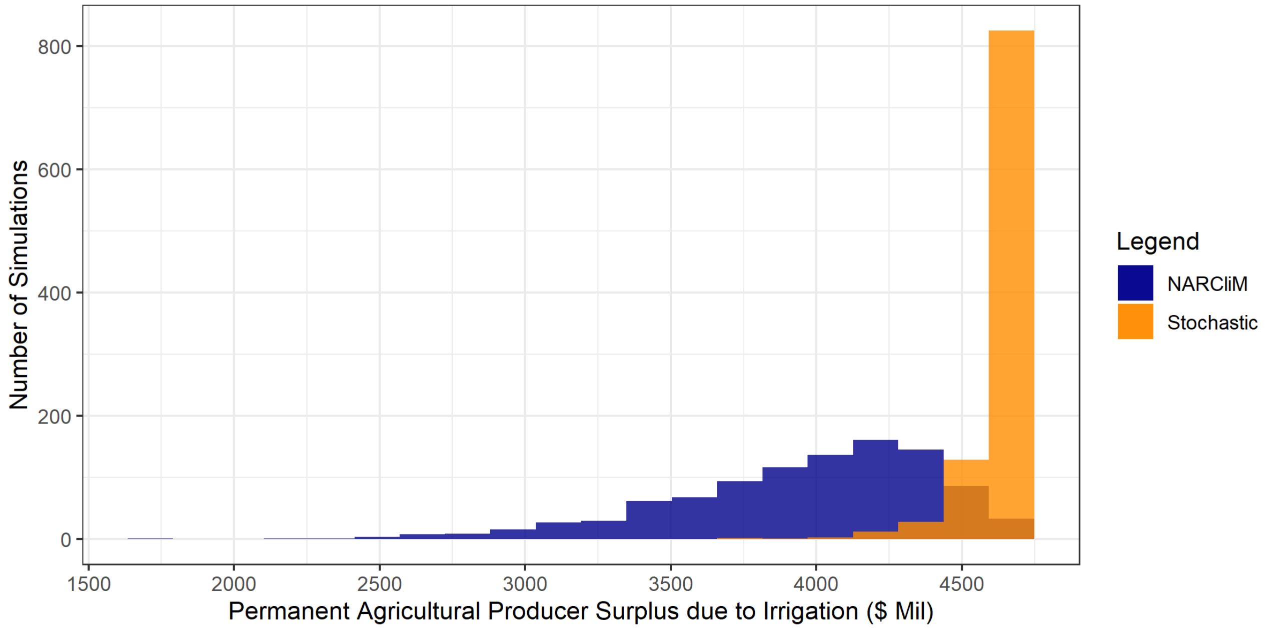
Figure 16 shows the NSW Murray permanent agriculture producer surplus. Under the dry future climate scenario these outcomes lie in a much wider range compared to that under the Long-term historical scenario, suggesting a higher level of uncertainty of permanent agricultural producer surplus associated with the drier climate assumption. Outcomes in the Murrumbidgee region (Figure 17 and Figure 18) follow similar patterns as in the NSW Murray region. These results are also consistent to finding from the agricultural hydrologic base case outcomes.

Figure 15. NSW Murray annual agriculture net present producer surplus over 40 years



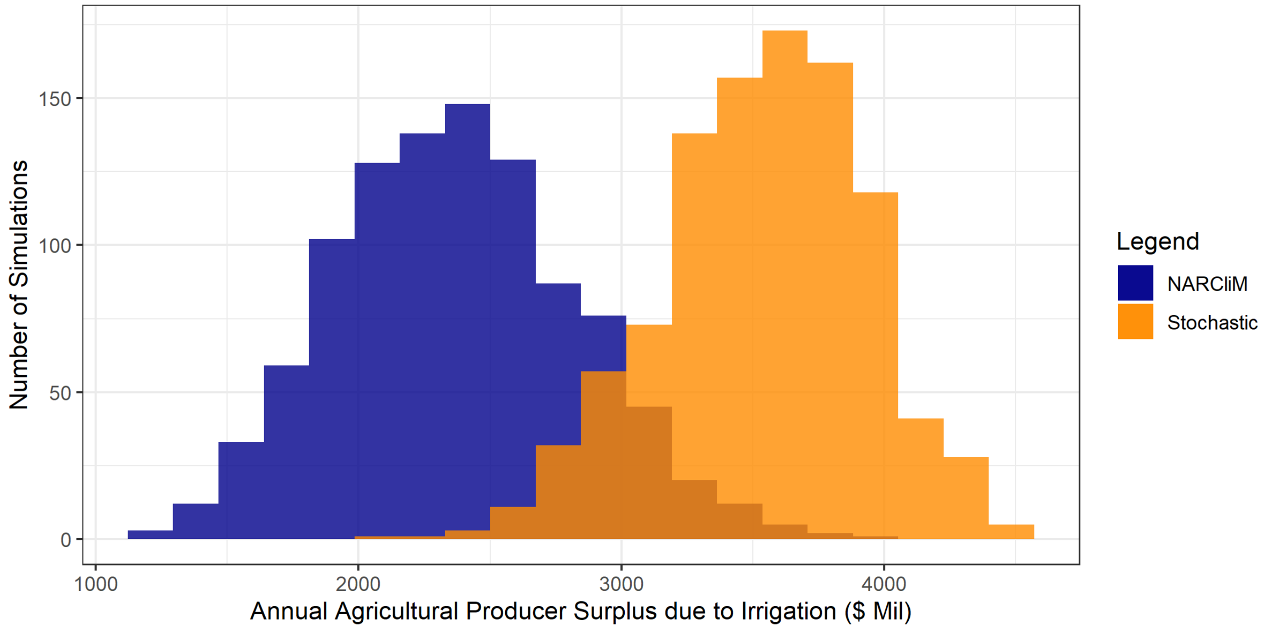
Note: stochastic is long-term historical climate and NARCliM is dry future climate scenario

Figure 16. NSW Murray permanent agriculture net present producer surplus over 40 years



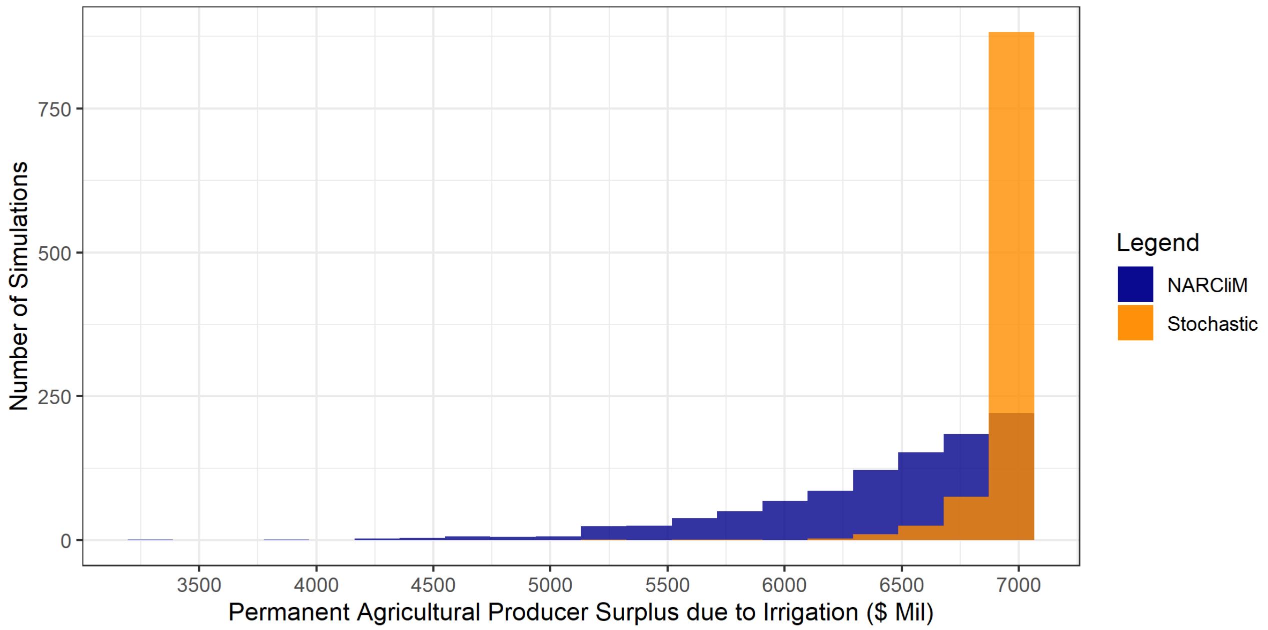
Note: stochastic is long-term historical climate and NARCliM is dry future climate scenario

Figure 17. Murrumbidgee annual agriculture net present producer surplus over 40 years



Note: stochastic is long-term historical climate and NARCliM is dry future climate scenario

Figure 18. Murrumbidgee permanent agriculture net present producer surplus over 40 years



Note: stochastic is long-term historical climate and NARCliM is dry future climate scenario

Assumptions and uncertainties

The analyses in the regional water strategies are based on the best available information at the time. As with all types of analyses, a range of assumptions, uncertainties and qualifications are made.

Assumptions adopted within this economic base case analysis include:

- Town water supply shortfalls consider only modelled surface water availability and do not include any consideration of existing alternative supply sources such as groundwater or desalination plants. The purpose of the analysis was to identify how secure the surface water supply is for each town. Further analysis needs to be undertaken to understand how these risks can be met by existing alternative water sources that the towns already access.
- Population increases have been included in accordance with the NSW Government's Common Planning Assumptions' high population growth forecasts. Towns within the NSW Murray and Murrumbidgee regions are predicted to have reductions in population; for these towns, it is assumed that population growth will be flat rather than decreasing.
- Current uses of water, in both general security and high security entitlements, are assumed to be constant over the 40 years examined. In practice, it is likely that technology and global demand for food and fibre will change the nature of the crops produced in the NSW Murray and Murrumbidgee region, therefore changing the amount of water used. Estimating these changes is beyond the regional water strategies project.

Uncertainties and qualifications relevant to this study include:

- Town water supply shortfall analysis presented is not a replacement for secure yield analysis undertaken by local water utilities as part of integrated water cycle management strategies; however, it can be used as an input into determining the secure yield.
- Economic outcomes are likely to be highly sensitive to the discount rate considered. The producer surpluses are based on long-run estimates. In practice, the profitability of each crop will vary year-by-year. Estimating these changes is beyond the scope of the regional water strategies project.
- The value of water to mines is likely to be highly dependent on the circumstances and operation of individual mines. As such, it is not able to accurately incorporate the value of water to mines and they have been excluded from the analysis.