FINAL METHODOLOGY REPORT

Economic analysis of the influence of timing on the productivity of water

Border Rivers, Barwon-Darling, Gwydir, Macquarie, and Namoi

Prepared for

NSW Department of Climate Change, Energy, the Environment and Water

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Executive summary

The task

The CIE has been commissioned by the Water Group in the Department of Climate Change, Energy the Environment and Water (the Water Group) to develop a methodology that can assess how economic impact on water users is influenced by timing when water take is restricted. The methodology is used to quantify the economic consequences for water users of the connectivity proposals in the Western Regional Water Strategy (the Strategy) have been used to pilot the development of this methodology. This information was provided to the Connectivity Expert Panel to inform their Interim Report. The final recommendations of the Expert Panel will also be subject to this methodology.

The Western Regional Water Strategy identified two connectivity proposals via the water sharing plans

- The first proposal is the critical dry condition trigger that protects the first flow of water after extended dry periods by restricting supplementary, floodplain harvesting, and B Class and C Class licence access in specific valleys.
- The second proposal is the finalisation of the review of the North-West Flow Plan, which restricts supplementary, floodplain harvesting, and B Class and C Class licence access in specific valleys to meet algal suppression and fish migration objectives.

Both proposals are likely to reduce long-term average annual diversions for licence holders in the Barwon-Darling, Border Rivers, Gwydir, Namoi, and Macquarie valleys

The Water Group has conducted extensive hydrologic analysis of the consequences associated with these proposals and developed eco-hydrologic modelling of the regions influenced by the proposed changes. However, The Water Group recognises that long-term average economic assessments will not capture the real economic impacts, especially when the volume of water depends on the climate cycle and the time in the cropping cycle. Therefore, it is important to translate the hydrologic modelling into economic outcomes at a more granular level so as to understand the influence of these proposed changes on both the water available to irrigators, as well as, on their planting decisions.

This report outlines the economic impact on the water users of each valley of restricting access to supplementary and B and C Class licences[1] under four assessed connectivity proposals of:

- Critical dry conditions triggers (first flush protections)
  - Menindee – 195GL active: access to supplementary, and B and C Class licences is restricted when storage in the upper Menindee Lakes (Wetherell, Pamamaroo, Tandure) is below 195 GL active[2]. Access is permitted in accordance with water sharing plan rules when active storage in the upper lakes returns above 250 GL active.
  - Menindee – 195GL total: access to supplementary, and B and C Class licences is restricted when total storage across all Menindee Lakes is below 195 GL. Access is permitted in accordance with water sharing plan rules when total storage in the lakes returns above 250 GL;
- North-West Flow Plan
  - Algal Suppression: access to supplementary, and B and C Class licences is restricted to preserve a flushing flow event in dry years to break up and disperse algal blooms access;
  - Fish migration: access to supplementary, and B and C Class licences is restricted to preserve events needed for fish dispersal, spawning and migration at appropriate times of the year.

Economic impact analysis - overview

The economic analysis utilises the hydrological multi-replicate outputs provided by the Water Group. The hydrological modelling is based on the past 130 years and output results have been reshaped into 13 alternative future climate scenarios (i.e. replicates) each covering a 40-year period.

The economic impact is disaggregated into two main components:

- **Farmers planting decision** *at the beginning of the season*, which impacts the total area of crops planted (hereafter referred to as the 'planting decision' or 'area of crops planted'), and
- **Water availability** *during the season*, which impacts the *yield* outcome and total harvested area at the end of the season (hereafter referred to as the 'yield outcome' or 'crops harvested').[3]

1 The restrictions are also intended to apply to floodplain harvesting licences. However, impacts on these licences is not included in this analysis as they were unable to be assessed by the hydrological model at the time this work was done in 2022.

2 Active storage is the water in storage that is able to be released and excludes the "dead" storage which cannot be released. Most storages have a small amount of dead storage below the outlet point that remains after the storage has been drained through the available outlets.

3 This assumes that a reduction in yield translates into less area harvested with 'full/average' yield.

The focus of the connectivity proposals are supplementary licences in the tributary valleys and Class B and C licences in the Barwon-Darling. These licences are extracted from flows that enter the system below the headwater storages and so are opportunistic in nature and usually not used to irrigate perennial crops. This analysis centres on two main annual crop types:

- Cotton in summer, and
- Winter crops (e.g. wheat).

The summer season starts at the time of cotton planting in October/November until March/April. After that the winter crop season starts in late March, April, or May, however, most of the winter crops are planted in May. This is based on the crop model component in the Water Group hydrological model.[4]

The economic impact of the proposals is assessed relative to the 'base case' outcomes reported in the tables above. The impact on the:

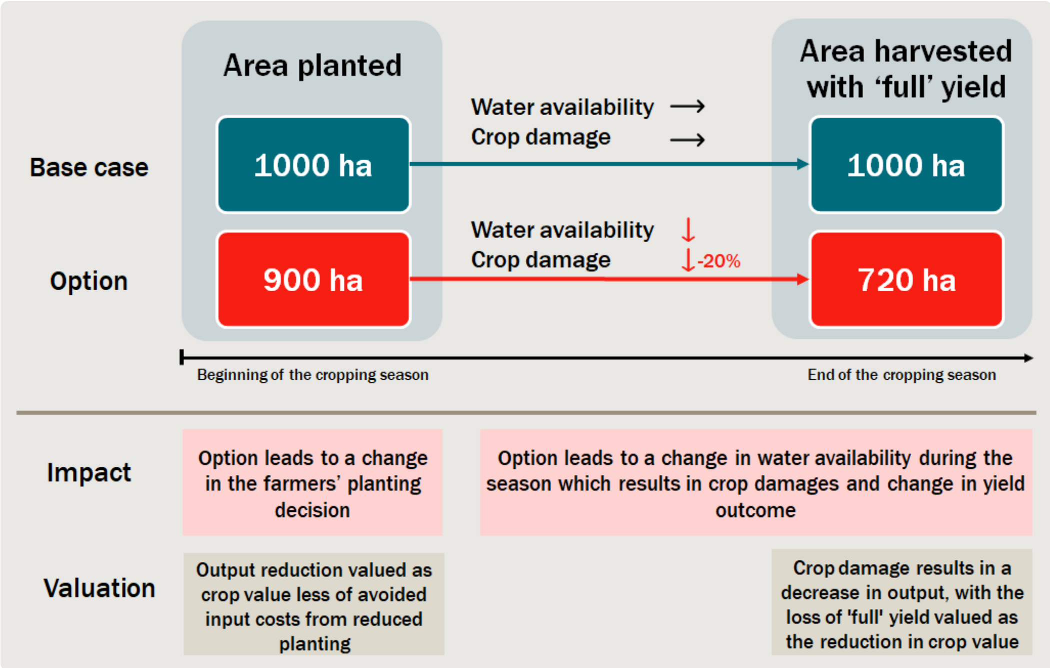
- *planting decision* is estimated as the change in the cropping area, valued at the net difference between forgone (or gained) value and avoided costs during the cropping season resulting from the proposals.
- *yield* is estimated as the change in the harvested area with full yield resulting from changes in yield outcomes. This change is valued based on the forgone (or gained) value.

The impacts are reported as the central case (probability-weighted) and the worst case based on the farmer's planting decision at the beginning of the season and water availability throughout the cropping season.

Chart 1 summarises on a high-level the underlying methodology.

4 The start/finish of the seasons differs slightly in the model depending on the region.

1 Illustrative example to estimate the impact of dry conditions trigger



Data source: CIE

Tables 2 and 3 present the economic outcomes under the current water sharing plan rules, referred to as the 'base case' or 'business-as-usual'. The tables below present the average economic outcomes in terms of long-term average planting at the beginning of the season, and value based on the 13 replicates over the 40-year period.

The present value has been calculated using a real social discount rate in accordance with the NSW Treasury Guidelines.[5] In summary:

- The Namoi and Gwydir valleys are the largest producers of irrigated cotton, followed by the Macquarie region. The Barwon-Darling and Border Rivers are the smallest cotton producers across the assessed valleys.
- The Namoi, Gwydir, and Border Rivers are the largest producers of irrigated winter crops.
- Total value of the area for summer (cotton) and winter (winter crops) planted is estimated between $2.7 billion and $6.2 billion (in present value terms) across the valleys. This represents the total amount of money generated by selling agricultural products at the farm gate.

5 NSW Treasury (2023), TPG23-08 NSW Government Guide to Cost-Benefit Analysis, available at: https://www.treasury.nsw.gov.au/sites/default/files/2023-04/tpg23-08_nsw-government-guide-to-cost-benefit-analysis_202304.pdf

2 Economic outcomes – long-term average planting per season

Crop	Border Rivers (ha)	Gwydir (ha)	Namoi (ha)	Barwon Darling (ha)	Macquarie (ha)
Cotton	22,309	50,869	53,961	24,873	46,283
Winter Crop	9,979	9,529	10,405	2,722	7,380
Grand total	**32,288**	**60,399**	**64,366**	**27,595**	**53,663**

Source: CIE

3 Economic outcomes – total value over 40 years

Crop	Border Rivers ($m, PV)	Gwydir ($m, PV)	Namoi ($m, PV)	Barwon Darling ($m, PV)	Macquarie ($m, PV)
Cotton	2,438	5,596	5,931	2,649	5,004
Winter Crop	256	215	250	55	166
Grand total	**2,694**	**5,811**	**6,181**	**2,704**	**5,170**

Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

Central case

The central results are based on the probability weighted result for each year across all replicates.[6]

Table 4 and chart 5 summarise the total economic impact (present value) of each option against the base case for impacts measured for both crop types.

- **The Algal Suppression option** see the *lowest* overall economic loss across all options for the Border Rivers, Gwydir, and Namoi valleys, but the second *largest* economic loss across all options for the Barwon-Darling.
- **The Menindee – 195GL active** option has the *largest* overall economic loss across all options for the Border Rivers, Gwydir, and Namoi valleys predominantly driven by less crop area planted at the beginning of the season, but also worse yield outcomes due to less water availability. In addition, the option has the second lowest economic losses for the Barwon-Darling and Macquarie.
- **The Menindee – 195GL total option** falls in between in terms of economic impact. For the Border Rivers and Gwydir this option represents the second *lowest* economic impact across all options and the second *largest* for the Namoi valley. In contrast, this option has the least impact on the Barwon-Darling.
- **The Fish Migration option** has the most substantial impact on the Barwon-Darling and has the second *largest* impact on the Border-Rivers and Gwydir.

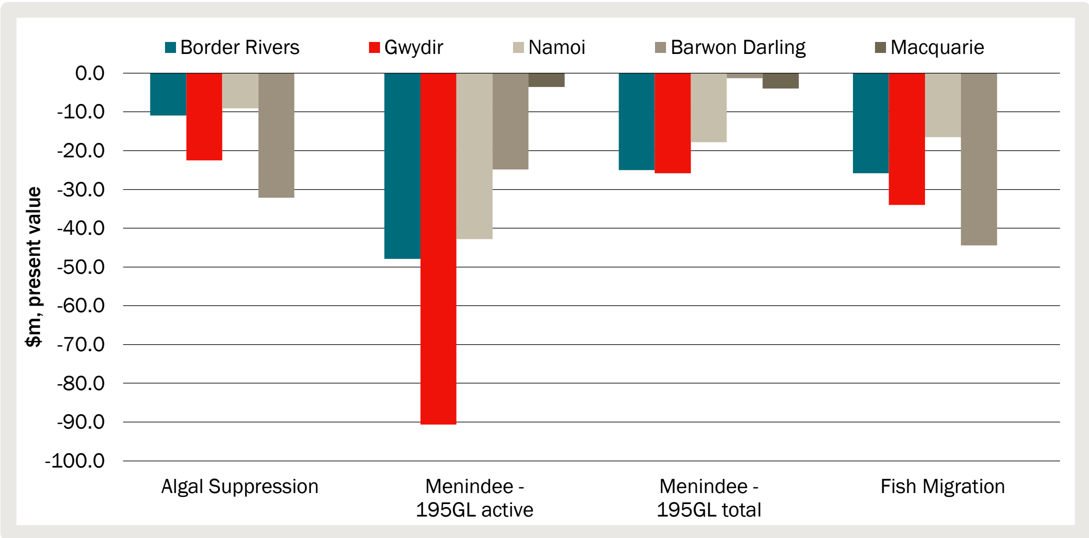
6 This means that each replica receives an equal weighting.

4 Central case results relative to base case– 40 years, present value ($m)

Option	Border Rivers ($m, PV)	Gwydir ($m, PV)	Namoi ($m, PV)	Barwon Darling ($m, PV)	Macquarie[7] ($m, PV)
Algal Suppression	-11.0	-22.5	-9.1	-32.1	NA
Menindee – 195GL active	-47.9	-90.6	-42.8	-24.8	-3.6
Menindee – 195GL total	-25.0	-25.8	-17.8	-1.3	-4.0
Fish Migration	-25.8	-34.0	-16.5	-44.4	NA
Option	**Border Rivers (per cent)**	**Gwydir (per cent)**	**Namoi (per cent)**	**Barwon Darling (per cent)**	**Macquarie (per cent)**
Algal Suppression	-0.4	-0.4	-0.1	-1.2	NA
Menindee – 195GL active	-1.8	-1.6	-0.7	-0.9	-0.1
Menindee – 195GL total	-0.9	-0.4	-0.3	0.0	-0.1
Fish Migration	-1.0	-0.6	-0.3	-1.6	NA

Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

5 Total economic impact against the base case (summer and winter) ($m)



Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

Table 6 summarises the impact (relative to the base case) over 40 years of each proposal on the farmer's planting decision in the beginning of the season for the summer (cotton) and winter season (winter crops):

7 The North-West Flow Plan does not apply to the Macquarie and so that valley was not included in the analysis of the algal suppression and fish migration restriction.

- Overall, the Border Rivers valley is the most impacted valley across all options in terms of changes to the total cotton and winter crop area planted, followed by the Gwydir, Barwon-Darling, and Namoi valleys.
- The Menindee - 195GL active option has (across all valleys) the most substantial impact, followed by the Fish migration option. The Algal suppression option sees the least impact. Note that the Fish migration and Algal suppression option have not been assessed for the Macquarie as the North-West Flow Plan does not apply to that valley.

6 Impact of options on the planting decision for cotton and winter crops (relative to the base case) – 40-year period

Crop type	Option	Border Rivers (per cent)	Gwydir (per cent)	Namoi (per cent)	Barwon Darling (per cent)	Macquarie (per cent)
Summer (cotton)	Algal Suppression	-0.78	-0.24	-0.04	-0.28	NA
	Menindee - 195GL active	-3.77	-2.04	-0.84	-1.70	-0.17
	Menindee - 195GL total	-1.94	-0.98	-0.41	-0.40	-0.10
	Fish Migration	-2.54	-1.18	-0.42	-0.65	NA
Winter (winter crops)	Algal Suppression	-0.46	0.06	-0.13	0.54	NA
	Menindee - 195GL active	-2.96	-1.00	-1.21	-0.34	-0.08
	Menindee - 195GL total	-1.39	-0.80	-0.38	0.49	0.00
	Fish Migration	-1.62	-0.45	-0.47	-0.08	NA

Source: CIE

Table 7 summarises the impact (relative to the base case) over 40 years of each proposal on the yield outcome at the end of the season for the summer (cotton) and winter season (winter crops). Impacts are presented in relative changes (percentage changes to the base case) and summarised separately for the tributary valleys and the Barwon-Darling, as the Barwon-Darling relies on inflows from the tributary valleys.

Summary results for summer (cotton) yield changes

- Tributary Valleys
  - Overall, all tributary valleys show similar impacts when examining the results on an option-by-option basis. The Menindee - 195GL active option has the most substantial impact, followed by the Fish migration option. Other options result in similar changes to yield outcomes.
- Barwon-Darling
  - The Barwon-Darling fares worst under the Fish migration and Algal suppression options, experiencing relatively larger impacts under these options.

Summary results for winter (winter crops) yield changes

- Tributary Valleys

  - The Gwydir and Border Rivers valleys are the most affected across all options in terms of changes to total winter crop yield. There is no impact observed for the Namoi, and the Macquarie shows small positive impacts on the yield. The Fish migration option has the most significant impact across affected valleys, followed by the Menindee - 195GL active option. The Algal suppression option has the least impact.
- Barwon-Darling:
  - The Barwon-Darling is among the most affected valleys in terms of changes to total winter crop yield, particularly under the Fish migration option, followed by the Menindee - 195GL active option. The Algal suppression option has the least impact. The somewhat marginal increase in yield outcome for winter crops is driven by a few extreme events where the water stress coefficient is higher than in the base case towards the end of the season. We note that winter crops are a basket of different crops with different growth cycles and planting and harvesting dates.

7 Impact of options on the yield outcomes for cotton and winter crops (relative to the base case) – 40-year period

Crop type	Option	Border Rivers (per cent)	Gwydir (per cent)	Namoi (per cent)	Barwon Darling (per cent)	Macquarie (per cent)
Summer (cotton)	Algal Suppression	-0.26	-0.33	-0.16	-1.12	NA
	Menindee - 195GL active	-0.70	-0.82	-0.44	-0.53	0.03
	Menindee - 195GL total	-0.40	-0.12	-0.21	-0.06	-0.01
	Fish Migration	-0.26	-0.24	-0.16	-1.41	NA
Winter (winter crops)	Algal Suppression	0.02	-0.35	0.00	-0.95	NA
	Menindee - 195GL active	-0.01	-1.63	0.00	-1.16	0.34
	Menindee - 195GL total	-0.06	-0.93	0.01	-0.58	0.10
	Fish Migration	0.04	-1.95	0.00	-1.55	NA

Source: CIE

Implications of the central case results

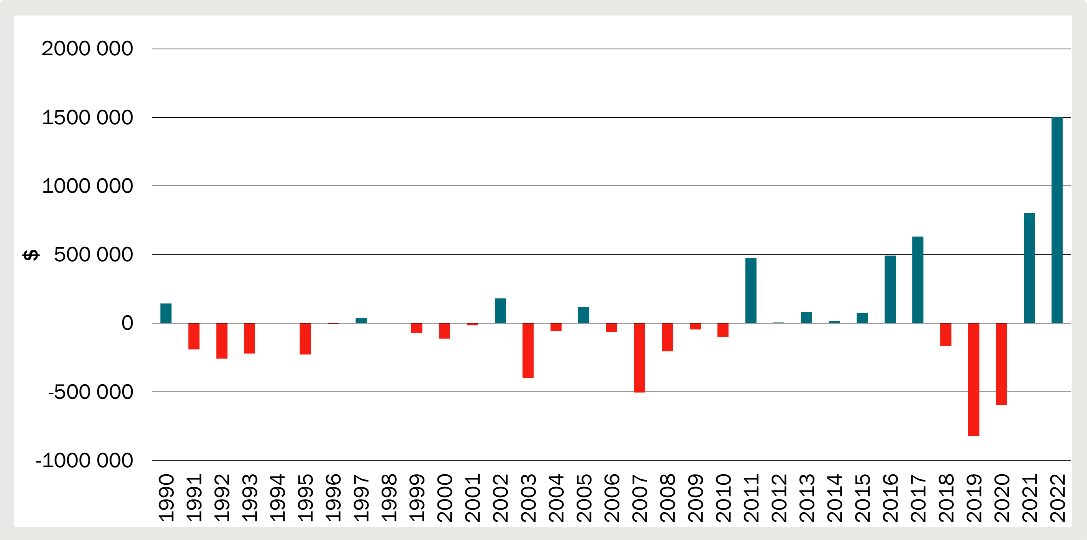
NSW's variable climate and susceptibility to drought have led farmers to adapt by focusing on seasonal crops, investing in technology, and employing improved management practices. However, the region's water-dependent industries face low reliability due to infrequent high flow events and long periods of low flows.

Consequently, these industries heavily rely on high flow years. For example, in the Border Rivers general security B licence s, the majority of water licence s in the region, have an average end-of-year allocation of 35 per cent, making them among the state's least reliable licences. If irrigators have access to supplementary or floodplain flows in the lead up to or during the summer cropping season, they use this and carry over their general security water for future use. This pattern of water use means that droughts that extend beyond 1 to 2 years can result in little to no water being available for agriculture.[8]

This is particularly important for cotton which is a high value crop but with high upfront and ongoing capital cost (e.g., seeds, fertilisers, and water).

Data from ABARES indicates that over the past 33 years average farm business profits in the NSW North-West Slopes and Plains, Central West and Far West varied considerably (chart 8). Overall, the trend shows that farms have the same number of 'good' and 'bad' in terms of farm profit and loss, however, 'good' years disproportionately compensate for years with losses. We note that this is based on the ABARES farm survey which includes all types of farms and is usually skewed towards larger farms, and this may not be fully representative of farms which plant cotton and winter crops.

8 Average farm business profit across affected valleys



Note: This is based on the ABARES farm survey and includes a sample of all types of farms in the NSW North West Slopes and Plains.

Data source: ABARES (2023), Farm data portal, NSW North West Slopes and Plains & Far West & Central West – Farm business profits

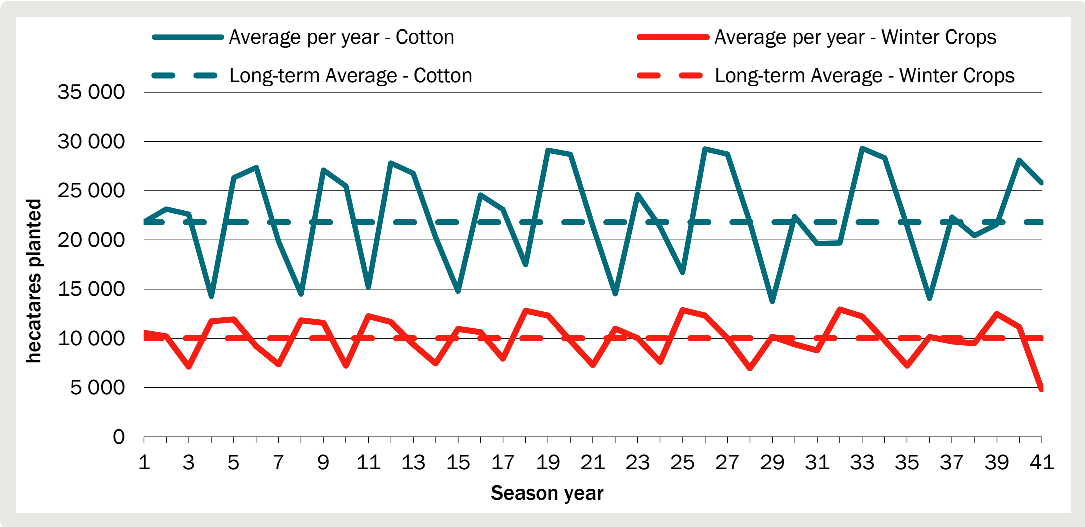
Chart 9 and 10 show the *hectares of crops planted* at the beginning of the summer and winter season and *hectares of crops harvested* at the end of the summer and winter season for the base case of the hydrological output for the Border Rivers valley (a representative valley for most valleys):

- after two above average years, either one or two 'bad' years follow for both cotton and winter crops in terms of both total areas planted (planting decision) and harvested (yield outcome), and
- after an above average cotton season in terms of planting and yield outcome, winter crop planting and yield is usually below average, and vice versa.

8 NSW The Water Group (2022), *Regional Water Strategy Border Rivers,* p.36

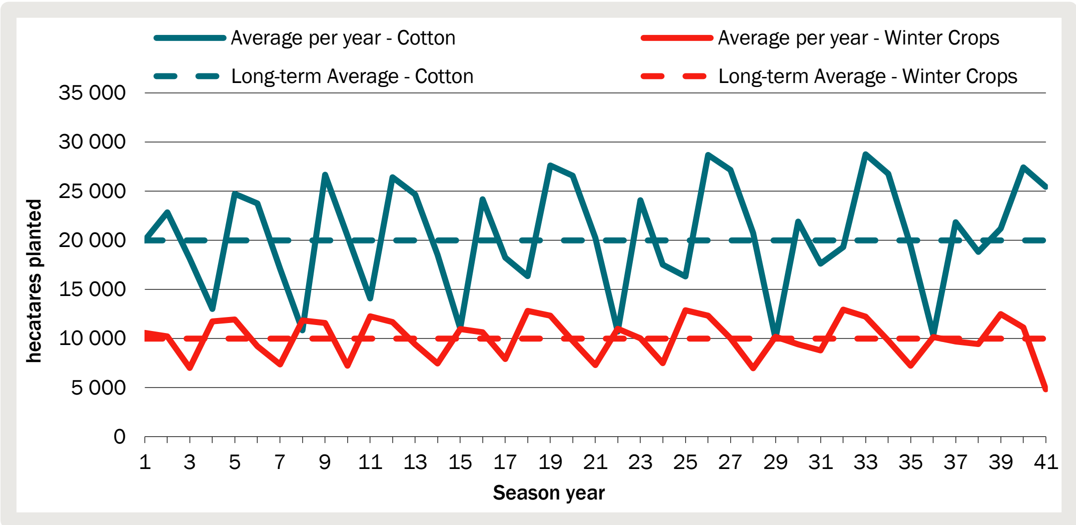
Overall, approximately 55 per cent of all year's show above average crop planting (planting decision) and harvesting (yield outcome). This is line with the observations from the ABARES survey if we assume that below average outcomes would result in farm business profit losses.

9 Hectares of crops planted (planting decision) – base case



Data source: CIE

10 Hectares of crops harvested (yield outcome) – base case



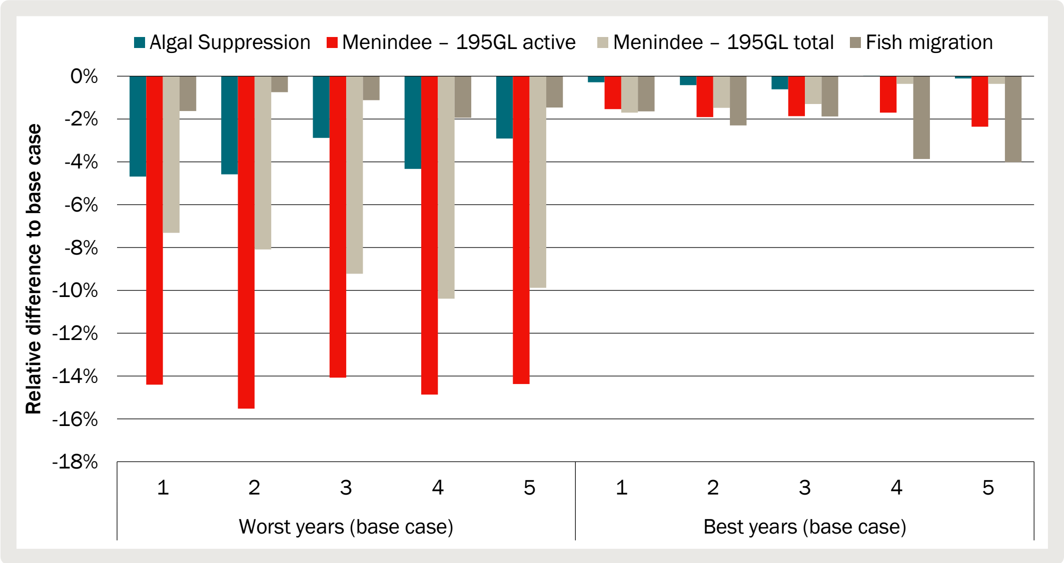
Data source: CIE

One major concern raised by stakeholders was that the economic impact from reducing water access may be more significant at certain times than others.

Generally, the central case results show that in years where crop planting and yield outcomes would already have been *low* are further exacerbated, while in 'good' years we observe very little change from each option. This can also be illustrated graphically for the most impacted valley. For example,

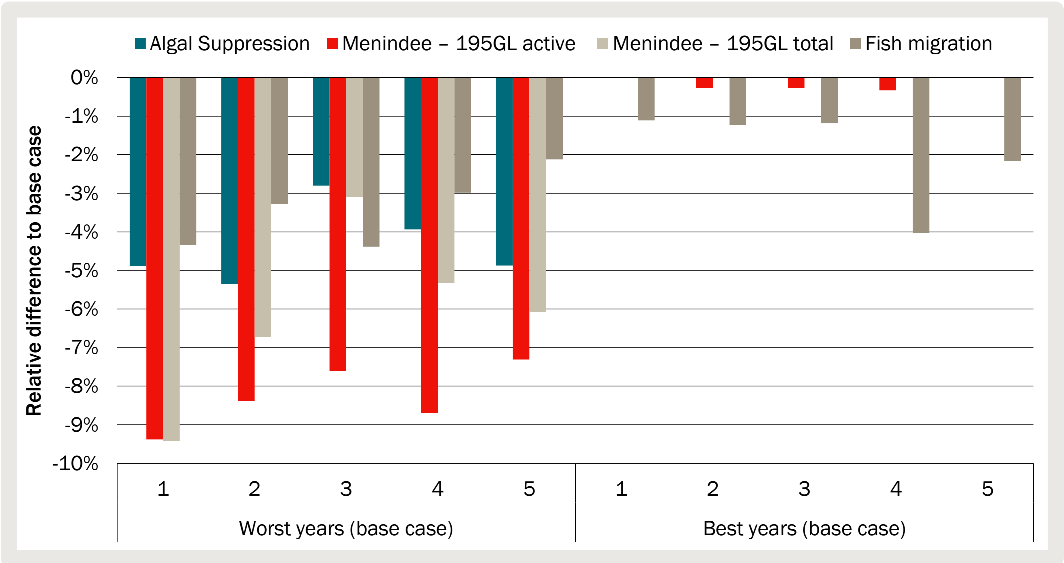
- Charts 11 shows the probability weighted cotton area planted for the five worst and best seasons by option for the Border Rivers (the most impacted valleys in terms of changes to cotton planting), and
- Chart 12 shows the probability weighted cotton area harvested five worst and best seasons by option for the Barwon-Darling (the most impacted valley in terms of changes to cotton yield).

11 Hectares of cotton planted by option – Border Rivers



Data source: CIE

12 Hectares of cotton harvest by option – Barwon-Darling



Data source: CIE

Worst case economic loss

The central case results are based on the probability weighted outcomes in each year observed across the 13 climate scenarios in the hydrological output. Overall, we note significant variations in economic impacts across different climate scenarios and years. Some of the assessed options across the valleys also demonstrate positive economic impacts.

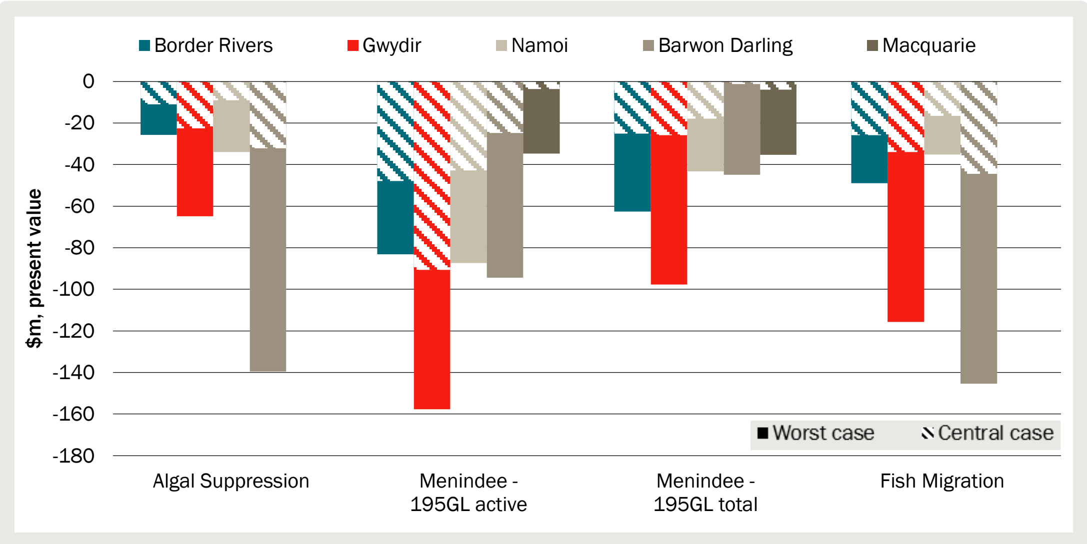
In this section we report the largest economic loss in each year. For some proposals the economic loss relative to the base case is largest in the years with higher water availability, but for other proposals the largest economic loss may occur in drought years.

The worst case in this analysis is the worst observed across the 13 climate scenarios. The results for the worst case can give an indication about the uncertainty (i.e., variability across the climate scenarios) of the central case results which is a probability weighted value across the climate scenarios.

Chart 13 presents the worst-case scenario along with the central case result for each option relative to the base case.

- Overall, the ranking of options by valley does not change.
- We observe for many options across the valley's large variations in economic outcomes (including positive outcomes). This explains partially the large difference between central case and worst-case results for some valleys (the range of outcomes across all climate scenarios is reported for each valley and option in 'Part II – Detailed Economic Analysis Results' of this report).

13 Central versus worst case results – 40 years, present value ($m)



Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

Limitations of this analysis and areas of improvement

There are some limitations with this analysis that should be noted and could be addressed in future work.

In general, this work relies on the output data provided by the Water Group's hydrological modelling.

- Total irrigated crop area planted is provided for each reach (i.e. farm) and can include a variety of crops. For the summer season, we have assumed this is cotton, while we do not know the exact share of cotton on those farms. Similarly, for the winter seasons we note that winter crops are a basket of different crops with different growth cycles and planting and harvesting dates.
  - An area of improvement is to model a variety of crops each season.
- Our analysis of yield reduction during the season due to water stress is based on a modelled mean water stress coefficient or soil moisture index. The mean water stress coefficient is an output of the hydrological model. We note that the hydrological model is not a 'crop model.' This means that the water stress coefficient or soil moisture index is estimated so that water diversions for each farm match past observations.
  - For that reason, we have calibrated a threshold at which water stress occurs so that the base case resembles the average NSW cotton yield of the past 40 years. All options are then assessed against the observed change compared to the base case.
  - An area of improvement could be to use regional yield data to calibrate the model.
- The hydrological model used relies solely on a water balance approach to estimate crop outputs (hectares planted and water stress coefficient). It assumes crop water demands relative to available water and continues to meet daily demands until water depletion. However, it should be noted that it does not consider the diverse strategies employed by irrigators to manage water during dry conditions, such as skip-row irrigation or delaying irrigation water application.
  - The economic model uses outputs from the hydrological model, as such this shortcoming would need to be addressed in the hydrological modelling.
- This analysis relies on probability weighted impacts. It is important to recognise that the timing of water restrictions can significantly affect business viability, particularly for irrigation enterprises. For instance, during periods of extended drought, brief relief periods, like in 2005, allowed businesses to generate crucial cash flow, sustaining operations and staff wages during subsequent dry spells. Restricted access during these critical intervals, typical after prolonged droughts, could disproportionately impact businesses beyond what probability-weighted impacts suggest.
  - To address this, we have presented the results for the worst case as this can give an indication about the uncertainty (i.e., variability across the climate scenarios) of the central case.

- Crop damage from water deficiency is based on generalised damage curves for cotton and irrigation crops.
  - In reality crop damages will differ by region and the type of crop. This analysis uses estimates of yield reductions for cotton during stress periods, developed by CSIRO, as well as general crop production impacts provided by specialists, including the Resource Management Officer from the Department of Primary Industries. There is not information about regional difference in crop productivity available at this time. This is an area that could be improved.
- Floodplain harvesting and unregulated contributions have not been considered
  - The majority of this analysis does not include restriction on floodplain harvesting. As this has potential to provide a large volume of water, this could considerably shorten the length of time that restrictions are necessary to achieve targets, particularly for the resumption of flow rule. This means that some of the measured economic impacts could be overstated.

PART I

Introduction and Methodology

1 Introduction

The CIE has been commissioned by the Water Group in the NSW Department of Climate Change, Energy, the Environment and Water (the Water Group) to assist with the development of a methodology that could be used to assess the economic consequences of implementing two actions from the Western Regional Water Strategy. Implementing these actions may reduce long-term average diversions for irrigators in the Barwon-Darling, Border Rivers[9], Gwydir, Namoi, and Macquarie valleys (hereafter the Valleys). The quantification of these actions would be provided to the Connectivity Expert Panel before the publication of its Interim Report[10]. The final recommendations of the Expert Panel will be subject to economic quantification as well.

The Water Group is interested to understand the economic impact of these actions and how it is influenced by the timing of when water take is restricted.

The Western Regional Water Strategy includes actions[11] to further investigate two connectivity proposals that could be implemented in water sharing plans:

- The first proposal are critical dry condition triggers that protect the first flow of water after an extended drought by restricting supplementary, floodplain harvesting, and B Class and C Class licence s in specific valleys.
- The second proposal is the finalisation of the review of the North-West Flow Plan, which restricts supplementary, floodplain harvesting, and B and C Class access in specific valleys to meet algal suppression and fish migration objectives.

To date, the Water Group has assessed economic impacts of the connectivity proposals based on long-term average annual changes to water availability for licence holders, and how this translates to economic outcomes[12] [13]. During consultation on the Draft Western Regional Water Strategy, the department heard that long-term average economic assessments will not capture the real economic impacts. This is because a volume of water may be more valuable depending on the

9 This analysis only covers impacts in the NSW component of the Border Rivers catchment.

10 Connectivity Expert Panel Interim Report can be accessed at Connectivity Expert Panel | Water (nsw.gov.au)

11 Refer to actions 3.1 and 3.2 in the Western Regional Water Strategy which can be accessed at Western Regional Water Strategy | Water (nsw.gov.au)

12 Western Regional Water Strategy: Attachment 3 (nsw.gov.au), p. 11

13 Regional Water Strategy - Western - Attachement 4 (nsw.gov.au), p. 11

climate cycle (for example after an extended drought to reduce the risk of businesses failing) or at a particular time of the cropping cycle (for example, when annual crops such as cotton are flowering or to finish off a crop).

Therefore, we have developed an economic model that utilises the daily time steps of the hydrological model. It translates the hydrological modelling into economic outcomes by incorporating farmers' planting decisions and in-season water availability, providing a more accurate reflection of real-world conditions. It also applies yield damage curves for different cropping stages, offering a detailed measure of the time value of water and its impact on crop yield.

Connectivity proposals

The Western Regional Water Strategy analysed four different options which will impact farmers across all Valleys (table 1.1):

- Critical dry conditions triggers (first flush protections)
  - Menindee – 195GL active[14]: access to supplementary and B and C Class licences is restricted when storage in the upper Menindee Lakes (Wetherell, Pamamaroo, Tandure) is below 195 GL active. Access is permitted in accordance with water sharing plan rules when active storage in the upper lakes returns above 250 GL active;
  - Menindee – 195GL total: access to supplementary licences and B and C Class licences s is restricted when total storage across all Menindee Lakes is below 195 GL. Access is permitted in accordance with water sharing plan rules when total storage in the lakes returns above 250 GL;
- North-West Flow Plan
  - Algal Suppression: access to supplementary, and B and C Class licences is restricted to preserves a flushing flow event in dry years to break up and disperse algal blooms access;
  - Fish migration: access to supplementary, and B and C Class licences is restricted to preserve events needed for fish dispersal, spawning and migration at appropriate times of the year).

14 Active storage is the water in storage that is able to be released and excludes the “dead” storage which cannot be released. Most storages have a small amount of dead storage below the outlet point that remains after the storage has been drained through the available outlets.

1.1 Description of options analysed

Target	Objective	Trigger for implementing restrictions	Trigger for lifting restrictions
Algal suppression	Preserve a flushing flow event in dry years to break up and disperse algal blooms	To achieve a flow of 3,000 ML/day for 7 days at Wilcannia if flows are below the following triggers throughout the spring/summer period: ▪ Walgett – 250 ML/day ▪ Brewarrina – 510 ML/day ▪ Bourke – 450 ML/day ▪ Wilcannia – 350 ML/day.	To achieve a flow of 3,000 ML/day for 7 days at Wilcannia if flows are below the following triggers throughout the spring/summer period: ▪ Walgett – 250 ML/day ▪ Brewarrina – 510 ML/day ▪ Bourke – 450 ML/day ▪ Wilcannia – 350 ML/day.
Menindee 195 GL – total	Provide for 6 months critical human and environmental needs in the Lower Darling	When total storage volume in Menindee Lakes falls below 195 GL	When the total storage volume in Menindee lakes rises above 250 GL (this allows for 60 GL to restart the lower Darling)
Menindee 195 GL – active	Provide for 12 months critical human and environmental needs in the Lower Darling	When active storage volume in the upper Menindee Lakes falls below 195 GL	When the active storage volume in upper Lakes rises above 250 GL (this allows for 60 GL to restart the lower Darling)
Fish migration	Preserve events needed for fish dispersal, spawning and migration at appropriate times of the year	To achieve a flow of: ▪ 14,000 ML/day at Brewarrina for five days, and ▪ 10,000 ML/day Bourke for five days	To achieve a flow of: ▪ 14,000 ML/day at Brewarrina for five days, and 10,000 ML/day Bourke for five days

Source: The Water Group

This report outlines the economic impact on farmers of restrictions to supplementary and B and C Class water licence access[15] from each of the four connectivity proposals, while examining how the proposals change farmers decisions and how the restricted water take during the season will impact the yield outcomes of crops in the region.

Therefore, the net economic value lost or gained due to the changes inflicted by the proposals can be narrowed down to two main components:

- **Farmers planting decision** at the beginning of the season, which impacts the total area of crops planted (hereafter referred to as the 'planting decision' or 'crops planted'.
- **Water availability** during the season, which impacts the yield outcome and total harvested area at the end of the season (hereafter the 'yield outcome' or 'crops harvested').

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15 The restrictions are also intended to apply to floodplain harvesting licences. However, impacts on these licences is not included in this analysis as they were unable to be assessed by the hydrological model at the time this work was done in 2022.

2 How will this impact farmers?

Impact of proposals on water availability

This economic analysis primarily focuses on assessing the impact of changes in water availability on total crop area planted and yield outcomes during the season. However, it is important to understand the underlying drivers behind these changes.

The proposed options will influence water availability throughout the season, thereby affecting farmers' decisions at the beginning of the season as they evaluate the expected water supply. But options will also impact the actual water availability during the season. These impacts are interconnected, as increased water usage during the season can deplete on-farm storages, subsequently influencing a farmer's planting decision for the following season, and vice versa. The change in total area planted is an indirect outcome influenced by farmers' expectations regarding actual and anticipated water availability.

In order to gauge the immediate or direct effects of the options, we will examine the following indicators:

- Access to supplementary (Border Rivers, Gwydir, Namoi and Macquarie valleys) and B and C Class licences (Barwon-Darling)
- Water diversions to the crops.

By analysing these indicators, we can gain insights into the immediate impacts resulting from the proposed options.

The Water Group has undertaken hydrological modelling of the past 130 years and reshaped output results into 13 climate scenarios each covering a 40-year period. The change to supplementary water access and water diversion is presented as long-term average diversions. For each climate scenario the sum across all years is divided by the number of years (i.e., 40 years), and the average across all climate scenarios is taken.

The table below shows the changes in long-term annual average water access, specifically in the supplementary and class B and C licence categories (measured in GL/year), across different valleys and options when compared with the base case, i.e., no change or business as usual. It is evident that all valleys experience impacts of varying degrees due to these options. Notably, the Menindee – 195GL active and Fish Migration options consistently stand out as having the greatest impact on water diversions.

Note that the North West Flow Plan does not apply to the Macquarie valley, so the Algal suppression and Fish migrations options have no impact in that valley.

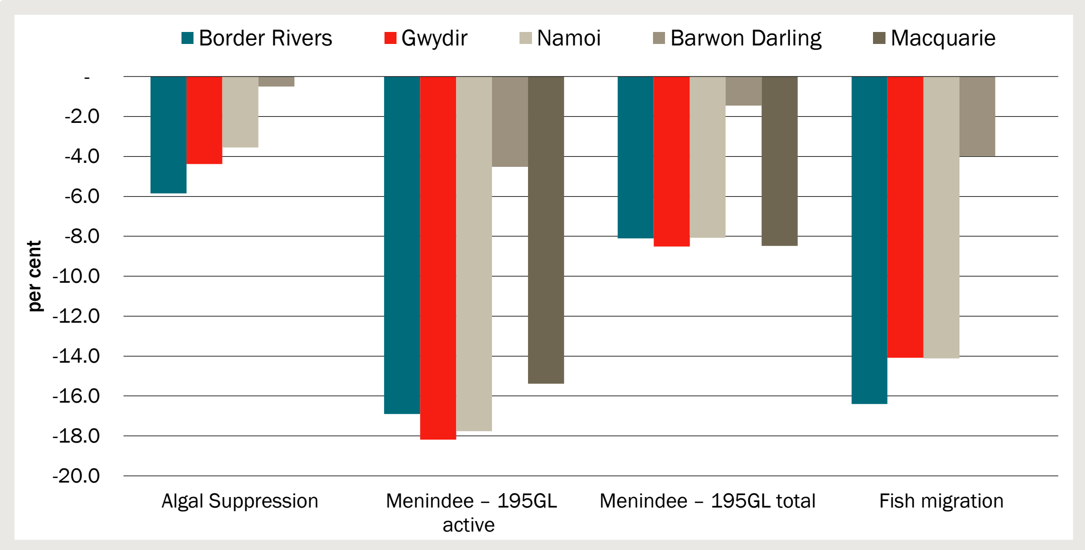
2.1 Long-term annual average supplementary/class B&C water access licences and diversion relative to the base case, by option

Valley	WAL affected	Base Case (GL/year)	Algal Suppression (GL/year)	Menindee – 195GL active (GL/year)	Menindee – 195GL total (GL/year)	Fish migration (GL/year)
Total WAL access						
Border Rivers	Supplementary	71	67	59	65	59
Gwydir	Supplementary	92	88	75	84	79
Namoi	Supplementary	49	48	41	45	42
Barwon Darling	Class B & Class C	127	126	121	125	122
Macquarie	Supplementary	15	NA	13	14	NA
Change in WAL access						
Border Rivers	Supplementary	NA	-4.2	-12.0	-5.8	-11.7
Gwydir	Supplementary	NA	-4.0	-16.7	-7.8	-12.9
Namoi	Supplementary	NA	-1.8	-8.8	-4.0	-7.0
Barwon Darling	Class B & Class C	NA	-0.6	-5.7	-1.8	-5.1
Macquarie	Supplementary	NA	NA	-2.3	-1.3	NA

Source: The Water Group

Although absolute water diversions vary between valleys depending on the chosen option, the relative changes exhibit more uniformity, with the exception of the Barwon-Darling valley (chart 2.2). For instance, the Menindee – 195GL active option consistently reduces supplementary water access by approximately 16 to 18 percent relative to the base case across all valleys. Similarly, the Menindee – 195GL total option shows a nearly identical relative impact, resulting in an 8 percent reduction compared to the base case across the various valleys.

2.2 Relative change in supplementary/class B&C water access



Data source: The Water Group

As outlined, the proposed connectivity options have direct consequences on the supplementary, and B and C Class licence access which will impact how farmers irrigate their crops, but also farmers' decision-making processes.

The direct effect of restricted licence access will be a change in the on-farm storage volume which will indirectly affect how much water farmers can divert to the crop. While farmers do have alternatives, e.g., general security licence access in the regulated valleys and rainfall, overall water availability will most likely decrease.

This will have an effect on farmers' decision-making processes. In the beginning of the season, farmers will make a planting decision on the amount of area to be cropped. This process includes the *expected* water availability (water access licence s and climatic conditions) and *actual* water availability (on farm storage at the beginning of the season), and the farmer's willingness to take risks.

Both *actual* and *expected* water availability might be impacted by restricting supplementary and B and C Class licence access as expected water availability is lower and actual water availability might be affected due to higher water take in the pre-season (in turn caused by restricted water access). This potential overall reduction in water availability will lead to a more constrained planting decision by the farmer.

All of this will have an impact on the total water that is diverted to the crop.

The table below shows the changes in long-term annual average water diversion to crops (measured in GL/year), across different valleys and options when compared with the base case (i.e. no change or business as usual).

The change in water diversions to crops across different options and valleys mirrors the trends seen in changes to supplementary and B and C Class water access. However, it is noteworthy that the absolute change in crop water diversions is less pronounced compared to the changes in supplementary and B and C Class water access. This suggests that either farmers have access to alternative water sources that compensate for the reduced water access, or they adapt their planting practices, leading to a reduced overall water take. This will be the key subject of the economic analysis.

2.3 Long-term annual average supplementary/class B&C water access and diversion relative to the base case, by option

Valley	Base Case (GL/year)	Algal Suppression (GL/year)	Menindee – 195GL active (GL/year)	Menindee – 195GL total (GL/year)	Fish migration (GL/year)
Total diversion to crops					
Border Rivers	123	121	117	120	119
Gwydir	237	235	230	234	232
Namoi	164	163	160	162	161
Barwon Darling	125	124	122	124	123
Macquarie	239	NA	238	239	NA
Change in diversion to crops					
Border Rivers	NA	-1.5	-5.6	-2.6	-3.8
Gwydir	NA	-1.5	-6.9	-2.9	-4.5
Namoi	NA	-0.8	-3.6	-1.7	-2.8
Barwon Darling	NA	-0.5	-2.7	-0.6	-1.9
Macquarie	NA	NA	-0.6	-0.4	NA

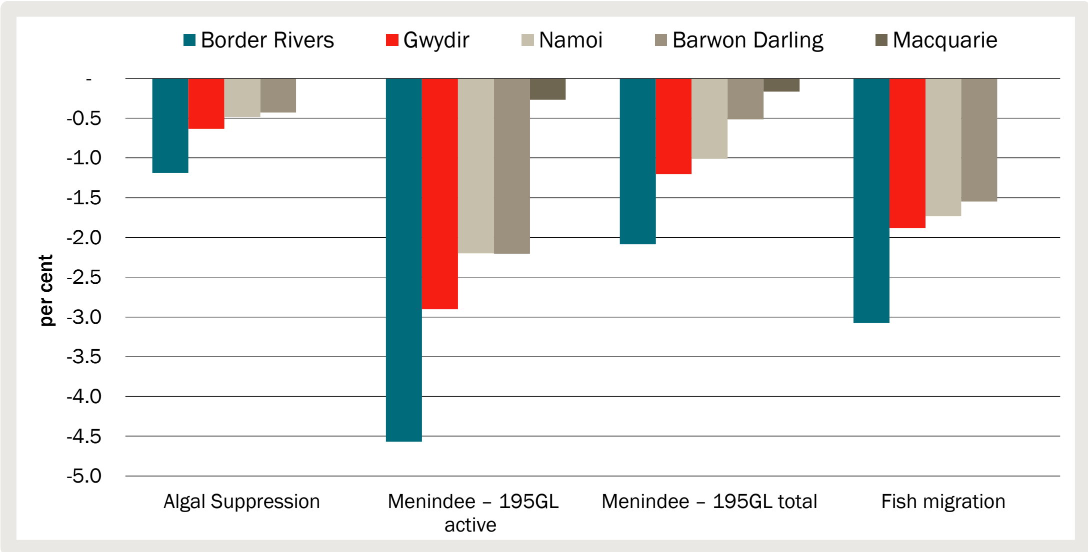
Source: The Water Group

As previously outlined, the relative changes in supplementary and B and C Class water access, relative to the base case, showed a degree of consistency across the various valleys and options. However, examining the changes in water diversion, relative to the base case, shows distinct impacts on different valleys, as shown in chart 2.2.

For instance, the Border Rivers valley experiences the most pronounced relative reduction in water diversion across all options, while other valleys demonstrate comparatively lower reductions.

Across options, the Menindee – 195GL active option consistently stands out as having the most substantial relative reduction in water diversion to crops across all valleys. This underscores the consistently significant impact of this option on crop water access throughout the regions. The Algal suppression option generally leads to a moderate reduction in crop water diversion across all valleys. This implies that, while it does indeed have an impact, its effects are relatively less severe when compared to the other available options.

2.4 Relative change in water diversion to crops



Data source: The Water Group

Decision making regarding cotton irrigation

Cotton is the main high-value crop grown in the Border Rivers, Barwon-Darling, Gwydir, Macquarie, and Namoi valleys. This section will outline the decision-making process before and during the season of cotton farmers. The implications from this decision making have fed directly into our methodology and approach to estimate the economic impact of the connectivity proposal.

Managers of integrated cotton farms maximise gross margins, or crop profitability, (or reduce potential losses) by changing decision-making in response to the availability of water (allocation announcements and on farms storage volumes) and seasonal forecasts.

Cotton is a high value summer crop and is input intensive in variable inputs of fertiliser, and irrigation and capital infrastructure especially in irrigation areas. The capital includes laser-planed blocks, head and tail ditches, channels and on-farm storage (ring tanks) which are designed to not only to store water from the system but capture runoff from tail drains and storms. Typically, these farms also require significant management expertise and often use farm advisors for crop nutrition, pest management and water use efficiency.

Cotton is regarded as a water sensitive crop where yield can fall dramatically without minimum soil moisture. This yield decline in combination with high variable input costs and large capital costs results in significant financial risks for growers. This is compared to more ‘reliable’ and lower gross margin summer crops such as sorghum where potential yield declines are proportionally less than for cotton —but with lower gross margin on average. This risk results in over 75 per cent of cotton in NSW typically being irrigated.

Dryland cotton is viewed as a highly risky crop, in terms of profitability, due to the impact of low or poorly timed rainfall on yields (and, therefore, gross margins). Typically, areas sown to dryland cotton will fluctuate widely from year-to-year depending on rainfall and cotton prices. While dryland cotton is often planted as a speculative crop, in anticipation of a better than average rainfall season, it can also be the result of the decision not to irrigate some blocks due to seasonal conditions and the availability of water from the system.

Pre-season planning

Planting decisions at the beginning of the season (around August or earlier) should be made on the basis of the remaining soil moisture (from the previous crop) and the expected water balance. This balance would comprise of:

- judgements on the upcoming rainfall season — where summer storms are crucial
- announcements of the proportion of the allocation that is likely to be delivered by the system after:
  - accounting for transmission losses from evaporation and seepage in both storages and channels
  - factoring any scope to buy temporary water from the market
- water from other sources including that remaining in on-farm storages and from groundwater. [16]

This water budget, for an average season, would largely determine the area of cotton planted — this area would be expected to match the blocks that have been prepared for cotton (capable of being irrigated from farm structure) less blocks that are fallowed or have a break crop. This step is crucial in ordering other inputs (such as fertiliser and crop chemicals) and organising the logistics for machinery, equipment and personnel available (especially in the case of irrigators in the Barwon-Darling).

Capacity to adapt through the season

As the season progresses, and the water balance becomes more certain, decision-makers have a range of options available to them with the objective of either:

- optimising the amount of moisture available to the area planted;
- limiting or minimising the amount of stress on the entire crop or part of the crop when there is shortfall; and
- taking advantage of conditions if they improve through the season.

Typically, on-farm storages provide managers with some capacity to smooth-out water availability over the short term especially when the timing of delivery from the river is uncertain due to high demand. Beyond this, managers have a range of options that include:

16 While water can be stored in ring-tanks and ditches, the timeframe will also depend on losses.

- split application of inputs — for example, there may be a partial application of inputs (particularly) fertiliser at planting and the remainder spread when there is more certainty about conditions.
- reduce or stop application of inputs to paddocks, including irrigation, which includes:
  – sacrificing blocks by no longer provide inputs including irrigation
  – converting the block to a dryland configuration with lower input using alternative row configurations such double skip, alternative row and super single. [17]

The candidate blocks for these actions are often the poorest performing paddocks in terms of yield and water use efficiency or those that involve the greatest transmission loss (that is, they are the furthest from the river or are supplied by leaky channels).

It is noted that these options, such as planting with the option to cut out rows later, are often not preferable. Inputs in the skip row have been wasted, and remaining plants may suffer more moisture stress than would have otherwise been the case, potentially impacting yields and fibre quality.

However, these actions would effectively maintain optimal yield, or minimise yield loss, in the core crop. Therefore, there are the range of tradeoffs, at the margin, faced by decision-makers with a crop under moisture stress. This underlies the importance of soil moisture monitoring, particularly automated.

17 We note that planting with the option to cut-out rows later is not preferable as inputs in the skip row have been wasted and remaining plants suffer more moisture stress than would have otherwise been the case.

3 Methodology

This chapter outlines on a high-level the methodology used to understand and estimate the economic impacts of the proposals on farmers. In addition, we present a methodology to calculate potential compensation for the economic loss suffered.

More detail can be found in the technical appendix A.

Methodology to understand the economic impact on farmers

The Water Group previously relied on an economic model that utilises daily hydrological modelling, which subsequently aggregates daily data into monthly data. Consequently, this approach results in the loss of certain valuable information, such as the ability to distinguish between periods of consecutive dry days, whether they occur, for example, as a continuous 10-day span or are spread out across the entire month.

In the model the valuation of water is based on a dollar per ML estimate. This approach is well suited to measure the benefits for town water supply (using the willingness to avoid water restrictions) and to agricultural/other commercial water use (using the marginal value of water for these users) but will be revisited under this model extension.

The main focus of the connectivity proposals are supplementary licences in the tributary valleys and class B and C licences in the Barwon Darling. These licences are extracted from flows that enter the system below the headwater storages and so are opportunistic in nature and usually not used to irrigate perennial crops. This analysis, therefore, focuses on two main annual crop types:

- Cotton in summer, and
- Crops such as wheat in winter (hereafter: winter crops).

The economic value lost due to the changes in the dry conditions trigger can be narrowed down to two main components, **farmers' planting decision** at the beginning of the season and **water availability** during the season (chart 3.1):

1. The value of lost output due to changes in the planting decisions of farmers:
   a) This is a direct output of the hydrological modelling. The estimated total crop area planted at the *beginning of the season* incorporates a risk function of farmers, available water and expected available water.

b) The value lost is then the difference between the crop area in the base case and the option times the value of the crop less of avoided input costs from reduced planting (table 3.2).

2 The value of lost output due to changes in water availability during the season affecting the yield of the crop.

a) The total value of harvested crops is reflective of the yield outcome at the end of the season. If the farmer is not able to divert enough water to the crop, the crop experiences water stress and the farmer will achieve an average or below average yield outcome and vice-versa.

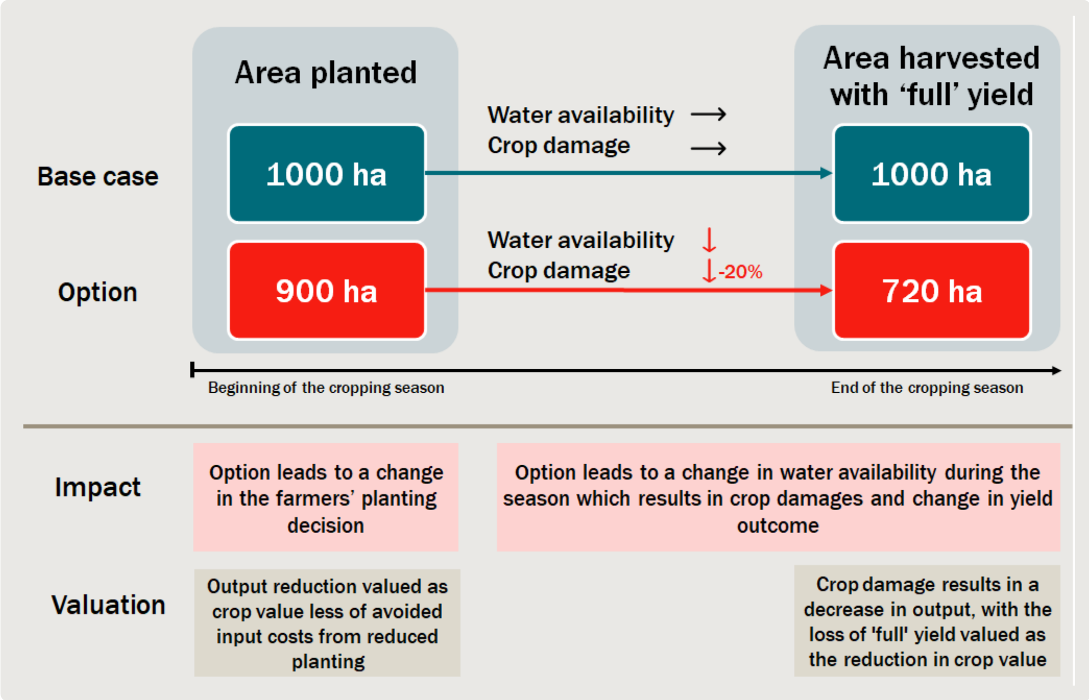
b) This is based on the water stress coefficient or soil moisture parameter estimated in the hydrological modelling. The water stress coefficient is based on the soil moisture content (daily) and triggers crop water diversions in the hydrological model. We utilise this water stress coefficient to make inferences about the crop damage and yield of the crop at the end of the season. To meet the objective of this analysis, economic impacts are only measured for outcomes below the average yield (see appendix A for a detailed explanation of our methodology and assumptions). This means, for example:

- if the water stress coefficient is *not below* the calibrated threshold at any time during a season, total area planted will be the same as total area harvested, which implies the yield outcome is either at the average or above.
- if the water stress coefficient is *below* the calibrated threshold for some observations during a season, the total area planted will not be the same as total area harvested, which implies the yield outcome is below the average.

c) This approach effectively measures the time value of water as the model applies a yield damage curve for different stages of the cropping cycle. The value lost is then the difference of the modelled yield after accounting for yield losses during time of water stress multiplied by the crop value (table 3.2).

d) The analysis is based on a regional level as actual yield data has been used to calibrate the outcomes of the hydrological model. If actual yield data were available on a farm level, this analysis could be further refined.

3.1 Illustrative example to estimate the impact of dry conditions trigger



Data source: CIE

3.2 Crop value and input cost by crop type

Crop type	Source	Crop value ($2023/ha)	Input cost ($2025/ha)
Cotton	Weighted average of cotton income and input cost (2009-2021)	6,723	4,935
Winter Crop	Weighted average of NSW cropping income and input cost (1999-2021)	1,420	1,207

Source: CRDC and Boyce CA (2021), *Australian Cotton Comparative Analysis 2021;* CRDC and Boyce CA (2012) *Australian Cotton Comparative Analysis 2012*; ABARES (2021-22), *Financial performance of cropping farms*

Sensitivity analysis

A critical aspect of performing economic analysis is checking the robustness of the estimates, especially when there is uncertainty related to specific parameters. Sensitivity analysis is a systematic process by which the key results of the analysis are tested based on a variety of alternate inputs.

Some relevant variables to sensitivity test include:

- alternative discount rates – this includes using discount rates other than the standard 5 per cent. NSW Treasury advised sensitivity test discount rates of 3 and 7 per cent.
- alternative value assumptions. Crop prices are highly variable over time due to a variety of reasons. For the purpose of this analysis, we have used a weighted

average over the past years for both cotton and a basket of winter crops. This assumption is tested by using a 20 per cent uplift and downlift to the used values, respectively.

- alter the threshold of the water stress coefficient. This is a critical parameter in the analysis of the project. The threshold was calibrated against real NSW cotton yield data over the past 20 years.
  - We have *not* been able to obtain valley specific cotton yield data which would allow for a more precise calibration and, therefore, have not tested alternative parameter values.

PART II

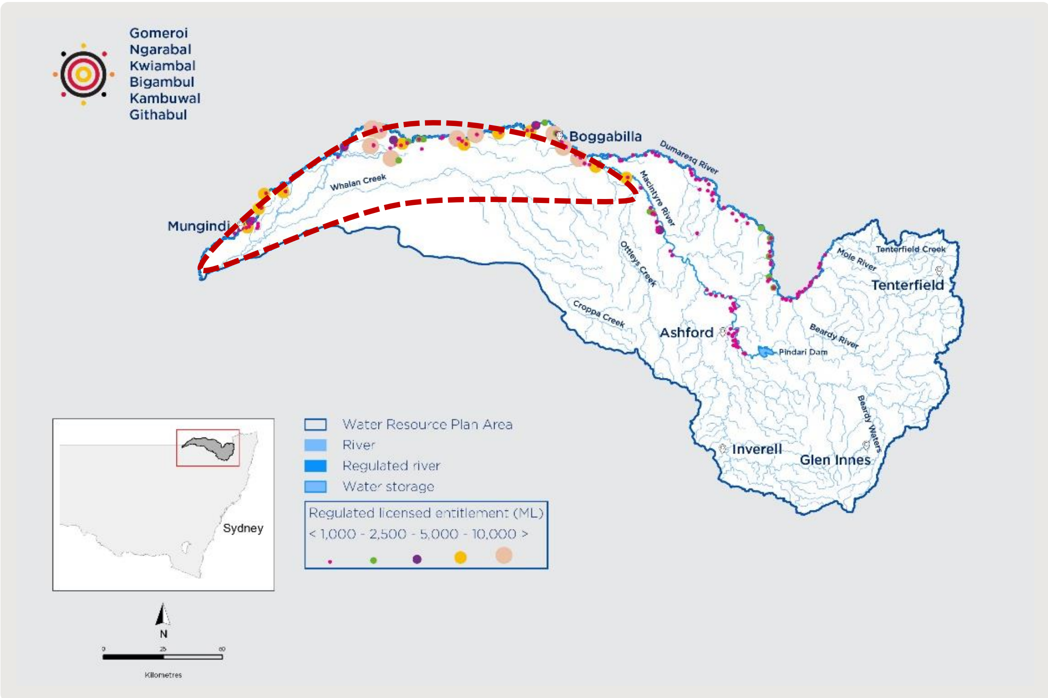
Detailed Results of the Economic Analysis

4 Border Rivers

The following chapter summarise the economic impacts of the proposed connectivity proposals across the Border Rivers valley relative to the base case. The reaches of the Border Rivers valley where supplementary water access licenses are likely to be impacted by these proposals are indicated by the circled area in the map below.

The economic analysis is based on the hydrological multi-climate scenarios outputs and the methodology to estimate the economic impact outlined in the previous chapter. The hydrological modelling is based on the past 130 years and output results have been reshaped into 13 replicate outputs each covering a 40-year period.

4.1 Border Rivers impacted reaches



Data source: The Water Group

Economic base case

The base case is a continuation of the current water-sharing plan rules and represents business-as-usual.

Value of planted crops at the beginning of the season

In the base case, a long-term average of 22 309 hectares of cotton are planted each season in October with a value of $150.0 million per season. Overall, the total average cotton area planted ranges between 13 746 and 29 307 hectares with a value of $92.4 to $197.0 million (chart 4.3).

For winter crops we observe a long-term average of 9 979 hectares are planted each season in May with a value of $14.2 million per season. Overall, the total average winter crops planted ranges between 4 809 and 12 943 hectares with a value of $6.8 to $18.4 million (chart 4.4).

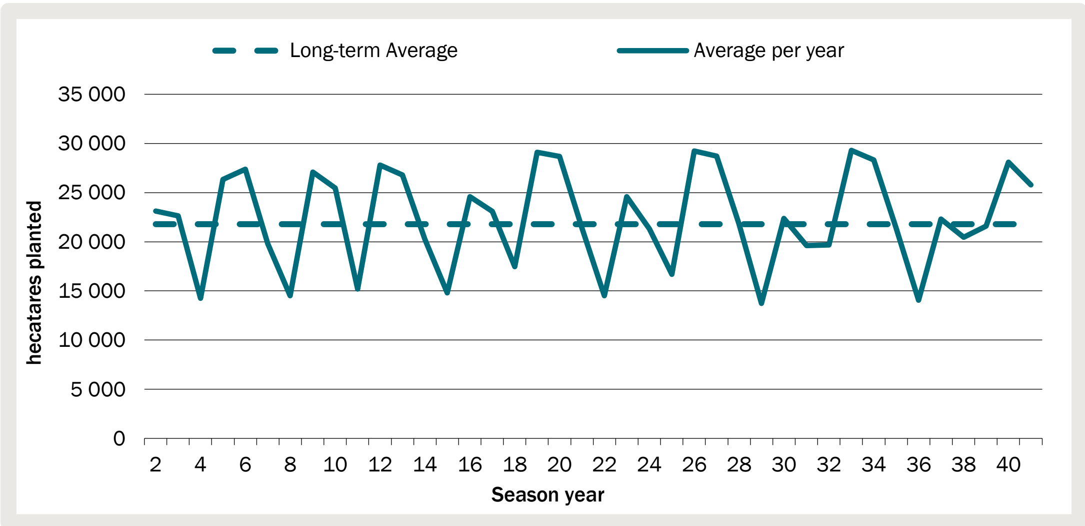
This shows the large variability depending on the available water, in particular for cotton. However, there are also more extreme years recorded across the climate scenarios (table 4.2).

4.2 Summary statistics cotton and winter crops planted per season (base case) – Border Rivers

Crop type	-	Hectares planted (ha)	Value of crop ($m, real)
Cotton	Min	13,746	92.4
	Long term average	22,309	150.0
	Max	29,307	197.0
Winter crops	Min	4,809	6.8
	Long term average	9,979	14.2
	Max	12,943	18.4

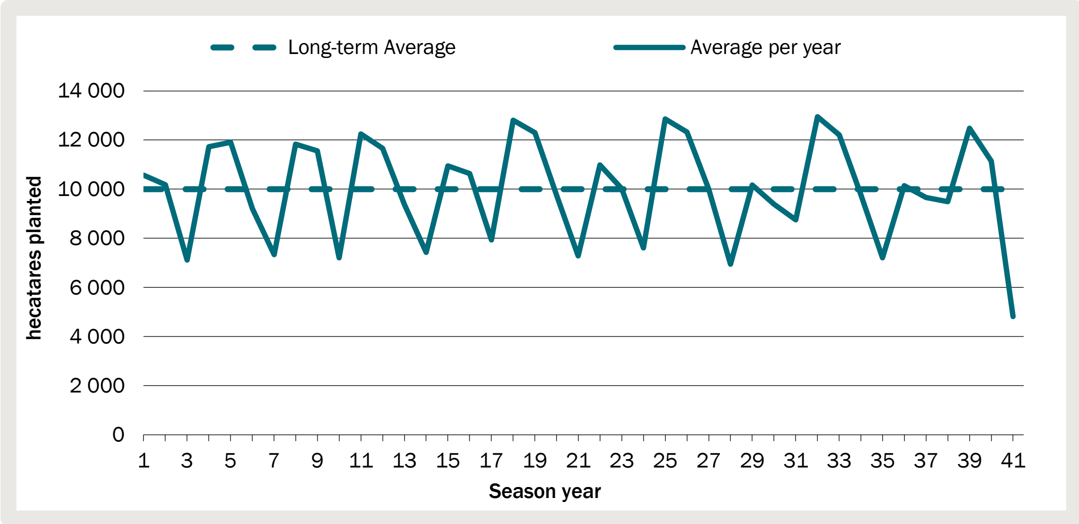
Note: Minimum and maximum values are based on the worst and best season recorded across years.
Source: CIE

4.3 Cotton planted by season (base case) – Border Rivers



Note: Season year 1 starts in April and ends in September; therefore, no cotton planting is recorded
Data source: CIE

4.4 Winter crops planted by season (base case) – Border Rivers



Data source: CIE

Value of harvested crops at the end of the season

In the base case, a long-term average of 22 309 hectares of cotton are planted and 20 417 hectares harvested each season with a value of $137.3 million per season. This means that in years where cotton experiences water stress the probability-weighted outcome is 8.5 per cent lower (table 4.5 and chart 4.6). Across all years and climate scenarios, we observe that in one third of the observations some loss occurs due to water stress and in two thirds of the cases no loss is recorded. This is broadly in line with the expectation that farmers require more 'good' years to absorb losses from 'bad' years.

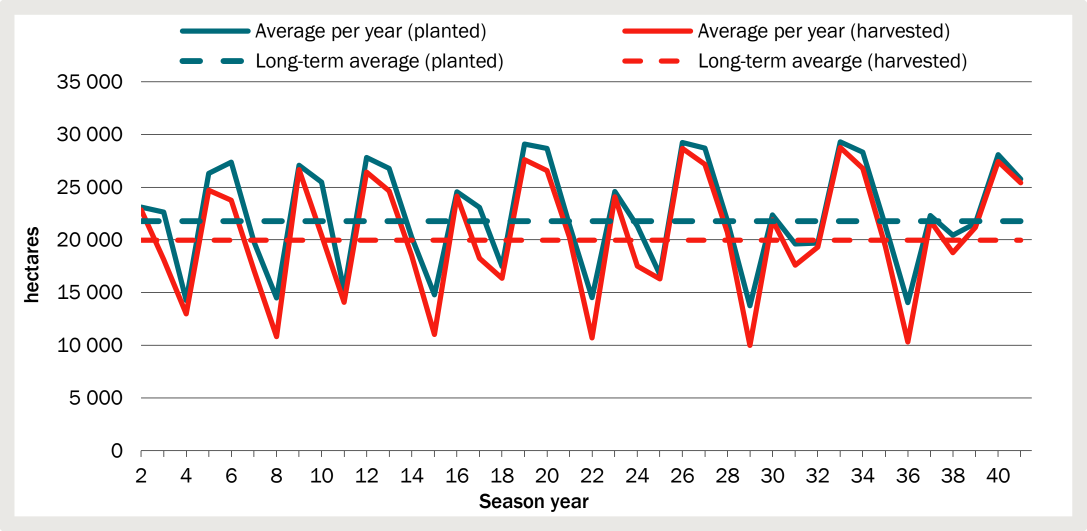
In the base case, a long-term average of 9 979 hectares are planted and 9 969 hectares are harvested each season with a value of $14.2 million per season. This means that in years where winter crops experience water stress the probability-weighted outcome is 0.1 per cent lower (table 4.5). This is much lower compared to cotton.

4.5 Long-term average cotton and winter crops planted and harvested (base case) – Border Rivers

Crop type	Hectares planted (ha)	Hectares harvested (ha)	Value of crop planted (ha)	Value of crop harvested (ha)	Difference (per cent)
Cotton	22,309	20,417	150.0	137.3	- 8.5
Winter crops	9,979	9,969	14.2	14.2	- 0.1

Source: CIE

4.6 Cotton planted versus harvested hectares (base case) – Border Rivers



Note: Season year 1 starts in April and ends in September; therefore, no cotton planting/harvesting is recorded

Data source: CIE

Central case impacts

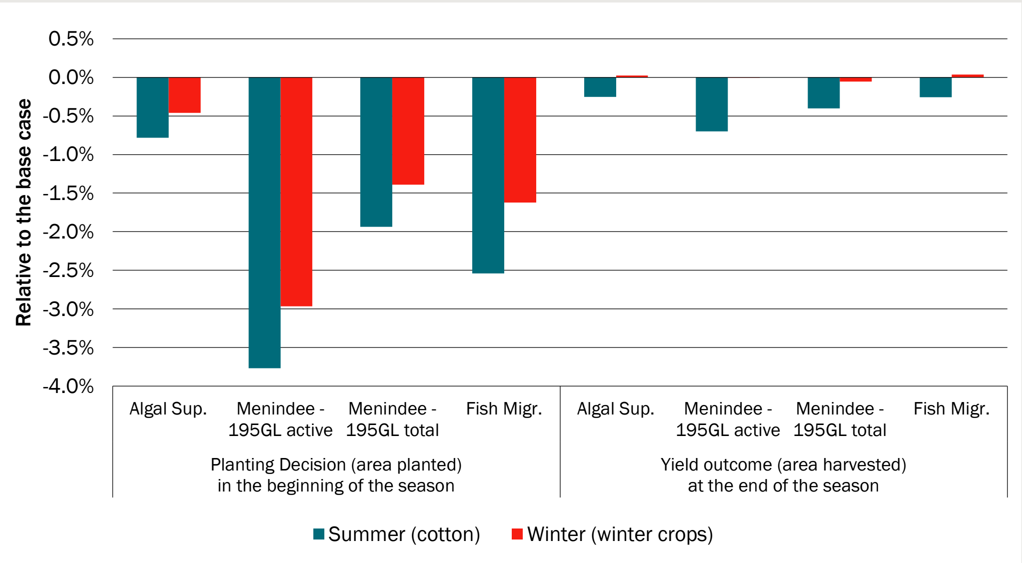
The central case compares outcomes of each proposed option against the economic base case outlined in the previous section. The central results are based on probability-weighted outcome for each year across all climate scenarios.

Chart 4.7 summarises the total probability-weighted impact over 40 years of each proposed option on the farmer's planting decision in the beginning of the season and the yield loss at the end of the season for both crop types relative to the base case:

- The Algal Suppression option has the least impact on the total area planted for both crop types, reducing it by less than 1 per cent compared to the base case. It has a negative impact on cotton yield (-0.5 per cent) and no impact on winter crops.
- The Menindee – 195GL active option has the largest negative impact across all assessed options.
  - The total cotton area planted experiences a reduction of 3.8 percent, while winter crops see a reduction of 3.0 percent relative to the base case.
  - In addition, due to restricted water access during the season cotton yield is reduced by 0.7 per cent and winter crop yield by 0.01 per cent.
- The Menindee – 195GL total option sees a reduction of the total cotton area planted by 1.9 per cent and 1.4 per cent for winter crops relative to the base case. In addition, due to restricted water access during the season cotton yield is somewhat reduced by 0.4 per cent and winter crop yield by 0.06 per cent.
- The Fish Migration option has overall the seconds largest impact across all options in particular on the total crop area planted. This leads to a 2.5 per cent decrease in cotton planted and 1.6 per cent in winter crops planted. Overall, yield loss is less than 0.3 per cent for cotton and marginally positive for winter crops.

The slight positive yield outcomes for winter crops from the Algal Suppression and Fish Migration options compared to the base case are attributed to changes in the pattern of water stress occurrence, resulting in fewer consecutive days of water stress. However, it's important to note that 'winter crops' encompass various crops with different growth stages and season lengths, which may not be fully addressed with the methodology used.

4.7 Probability-weighted impact of options on planting decision and yield relative to base case – Border Rivers



Data source: CIE

The total economic impact of the assessed options has been estimated over a 40-year period, while for each year the probability-weighted result across the 13 climate scenarios has been taken. The present value has been calculated using a real social discount rate in accordance with the NSW Treasury Guidelines.[18]

All proposals are assessed against the economic base case. In summary:

- The economic impact on the farmer’s planting decision is estimated as the change in the cropping area and valued at the net difference between forgone (or gained) value and avoided costs during the cropping season resulting from the proposals.
- The economic impact on the farmer’s yield is estimated as the change in the harvested area resulting from changes is yield outcomes and valued at the crop value that has been forgone (or gained) due to the assessed proposals.

The total economic loss due to the proposed options ranges from -$54.7 million to -$102.0 million in undiscounted terms and -$25.0 million to -$47.9 million in present value terms (table 4.8).

18 NSW Treasury (2023), TPG23-08 NSW Government Guide to Cost-Benefit Analysis, available at: https://www.treasury.nsw.gov.au/sites/default/files/2023-04/tpg23-08_nsw-government-guide-to-cost-benefit-analysis_202304.pdf

The Algal Suppression option has considerably less impact compared to the other options. The Menindee – 195GL active option has the highest economic burden for farmers, while the Menindee – 195GL total option and Fish migration options are relatively similar.

Chart 4.9 provides a comprehensive overview of the economic impact of each option compared to the economic base case, considering both impact measures and both crop types:

- The Algal Suppression option stands out with the lowest overall economic loss, amounting to $11.0 million in present value terms. This is an overall reduction of 0.4 per cent relative to the base case.
- In contrast, the Menindee – 195GL active option exhibits the most significant economic loss among all options, totalling $47.9 million in present value terms. This is an overall reduction of 1.8 per cent relative to the base case.
- The Menindee – 195GL total option leads to an economic loss of $25.0 million in present value terms. This is an overall reduction of 0.9 per cent relative to the base case.
- The Fish Migration option closely mirrors the outcome of the Menindee – 195GL total option, resulting in an overall economic loss of $25.8 million in present value terms. This is an overall reduction of 1.0 per cent relative to the base case.

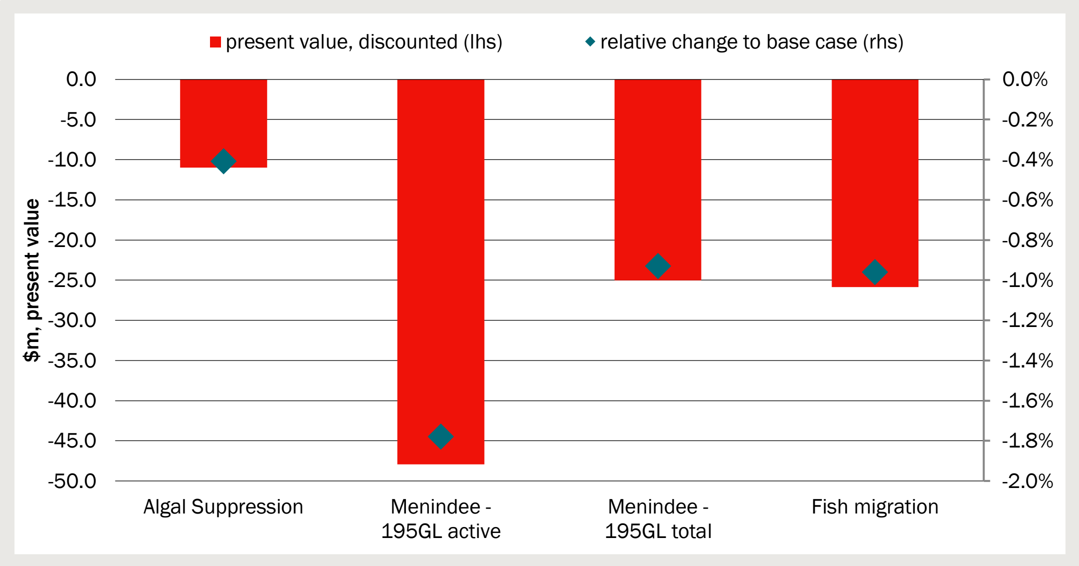
4.8 Central case results relative to base case, undiscounted and discounted – Border Rivers

Option	Central Case ($m, real undiscounted)	Central Case ($m present value discounted)	Central Case (per cent change)
Algal Suppression	-26.2	-11.0	-0.4
Menindee - 195GL active	-102.0	-47.9	-1.8
Menindee - 195GL total	-54.7	-25.0	-0.9
Fish migration	-56.5	-25.8	-1.0

Note: Present value figures are based on real social discount rate of 5 per cent.

Source: CIE

4.9 Summary of central case results relative to the base case ($m, present value) – Border Rivers



Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

Detailed results

Tables 4.10 and 4.11 summarise in detail the economic impact of each option against the base case by type of impact measured and crop type.

4.10 Economic impact on farmer's planting decision – Border Rivers

Option	Crop type	Total Value less of input cost ($m, PV)	Relative to base case ($m, PV)	Change (per cent)
Base Case	Cotton	715	NA	NA
	Winter Crop	38	NA	NA
	Total	**754**	**NA**	**NA**
Algal Suppression	Cotton	710	-5.6	-0.8
	Winter Crop	38	-0.2	-0.5
	Total	**748**	**-5.8**	**-0.8**
Menindee – 195GL active	Cotton	685	-30.5	-4.3
	Winter Crop	37	-1.2	-3.2
	Total	**722**	**-31.7**	**-4.2**
Menindee – 195GL total	Cotton	700	-15.3	-2.1
	Winter Crop	38	-0.6	-1.4
	Total	**738**	**-15.8**	**-2.1**
Fish migration	Cotton	697	-18.7	-2.6
	Winter Crop	38	-0.6	-1.6
	Total	**734**	**-19.3**	**-2.6**

Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

4.11 Economic impact on farm yield – Border Rivers

Option	Crop type	Total Value ($m, PV)	Relative to base case ($m, PV)	Change (per cent)
Base Case	Cotton	2,438	NA	NA
	Winter Crop	256	NA	NA
	Total	**2,694**	**NA**	**NA**
Algal Suppression	Cotton	2,433	-5.2	-0.2
	Winter Crop	256	0.1	0.0
	Total	**2,689**	**-5.2**	**-0.2**
Menindee – 195GL active	Cotton	2,422	-16.2	-0.7
	Winter Crop	256	-0.1	0.0
	Total	**2,678**	**-16.2**	**-0.6**
Menindee – 195GL total	Cotton	2,429	-9.1	-0.4
	Winter Crop	256	-0.1	0.0
	Total	**2,685**	**-9.2**	**-0.3**
Fish migration	Cotton	2,432	-6.7	-0.3
	Winter Crop	256	0.1	0.0
	Total	**2,688**	**-6.6**	**-0.2**

Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

Worst case economic loss

The central case results are based on the probability-weighted impact observed across the climate scenarios in the hydrologic output. In this section we report the worst-case economic loss. For some proposals the economic loss is largest in the years with higher water availability, but for other proposals the largest economic loss may occur in drought years. The worst case in this analysis is the worst replica observed across the 13 climate scenarios.

Chart 4.12 summarise the total economic impact for the central and worst case of each option against the economic base case for both impacts measured and both crop types and chart 4.13 shows the results for each replica ranked from worst to best.

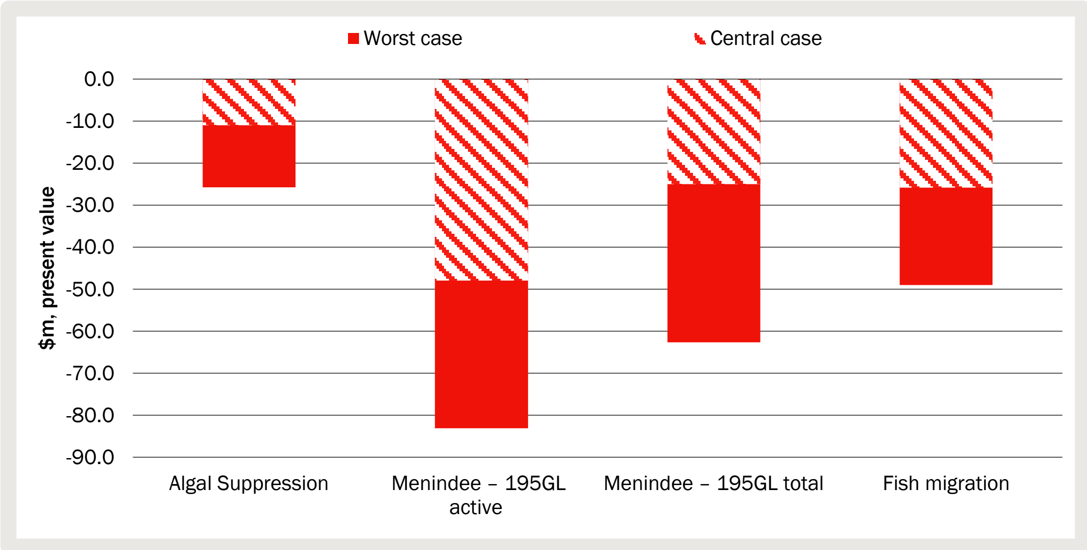
In summary:

- The Algal Suppression option's worst-case scenario still results in the lowest overall economic loss among all options, totalling $25.8 million in present value terms. However, this represents more than double compared to the central case. This option demonstrates the least variability in outcomes among all options.[19]
- The Menindee – 195GL active option presents a worst-case economic loss exceeding $83.1 million in present value terms, nearly double the central case.

19 The variability is measured by using the standard deviation across the results by replica.

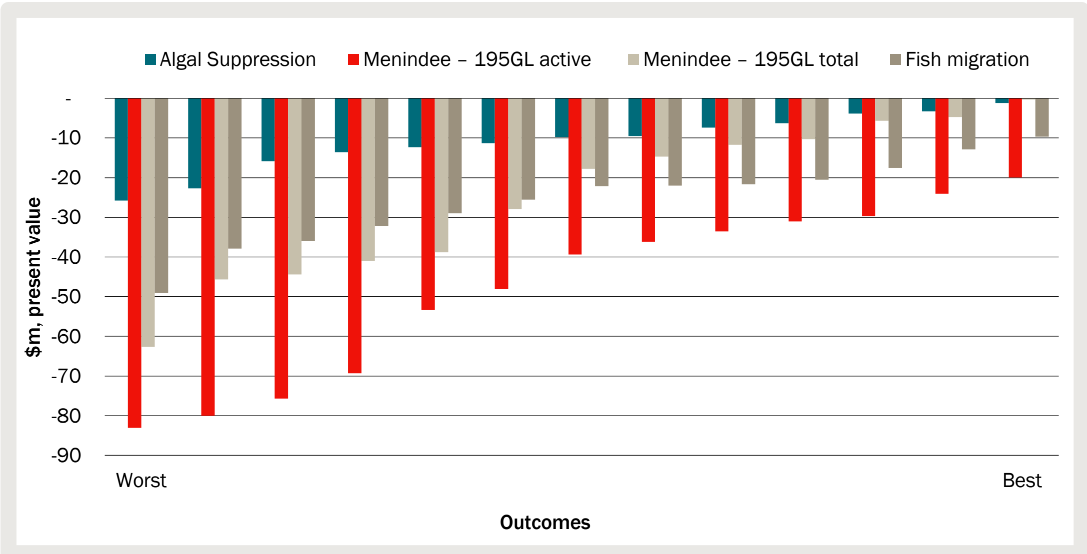
- The Menindee – 195GL total option results in a worst-case economic loss of $62.6 million in present value terms, more than doubling the central case figure.
- The Fish Migration option closely resembles the Menindee – 195GL total option, with a worst-case economic loss of $49.0 million in present value terms. Notably, this option displays the widest range of outcomes across all options.

4.12 Worst and central case results relative to the base case over 40 years ($m, PV) – Border Rivers



Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

4.13 Results for each replica over 40 years ($m, PV) – Border Rivers



Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

Sensitivity analysis

Overall, the ranking of the options does not change for the different sensitivity test, while the alternative discount rates have the largest impact on the results (table 4.14).

4.14 Sensitivity test results over 40 years ($m, present values) – Border Rivers

Option	Central Case ($m, PV)	3 per cent discount rate ($m, PV)	7 per cent discount rate ($m, PV)	+20 per cent value ($m, PV)	-20 per cent value ($m, PV)
Algal Suppression	-11.0	-15.0	-8.3	-13.2	-8.8
Menindee - 195GL active	-47.9	-62.4	-38.4	-57.5	-38.4
Menindee - 195GL total	-25.0	-33.0	-19.8	-30.0	-20.0
Fish migration	-25.8	-33.9	-20.6	-31.0	-20.7

Note: Present value figures are based on real social discount rate of 5 per cent.

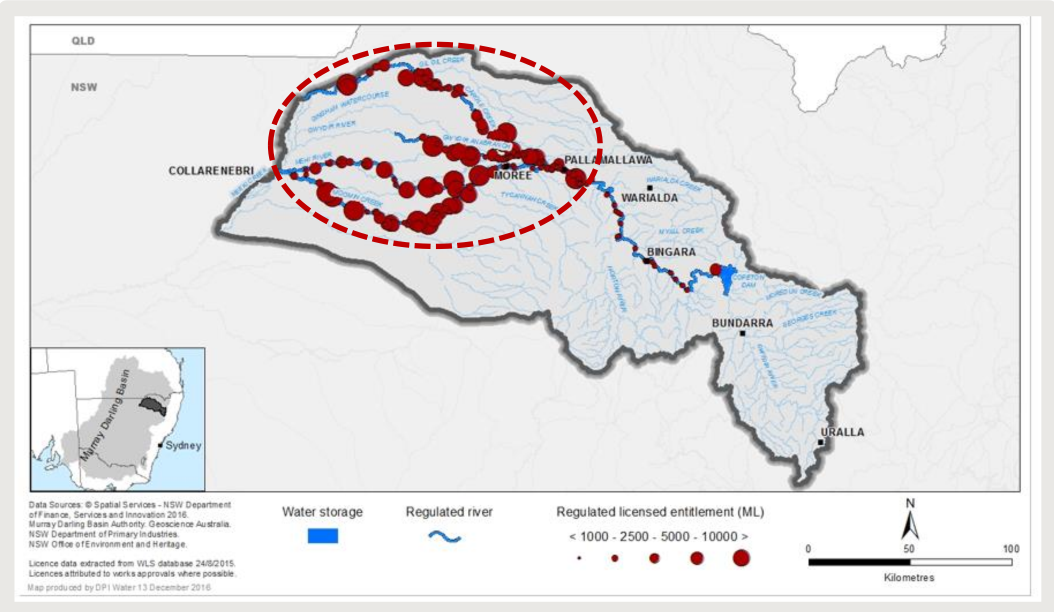
Source: CIE

5 Gwydir

The following chapter summarises the economic impacts of the proposed connectivity proposals across the Gwydir valley relative to the base case, i.e., business as usual. The reaches of the Gwydir valley where supplementary water access licenses are likely to be impacted by these proposals is indicated by the circled area in the map below.

The economic analysis is based on the hydrological multi-replicate outputs and the methodology to estimate the economic impact outlined in the previous chapter. The hydrological modelling is based on the past 130 years and output results have been reshaped into 13 replicate outputs each covering a 40-year period.

5.1 Gwydir impacted reaches



Data source: The Water Group

Economic base case

The base case is a continuation of the current water-sharing plan rules and represents business-as-usual.

Value of planted crops at the beginning of the season

In the base case, a long-term average of 50 869 hectares of cotton are planted each season in October with a value of $342.0 million per season. Overall, the total average cotton area planted ranges between 29 424 and 69 295 hectares with a value of $197.8 to $465.9 million (chart 5.3).

For winter crops we observe a long-term average of 9 529 hectares are planted each season in May with a value of $13.5 million per season. Overall, the total average winter crops planted ranges between 7 783 and 11 114 hectares with a value of $11.1 to $15.8 million (chart 5.4).

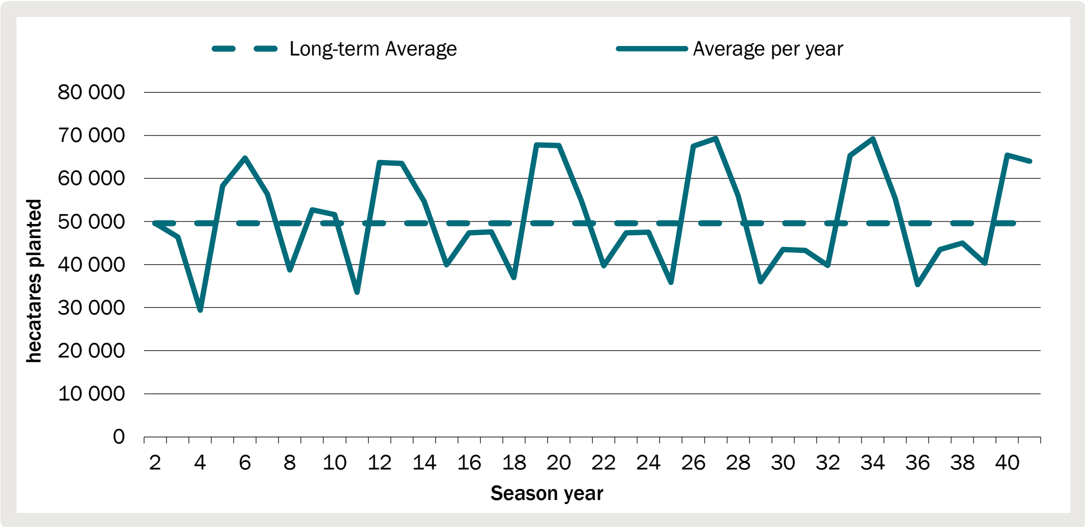
This shows the large variability in planted crops, depending on the available water, in particular for cotton. However, there are also more extreme years recorded across the climate scenarios (table 5.2).

5.2 Summary statistics cotton and winter crops planted per season (base case) – Gwydir

Crop type	-	Hectares planted (ha)	Value of crop ($m, real)
Cotton	Min	29,424	197.8
	Long term average	50,869	342.0
	Max	69,295	465.9
Winter crops	Min	7,783	11.1
	Long term average	9,529	13.5
	Max	11,114	15.8

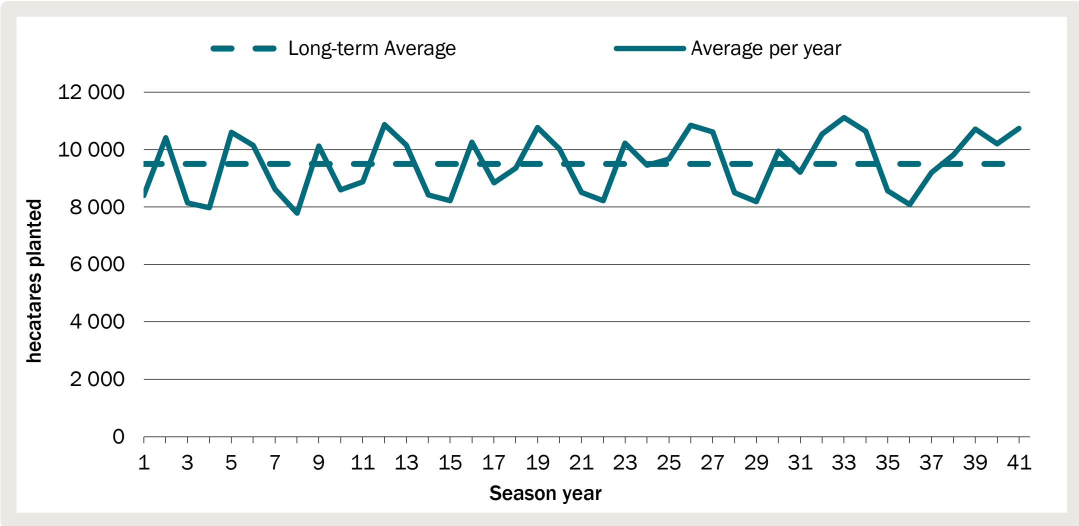
Note: Minimum and maximum values are based on the worst and best season recorded across years.
Source: CIE

5.3 Cotton planted by season (base case) – Gwydir



Note: Season year 1 starts in April and ends in September; therefore, no cotton planting is recorded
Data source: CIE

5.4 Winter crops planted by season (base case) – Gwydir



Data source: CIE

Value of harvested crops at the end of the season

In the base case, a long-term average of 50 869 hectares of cotton are planted and 46 902 hectares harvested each season with a value of $315.3 million per season. This means that in years where cotton experiences water stress the probability-weighted outcome is 9.2 per cent lower (table 5.5 and chart 5.6). Across all years and climate scenarios, we observe that in one third of the observations some loss occurs due to water stress and in two thirds of the cases no loss is recorded. This is broadly in line with the expectation that farmers require more 'good' years to absorb losses from 'bad' years.

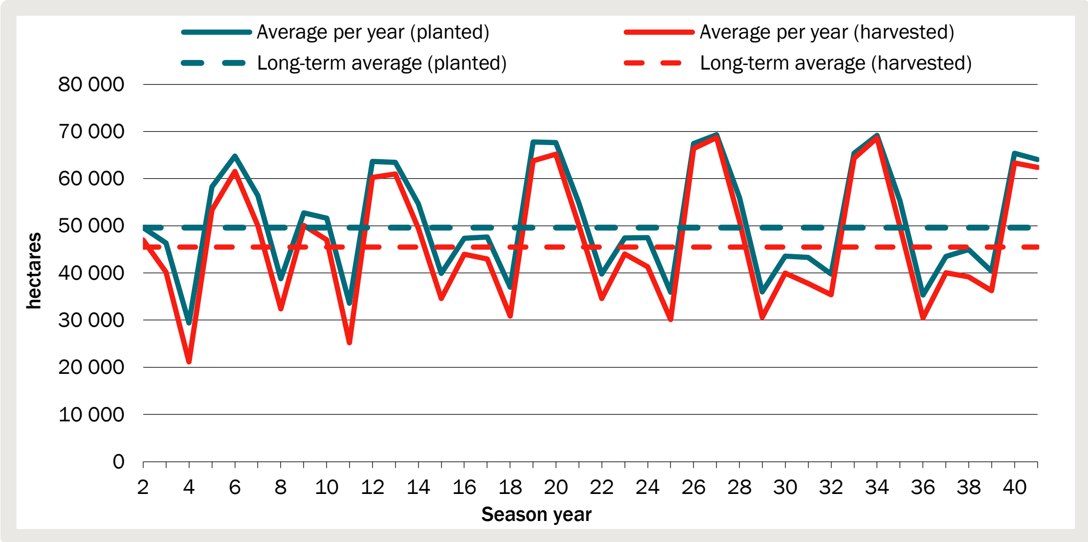
In the base case, a long-term average of 9 529 hectares are planted and 8 541 hectares are harvested each season with a value of $12.1 million per season. This means that in years where winter crops experience water stress the probability-weighted outcome is 9.0 per cent lower (table 5.5 and chart 5.7). This is very similar to cotton.

5.5 Long-term average cotton and winter crops planted and harvested (base case) – Gwydir

Crop type	Hectares planted (ha)	Hectares harvested (ha)	Value of crop planted ($m, real)	Value of crop harvested ($m, real)	Difference (per cent)
Cotton	50,869	46,902	342.0	315.3	- 9.2
Winter crops	9,529	8,541	13.5	12.1	- 9.0

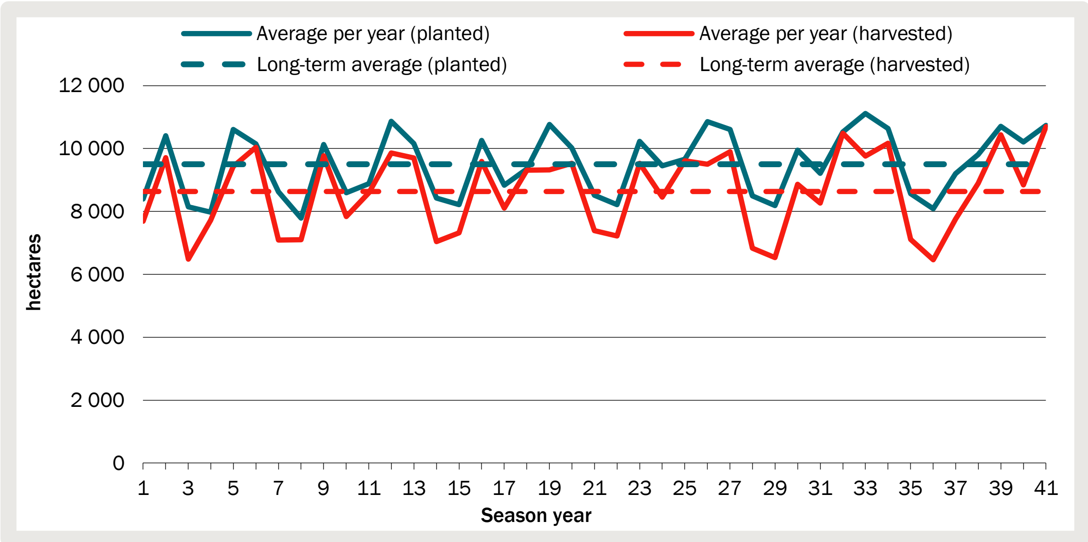
Source: CIE

5.6 Cotton planted versus harvested hectares (base case) – Gwydir



Note: Season year 1 starts in April and ends in September; therefore, no cotton planting/harvesting is recorded
Data source: CIE

5.7 Winter Crops planted versus harvested hectares (base case) – Gwydir



Note: Season year 1 starts in April and ends in September; therefore, no cotton planting/harvesting is recorded
Data source: CIE

Central case impacts

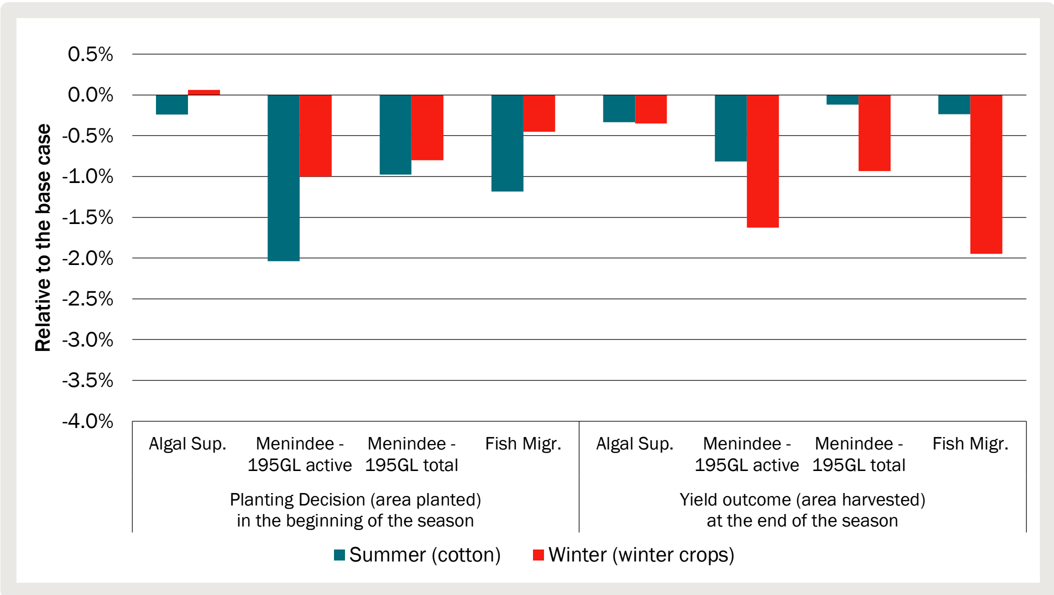
The central case compares outcomes of each proposed option against the economic base case outlined in the previous section. The central results are based on probability-weighted outcome for each year across all climate scenarios.

Chart 5.8 summarises the total probability-weighted impact over 40 years of each proposed option on the farmers planting decision in the beginning of the season and the yield loss at the end of the season for both crop types relative to the base case:

- The Algal Suppression option has the least impact on the total cotton area planted reducing it by less than 0.2 per cent compared to the base case. The option sees a minor positive impact on total area of winter crops planted. It has a minor negative impact on cotton yield of 0.3 per cent and a 0.4 per cent impact on winter crop yields.
- The Menindee – 195GL active option has the largest negative impact across all assessed options.
  - The total cotton area planted experiences a reduction of 2.0 percent, while winter crops see a reduction of 1.0 percent relative to the base case.
  - In addition, due to restricted water access during the season cotton and winter crop yields are reduced by 0.8 per cent and 1.6 per cent respectively.
- The Menindee – 195GL total option sees a reduction of the total cotton area planted by 0.9 per cent and 0.8 per cent for winter crops relative to the base case. In terms of yield outcome, we observe a slight decrease for cotton and a 0.9 per cent decrease for winter crops.
- The Fish migration option has overall the seconds largest impact across all options in particular on the total crop area planted. This leads to a 1.2 per cent decrease in cotton planted and 0.5 per cent in winter crops planted. Overall, yield loss is less than 0.2 per cent for cotton and 1.9 per cent for winter crops.

It is important to note that 'winter crops' encompass various crops with different growth stages and season lengths, which may not be fully addressed with the methodology used. In addition, we observe that extreme events distort the probability-weighted outcomes.

5.8 Probability-weighted impact of options on planting decision and yield relative to base case – Gwydir



Data source: CIE

The total economic impact of the assessed options has been estimated over a 40-year period, while for each year the probability-weighted result across the 13 climate scenarios has been taken. The present value has been calculated using a real social discount rate in accordance with the NSW Treasury Guidelines.[20]

All proposals are assessed against the economic base case. In summary:

- The economic impact on the farmer's planting decision is estimated as the change in the cropping area and valued at the net difference between forgone (or gained) value and avoided costs during the cropping season resulting from the proposals.
- The economic impact on the farmer's yield is estimated as the change in the harvested area resulting from changes is yield outcomes and valued at the crop value that has been forgone (or gained) due to the assessed proposals.

The total economic loss due to the proposed options ranges from -\$52.4 million to -\$186.0 million in undiscounted terms and -\$25.8 million to -\$90.6 million in present value terms (table 5.9).

The Algal Suppression and Menindee - 195GL total options have considerably less impact compared to the other options. The Menindee – 195GL active option has the highest economic burden for farmers followed by the Fish migration option.

Charts 5.10 provides a comprehensive overview of the economic impact of each option compared to the economic base case, considering both impact measures and both crop types:

- The Algal Suppression option has overall second lowest economic loss, amounting to \$22.5 million in present value terms. This is an overall reduction of 0.4 per cent relative to the base case.
- In contrast, the Menindee – 195GL active option exhibits the most significant economic loss among all options, totalling \$90.6 million in present value terms. This is an overall reduction of 1.6 per cent relative to the base case.
- The Menindee – 195GL total option stands out with the overall lowest economic loss of \$25.8 million in present value terms. This is an overall reduction of 0.4 per cent relative to the base case.
- The Fish migration option results in an overall economic loss of \$34.0 million in present value terms. This is an overall reduction of 0.6 per cent relative to the base case.

5.9 Central case results, undiscounted and discounted – Gwydir

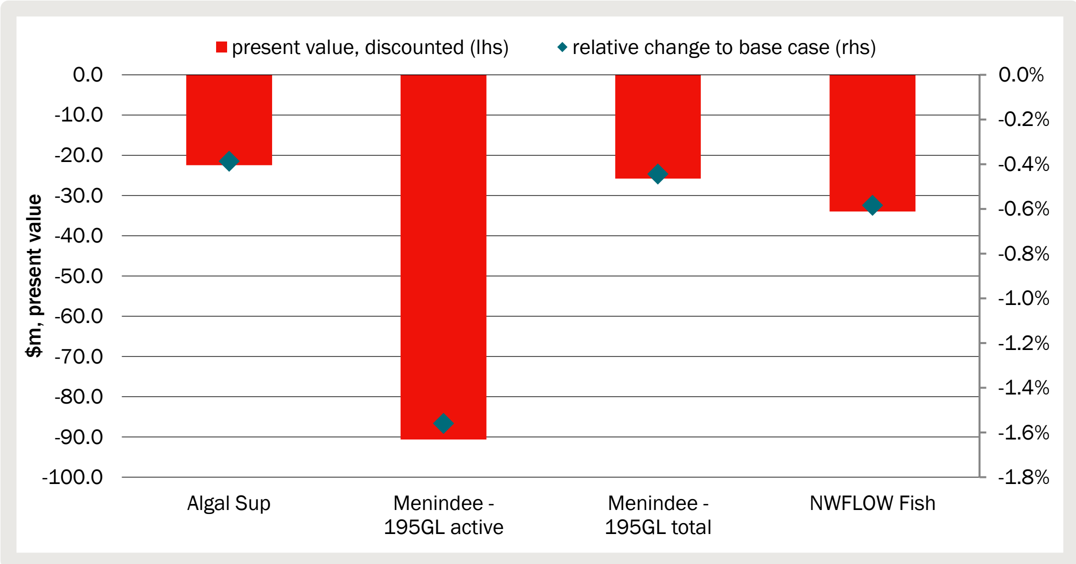
Option	Central Case ($m real undiscounted)	Central Case ($m present value real discounted)	Central Case (per cent change)
Algal Suppression	-52.4	-22.5	-0.4
Menindee - 195GL active	-186.0	-90.6	-1.6
Menindee - 195GL total	-55.4	-25.8	-0.4
Fish migration	-82.6	-34.0	-0.6

Note: Present value figures are based on real social discount rate of 5 per cent.

Source: CIE

20 NSW Treasury (2023), TPG23-08 NSW Government Guide to Cost-Benefit Analysis, available at: https://www.treasury.nsw.gov.au/sites/default/files/2023-04/tpg23-08_nsw-government-guide-to-cost-benefit-analysis_202304.pdf

5.10 Summary of central case results relative to the base case ($m, present value) – Gwydir



Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

Detailed results

Tables 5.11 and 5.12 summarise in detail the economic impact of each option against the base case by type of impact measured and crop type.

5.11 Economic impact on farmers' planting decision – Gwydir

Option	Crop type	Total Value less of input cost ($m, PV)	Relative to base case ($m, PV)	Change (per cent)
Base Case	Cotton	1,624	NA	NA
	Winter Crop	36	NA	NA
	Total	**1,660**	**NA**	**NA**
Algal Suppression	Cotton	1,620	-4.3	-0.3
	Winter Crop	36	0.0	0.0
	Total	**1,656**	**-4.3**	**-0.3**
Menindee - 195GL active	Cotton	1,587	-37.2	-2.3
	Winter Crop	36	-0.3	-0.9
	Total	**1,623**	**-37.5**	**-2.3**
Menindee - 195GL total	Cotton	1,607	-17.3	-1.1
	Winter Crop	36	-0.2	-0.7
	Total	**1,643**	**-17.6**	**-1.1**
Fish migration	Cotton	1,605	-19.3	-1.2
	Winter Crop	36	-0.1	-0.4
	Total	**1,641**	**-19.4**	**-1.2**

Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

5.12 Economic impact on farmers' yield – Gwydir

Option	Crop type	Total Value less of input cost ($m, PV)	Relative to base case ($m, PV)	Change (per cent)
Base Case	Cotton	5,596	NA	NA
	Winter Crop	215	NA	NA
	Total	**5,811**	**NA**	**NA**
Algal Suppression	Cotton	5,578	-17.9	-0.3
	Winter Crop	214	-0.3	-0.1
	Total	**5,793**	**-18.2**	**-0.3**
Menindee – 195GL active	Cotton	5,545	-50.6	-0.9
	Winter Crop	212	-2.5	-1.2
	Total	**5,758**	**-53.1**	**-0.9**
Menindee – 195GL total	Cotton	5,589	-7.2	-0.1
	Winter Crop	214	-1.1	-0.5
	Total	**5,802**	**-8.2**	**-0.1**
Fish migration	Cotton	5,585	-10.7	-0.2
	Winter Crop	211	-3.8	-1.8
	Total	**5,796**	**-14.6**	**-0.3**

Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

Worst case economic loss

The central case results are based on the probability-weighted impact observed across the climate scenarios in the hydrologic output. In this section we report the worst-case economic loss. For some proposals the economic loss is largest in the years with higher water availability, but for other proposals the largest economic loss may occur in drought years. The worst case in this analysis is the worst replica observed across the 13 climate scenarios.

Charts 5.13 summarise the total economic impact for the central and worst case of each option against the economic base case for both impacts measured and both crop types and chart 5.14 shows the results for each replica ranked from worst to best.

In summary:

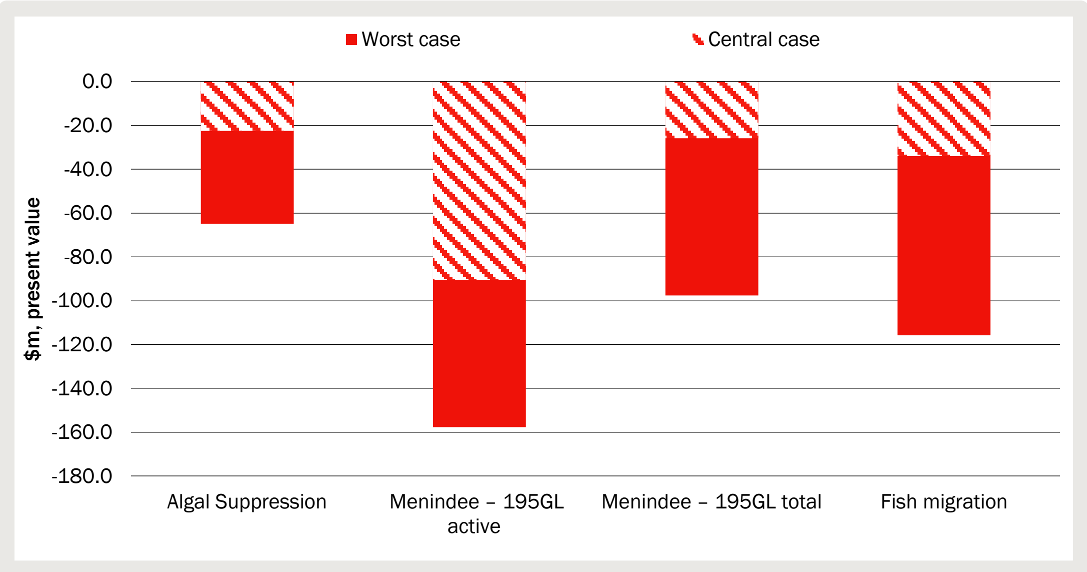
- The Algal Suppression option's worst-case scenario results in the lowest overall economic loss among all options, totalling $64.9 million in present value terms. However, this represents approximately a threefold increase compared to the central case. This option demonstrates the least variability in outcomes among all options.[21]
- The Menindee – 195GL active option presents a worst-case economic loss exceeding $157.7 million in present value terms, almost double compared to the

21 The variability is measured by using the standard deviation across the results by replica.

central case. Notably, this option displays the widest range of outcomes across all options. The main reason for this is the yield outcome results which are very sensitive in this option.

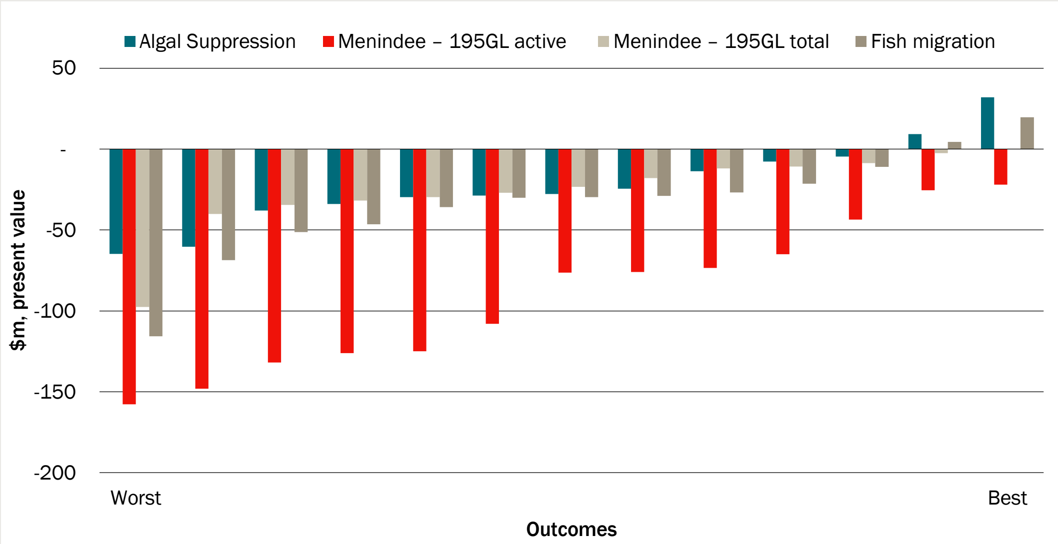
- The Menindee – 195GL total option results in a worst-case economic loss of $97.6 million in present value terms, four times higher than the central case figure.
- The Fish Migration option has a worst-case economic loss of $115.7 million in present value terms.

5.13 Worst and central case results relative to the base case over 40 years ($m, PV) – Gwydir



Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

5.14 Results for each replica over 40 years ($m, PV) – Gwydir



Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

Sensitivity analysis

Overall, the ranking of the options does not change for the different sensitivity test, while the alternating discount rates have the largest impact on the results (table 5.15).

5.15 Sensitivity test results over 40 years ($m, present values) – Gwydir

Option	Central Case ($m, PV)	3 per cent discount rate ($m, PV)	7 per cent discount rate ($m, PV)	+20 per cent value ($m, PV)	-20 per cent value ($m, PV)
Algal Suppression	-22.5	-30.8	-16.9	-27.0	-18.0
Menindee - 195GL active	-90.6	-116.3	-73.6	-108.8	-72.5
Menindee - 195GL total	-25.8	-33.4	-21.1	-31.0	-20.7
Fish migration	-34.0	-46.7	-25.8	-40.8	-27.2

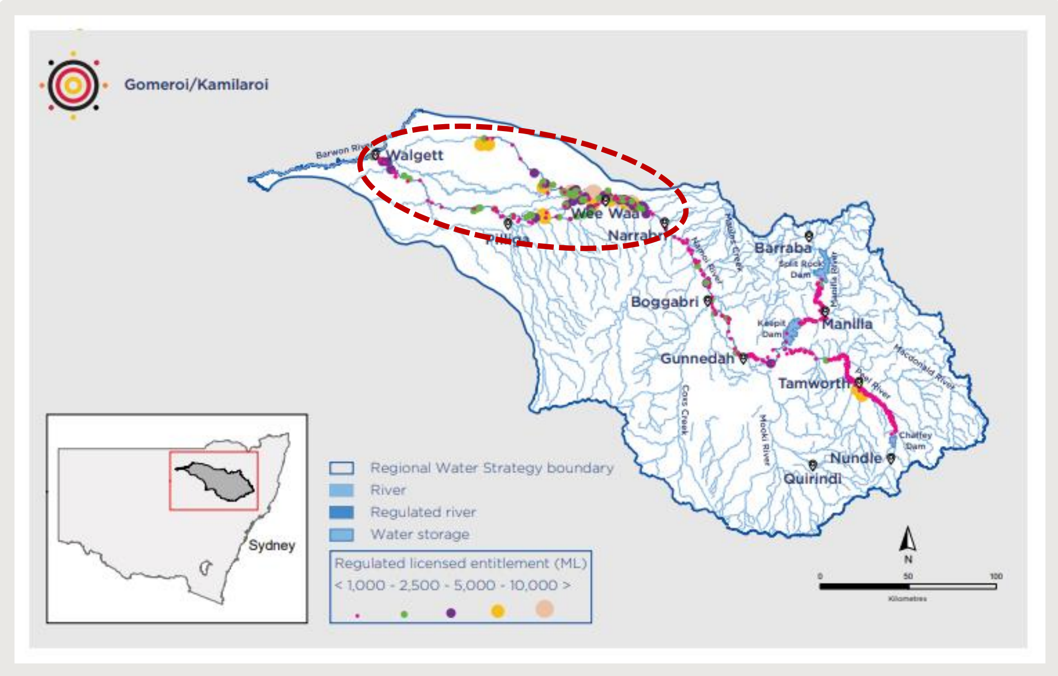
Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

6 Namoi

The following chapter summarise the economic impacts of the proposed connectivity proposals across the Namoi valley relative to the base case, i.e., business as usual. The reaches of the Namoi valley where supplementary water access licenses are likely to be impacted by these proposals are indicated by the circled area in the map below

The economic analysis is based on the hydrological multi-replicate outputs and the methodology to estimate the economic impact outlined in the previous chapter. The hydrological modelling is based on the past 130 years and output results have been reshaped into 13 replicate outputs each covering a 40-year period.

6.1 Namoi impacted reaches



Data source: The Water Group

Economic base case

The base case is a continuation of the current water-sharing plan rules and represents business-as-usual.

Value of planted crops at the beginning of the season

In the base case, a long-term average of 53 961 hectares of cotton are planted each season in October with a value of $362.8 million per season. Overall, the total average cotton area planted ranges between 43 396 and 63 628 hectares with a value of $291.8 to $427.8 million (chart 6.3).

For winter crops we observe a long-term average of 10 405 hectares are planted each season in May with a value of $14.8 million per season. Overall, the total average winter crops planted ranges between 9 786 and 11 050 hectares with a value of $13.9 to $15.7 million (chart 6.4).

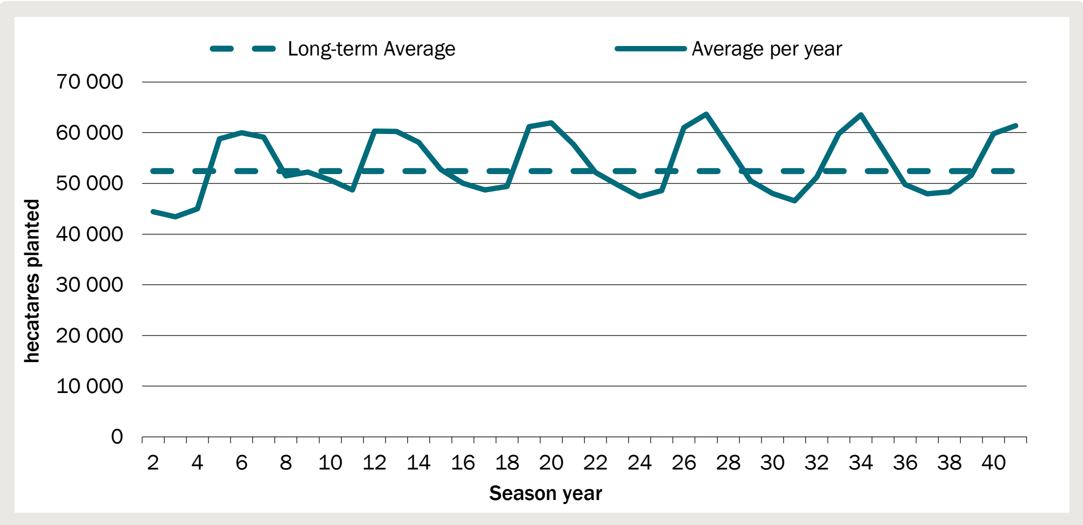
This shows the large variability depending on the available water, in particular for cotton. However, there are also more extreme years recorded across the climate scenarios (table 6.2).

6.2 Summary statistics cotton and winter crops planted per season (base case) – Namoi

Crop type		Hectares planted (ha)	Value of crop ($m, real)
Cotton	Min	43,396	291.8
	Long term average	53,961	362.8
	Max	63,628	427.8
Winter crops	Min	9,786	13.9
	Long term average	10,405	14.8
	Max	11,050	15.7

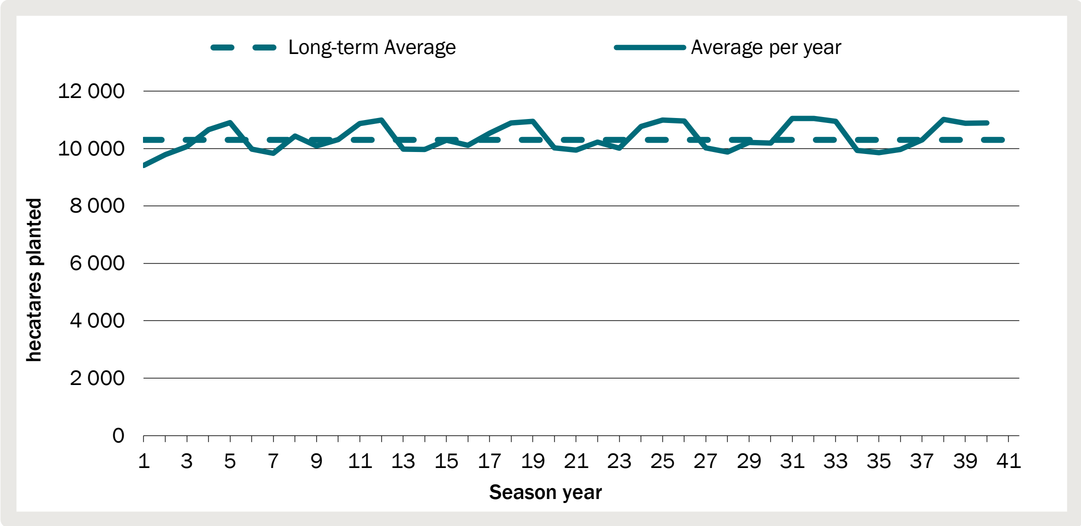
Note: Minimum and maximum values are based on the worst and best season recorded across years.
Source: CIE

6.3 Cotton planted by season (base case) – Namoi



Note: Season year 1 starts in April and ends in September; therefore, no cotton planting is recorded
Data source: CIE

6.4 Winter crops planted by season (base case) – Namoi



Data source: CIE

Value of harvested crops at the end of the season

In the base case, a long-term average of 53 961 hectares of cotton are planted and 49 831 hectares harvested each season with a value of $335.0 million per season. This means that in years where cotton experiences water stress the probability-weighted outcome is 7.7 per cent lower (table 6.5 and chart 6.6). Across all years and climate scenarios, we observe that in one third of the observations some loss occurs due to water stress and in two thirds of the cases no loss is recorded. This is broadly in line with the expectation that farmers require more 'good' years to absorb losses from 'bad' years.

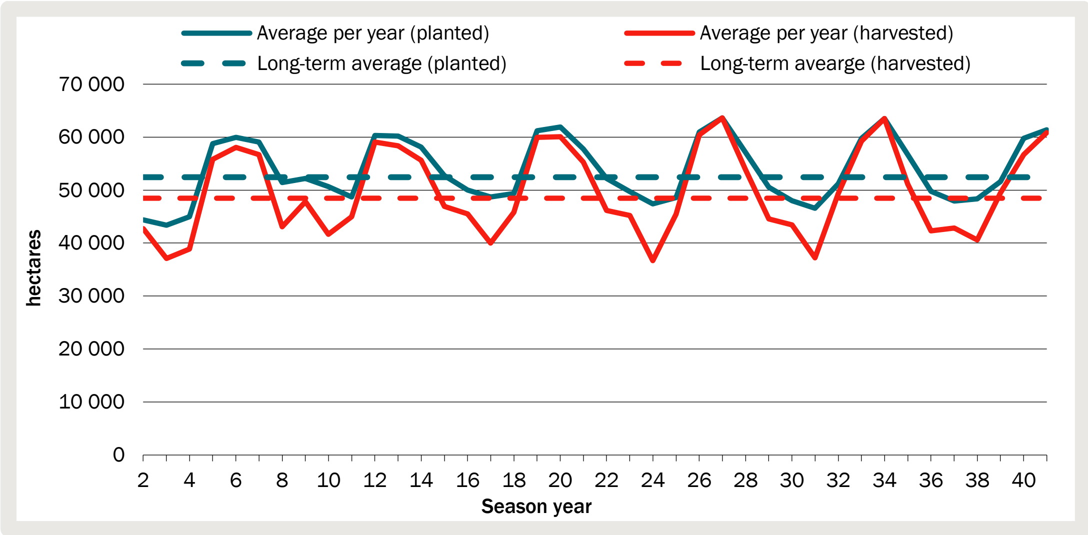
In the base case, a long-term average of 10 405 hectares are planted and 9 895 hectares are harvested each season with a value of $14.1 million per season. This means that in years where winter crops experience water stress the probability-weighted outcome is 4.9 per cent lower (table 6.5 and chart 6.7). This is similar to the outcomes observed for cotton.

6.5 Long-term average cotton and winter crops planted and harvested (base case) – Namoi

Crop type	Hectares planted (ha)	Hectares harvested (ha)	Value of crop planted ($m, real)	Value of crop harvested ($m, real)	Difference (per cent)
Cotton	53,961	49,831	362.8	335.0	- 7.7
Winter crops	10,405	9,895	14.8	14.1	- 4.9

Source: CIE

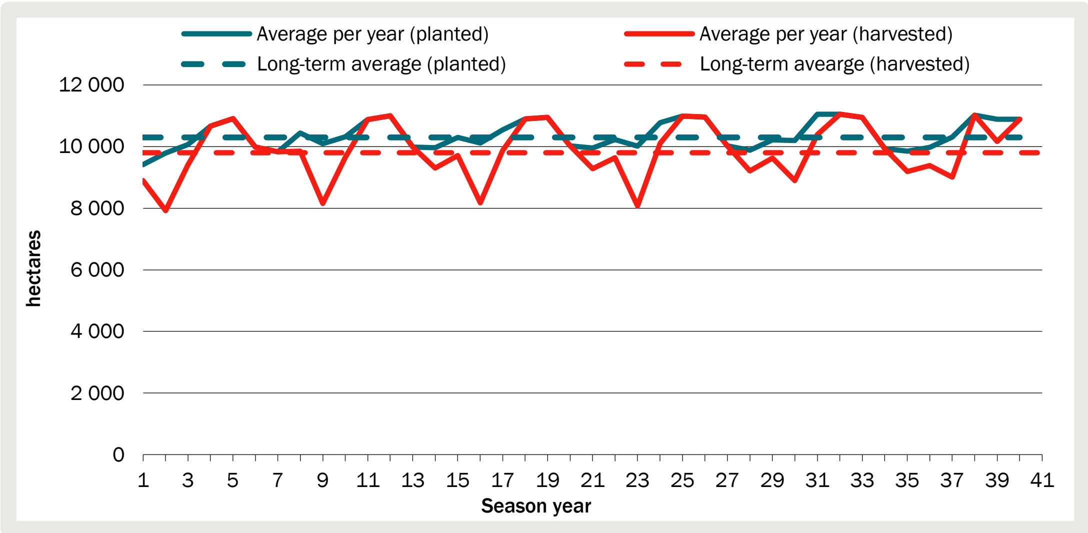
6.6 Cotton planted versus harvested hectares (base case) – Namoi



Note: Season year 1 starts in April and ends in September; therefore, no cotton planting/harvesting is recorded

Data source: CIE

6.7 Winter Crops planted versus harvested hectares (base case) – Namoi



Note: Season year 1 starts in April and ends in September; therefore, no cotton planting/harvesting is recorded

Data source: CIE

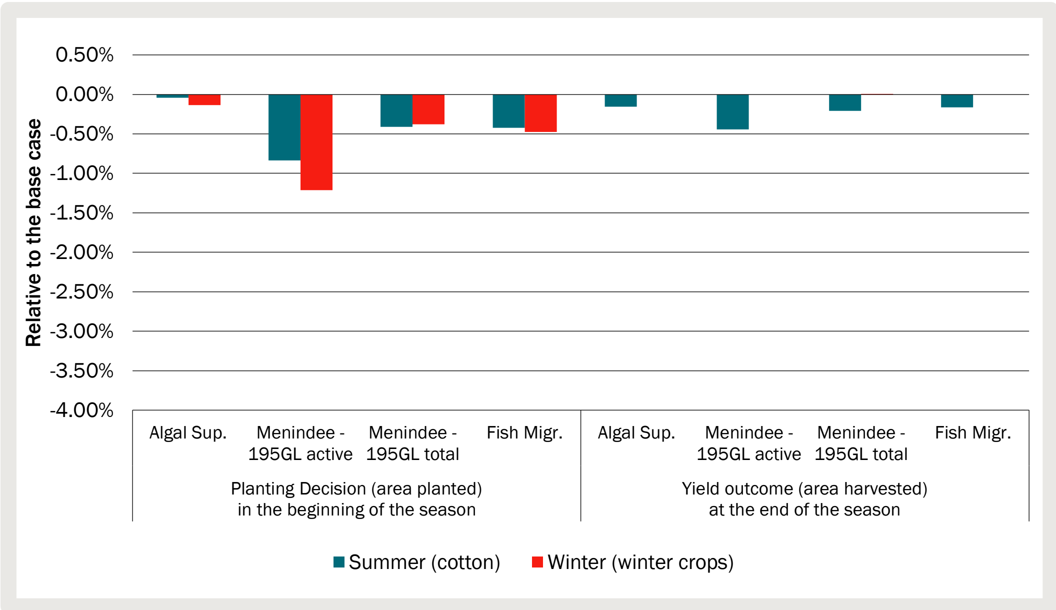
Central case impacts

The central case compares outcomes of each proposed option against the economic base case outlined in the previous section. The central results are based on probability-weighted outcome for each year across all climate scenarios.

Chart 6.8 summarises the total probability-weighted impact over 40 years of each proposed option on the farmers planting decision in the beginning of the season and the yield loss at the end of the season for both crop types relative to the base case:

- The Algal Suppression option has the least impact on the total area planted for both crop types, reducing it by less than 0.1 per cent compared to the base case. It has a minor negative impact on cotton yield and no impact on winter crops.
- The Menindee – 195GL active option has the largest negative impact across all assessed options.
  - The total cotton area planted experiences a reduction of 0.8 percent, while winter crops see a reduction of 1.2 percent relative to the base case.
  - In addition, due to restricted water access during the season cotton yield is reduced by 0.4 per cent while no impact is measured for winter crop yield.
- The Menindee – 195GL total option sees a reduction of the total cotton area planted by 0.4 per cent and 0.5 per cent for winter crops relative to the base case. In addition, due to restricted water access during the season cotton yield is somewhat reduced by 0.2 per cent and winter crop yield is slightly improved.
- The Fish migration option has overall the seconds largest impact across all options in particular on the total crop area planted. This leads to a 0.4 per cent decrease in cotton planted and 0.5 per cent in winter crops planted. Overall, yield loss is less than 0.1 per cent for cotton.

6.8 Probability-weighted impact of options on planting decision and yield relative to base case – Namoi



Data source: CIE

The total economic impact of the assessed options has been estimated over a 40-year period, while for each year the probability-weighted result across the 13 climate scenarios has been taken. The present value has been calculated using a real social discount rate in accordance with the NSW Treasury Guidelines.[22]

All proposals are assessed against the economic base case. In summary:

- The economic impact on the farmer's planting decision is estimated as the change in the cropping area and valued at the net difference between forgone (or gained) value and avoided costs during the cropping season resulting from the proposals.
- The economic impact on the farmer's yield is estimated as the change in the harvested area resulting from changes is yield outcomes and valued at the crop value that has been forgone (or gained) due to the assessed proposals.

The total economic loss due to the proposed options ranges from -$21.8 million to -$92.9 million in undiscounted terms and -$9.1 million to -$42.8 million in present value terms (table 6.9).

The Algal Suppression has considerably less impact compared to the other options. The Menindee – 195GL active option has the highest economic burden for farmers followed by the Menindee – 195GL total option.

Charts 6.10 provides a comprehensive overview of the economic impact of each option compared to the economic base case, considering both impact measures and both crop types:

- The Algal Suppression option stands out with the lowest overall economic loss, amounting to $9.1 million in present value terms. This is an overall reduction of 0.1 per cent relative to the base case.
- In contrast, the Menindee – 195GL active option exhibits the most significant economic loss among all options, totalling $42.8 million in present value terms. This is an overall reduction of 0.7 per cent relative to the base case.
- The Menindee – 195GL total option leads to an economic loss of $17.8 million in present value terms. This is an overall reduction of 0.3 per cent relative to the base case.
- The Fish migration option results in the overall second-lowest economic loss of $16.5 million in present value terms. This is an overall reduction of 0.3 per cent relative to the base case.

6.9 Central case results, undiscounted and discounted – Namoi

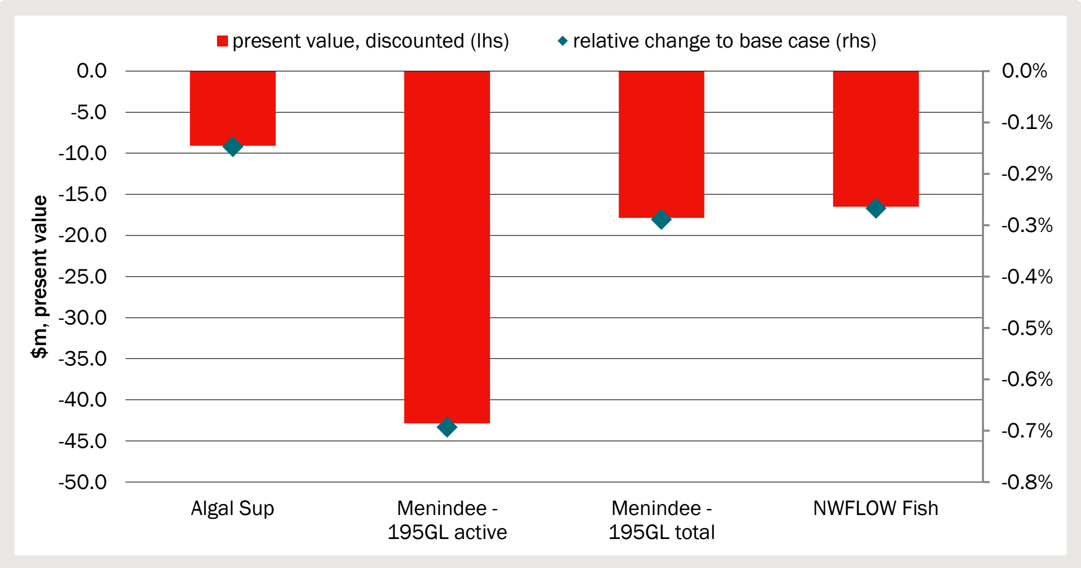
Option	Central Case ($m, real undiscounted)	Central Case ($m, real discounted)	Central Case (per cent change)
Algal Suppression	-21.8	-9.1	-0.1
Menindee - 195GL active	-92.9	-42.8	-0.7
Menindee - 195GL total	-44.1	-17.8	-0.3

22 NSW Treasury (2023), TPG23-08 NSW Government Guide to Cost-Benefit Analysis, available at: https://www.treasury.nsw.gov.au/sites/default/files/2023-04/tpg23-08_nsw-government-guide-to-cost-benefit-analysis_202304.pdf

Option	Central Case ($m, real undiscounted)	Central Case ($m, real discounted)	Central Case (per cent change)
Fish migration	-37.8	-16.5	-0.3

Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

6.10 Summary of central case results relative to the base case ($m, present value) – Namoi



Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

Detailed results

Tables 6.11 and 6.12 summarise in detail the economic impact of each option against the base case by type of impact measured and crop type.

6.11 Economic impact on farmers' planting decision – Namoi

Option	Crop type	Total Value less of input cost ($m, PV)	Relative to base case ($m, PV)	Change (per cent)
Base Case	Cotton	1,711	NA	NA
	Winter Crop	40	NA	NA
	Total	**1,750**	**NA**	**NA**
Algal Suppression	Cotton	1,710	-0.7	0.0
	Winter Crop	39	0.0	-0.1
	Total	**1,750**	**-0.8**	**0.0**
Menindee - 195GL active	Cotton	1,695	-15.8	-0.9
	Winter Crop	39	-0.5	-1.2
	Total	**1,734**	**-16.2**	**-0.9**

Option	Crop type	Total Value less of input cost ($m, PV)	Relative to base case ($m, PV)	Change (per cent)
Menindee - 195GL total	Cotton	1,703	-7.5	-0.4
	Winter Crop	39	-0.1	-0.3
	Total	**1,743**	**-7.7**	**-0.4**
Fish migration	Cotton	1,704	-7.3	-0.4
	Winter Crop	39	-0.2	-0.4
	Total	**1,743**	**-7.4**	**-0.4**

Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

6.12 Economic impact on farmers' yield – Namoi

Option	Crop type	Total Value ($m, PV)	Relative to base case ($m, PV)	Change (per cent)
Base Case	Cotton	5,931	NA	NA
	Winter Crop	250	NA	NA
	Total	**6,181**	**NA**	**NA**
Algal Suppression	Cotton	5,923	-8.3	-0.1
	Winter Crop	250	0.0	0.0
	Total	**6,173**	**-8.3**	**-0.1**
Menindee – 195GL active	Cotton	5,904	-26.6	-0.4
	Winter Crop	250	0.0	0.0
	Total	**6,154**	**-26.6**	**-0.4**
Menindee – 195GL total	Cotton	5,921	-10.2	-0.2
	Winter Crop	250	0.0	0.0
	Total	**6,171**	**-10.2**	**-0.2**
Fish migration	Cotton	5,922	-9.1	-0.2
	Winter Crop	250	0.0	0.0
	Total	**6,172**	**-9.1**	**-0.1**

Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

Worst case economic loss

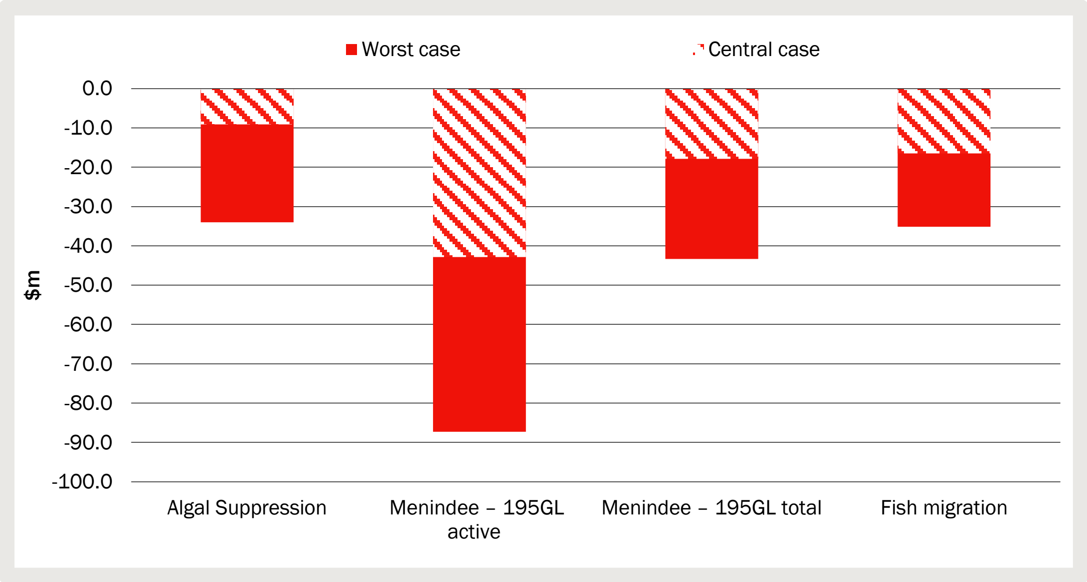
The central case results are based on the probability-weighted impact observed across the climate scenarios in the hydrologic output. In this section we report the worst-case economic loss. For some proposals the economic loss is largest in the years with higher water availability, but for other proposals the largest economic loss may occur in drought years. The worst case in this analysis is the worst replica observed across the 13 climate scenarios.

Charts 6.13 summarise the total economic impact for the central and worst case of each option against the economic base case for both impacts measured and both crop types and chart 6.14 shows the results for each replica ranked from worst to best.

In summary:

- The Algal Suppression option's worst-case scenario still results in the lowest overall economic loss among all options, totalling $34.0 million in present value terms. However, this represents more than a fourfold increase compared to the central case. This option demonstrates the least variability in outcomes among all options.[23]
- The Menindee – 195GL active option presents a worst-case economic loss exceeding $87.3 million in present value terms, more than three times more than the central case. Notably, this option displays the widest range of outcomes across all options.
- The Menindee – 195GL total option results in a worst-case economic loss of $43.3 million in present value terms, more than doubling the central case figure.
- The Fish Migration option closely resembles the Menindee – 195GL total option, with a worst-case economic loss of $35.1 million in present value terms.

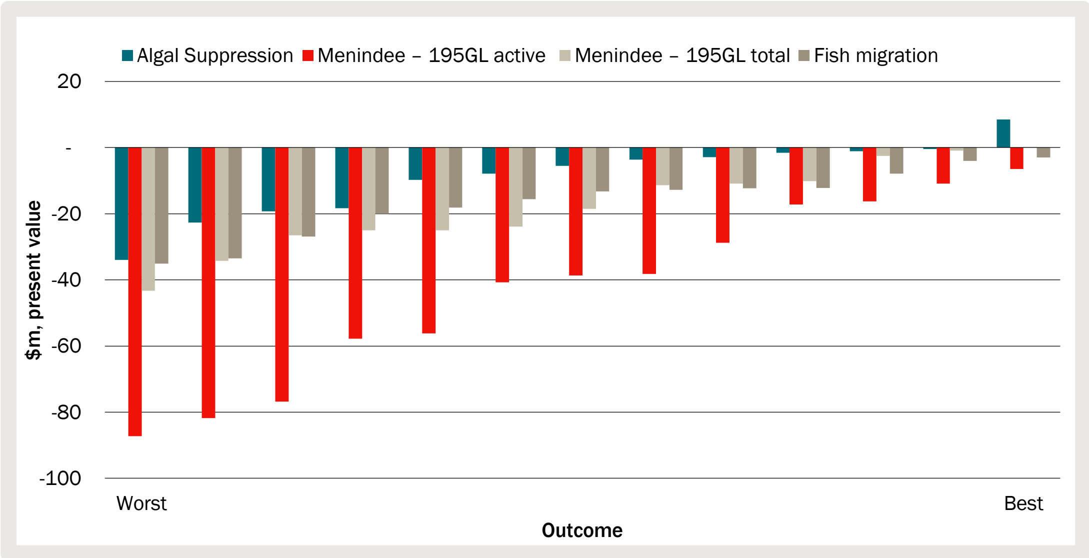
6.13 Worst and central case results relative to the base case over 40 years ($m, PV) – Namoi



Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

23 The variability is measured by using the standard deviation across the results by replica.

6.14 Results for each replica over 40 years ($m, PV) – Namoi



Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

Sensitivity analysis

Overall, the ranking of the options does not change for the different sensitivity test, while the alternating discount rates have the largest impact on the results (table 6.15).

6.15 Sensitivity test results over 40 years ($m, present values) – Namoi

Option	Central Case ($m, PV)	3 per cent discount rate ($m, PV)	7 per cent discount rate ($m, PV)	+20 per cent value ($m, PV)	-20 per cent value ($m, PV)
Algal Suppression	-9.1	-12.4	-7.0	-10.9	-7.3
Menindee - 195GL active	-42.8	-56.2	-34.1	-51.4	-34.3
Menindee - 195GL total	-17.8	-24.6	-13.6	-21.4	-14.3
Fish migration	-16.5	-22.0	-13.0	-19.8	-13.2

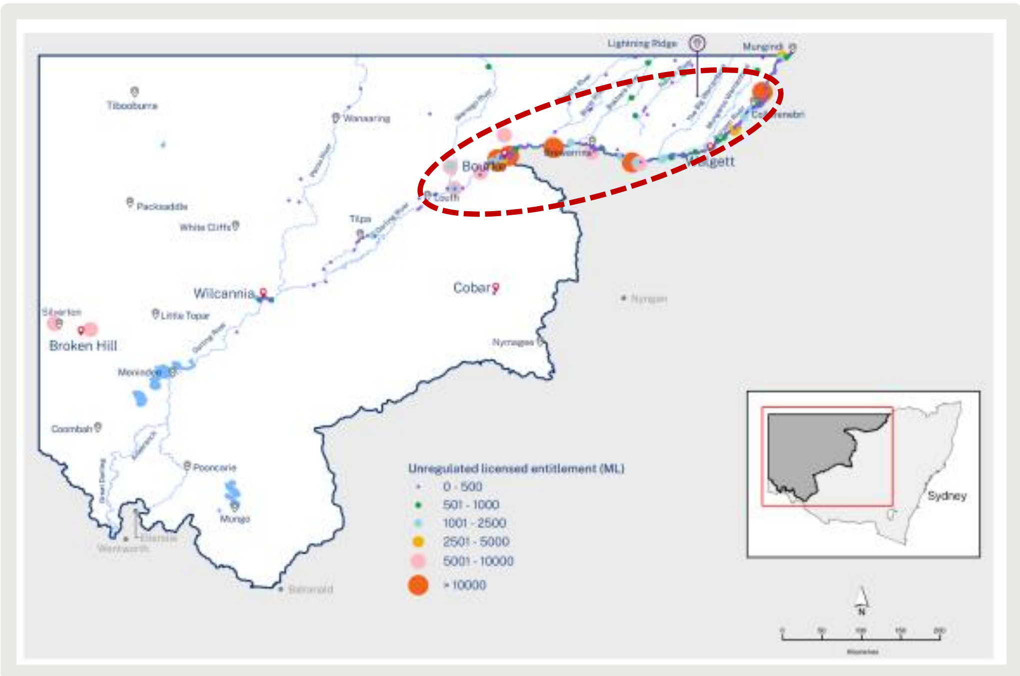
Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

7 Barwon-Darling

The following chapter summarise the economic impacts of the proposed connectivity proposals across the Barwon-Darling valley relative to the base case, i.e., business as usual. The reaches of the Barwon-Darling where B and C Class water access licenses are likely to be impacted by these proposals are indicated by the circled area in the map below

The economic analysis is based on the hydrological multi-replicate outputs and the methodology to estimate the economic impact outlined in the previous chapter. The hydrological modelling is based on the past 130 years and output results have been reshaped into 13 replicate outputs each covering a 40-year period.

7.1 Barwon Darling impacted reaches



Data source: The Water Group

Economic base case

The base case is a continuation of the current water-sharing plan rules and represents business-as-usual.

Value of planted crops at the beginning of the season

In the base case, a long-term average of 27 783 hectares of cotton are planted each season in October with a value of $166.6 million per season. Overall, the total average cotton area planted ranges between 20 792 and 28 534 hectares with a value of $139.8 to $191.8 million (chart 7.3).

For winter crops we observe a long-term average of 2 722 hectares are planted each season in May with a value of $3.9 million per season. Overall, the total average winter crops planted ranges between 2 475 and 2 907 hectares with a value of $3.5 to $3.9 million (chart 7.4).

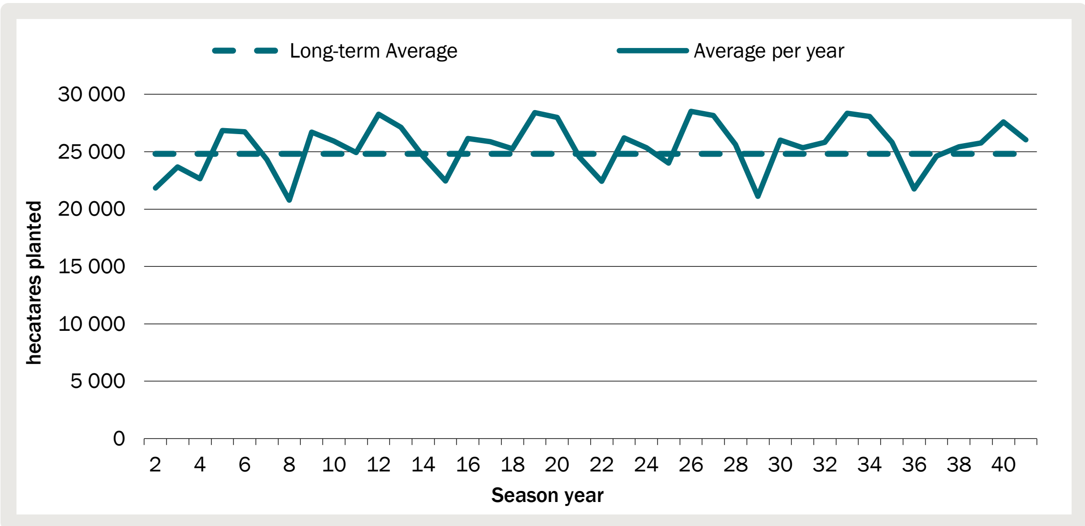
This shows the large variability depending on the available water, in particular for cotton. However, there are also more extreme years recorded across the climate scenarios (table 7.2).

7.2 Summary statistics cotton and winter crops planted per season (base case) – Barwon-Darling

Crop type		Hectares planted (ha)	Value of crop ($m, real)
Cotton	Min	20,792	139.8
	Long term average	24,783	166.6
	Max	28,534	191.8
Winter crops	Min	2,475	3.5
	Long term average	2,722	3.9
	Max	2,907	4.1

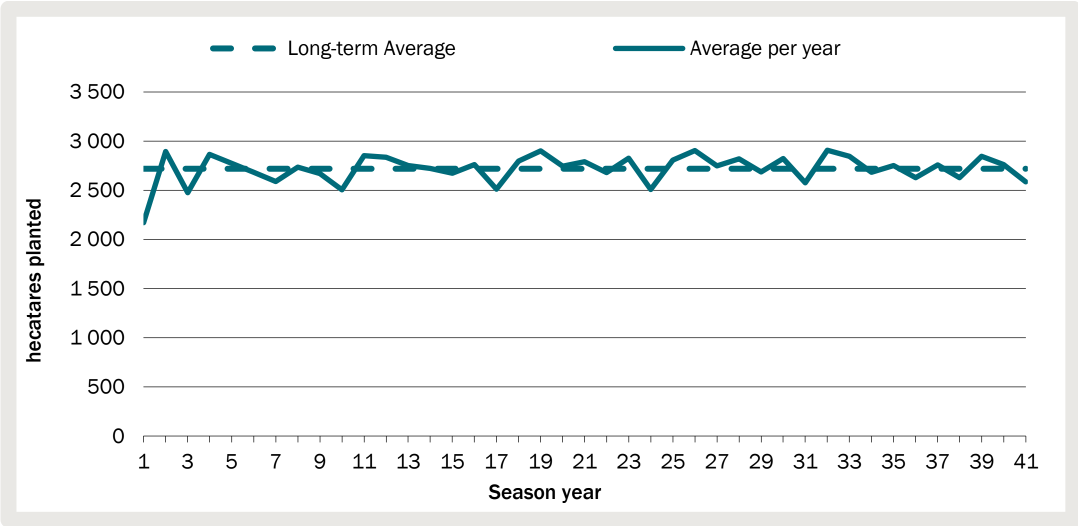
Note: Minimum and maximum values are based on the worst and best season recorded across years.
Source: CIE

7.3 Cotton planted by season (base case) – Barwon-Darling



Note: Season year 1 starts in April and ends in September; therefore, no cotton planting is recorded
Data source: CIE

7.4 Winter crops planted by season (base case) – Barwon-Darling



Data source: CIE

Value of harvested crops at the end of the season

In the base case, a long-term average of 24 783 hectares of cotton are planted and 22 924 hectares harvested each season with a value of $154.1 million per season. This means that in years where cotton experiences water stress the probability-weighted outcome is 7.5 per cent lower (table 7.5 and chart 7.6). Across all years and climate scenarios, we observe that in one third of the observations some loss occurs due to water stress and in two thirds of the cases no loss is recorded. This is broadly in line with the expectation that farmers require more 'good' years to absorb losses from 'bad' years.

In the base case, a long-term average of 2 722 hectares are planted and 2 147 hectares are harvested each season with a value of $3.0 million per season. This means that in years where winter crops experience water stress the probability-weighted outcome is 21.2 per cent lower (table 7.5 and chart 7.7). This is much higher compared to cotton as the Barwon-Darling valley experiences on average more severe winter droughts than any other valley in this analysis.

We note that the threshold of the water stress coefficient at which yield damages occur was calibrated to match average cotton yield outcomes. In general, farmers prioritise cotton over winter crops in the Barwon-Darling.[24]

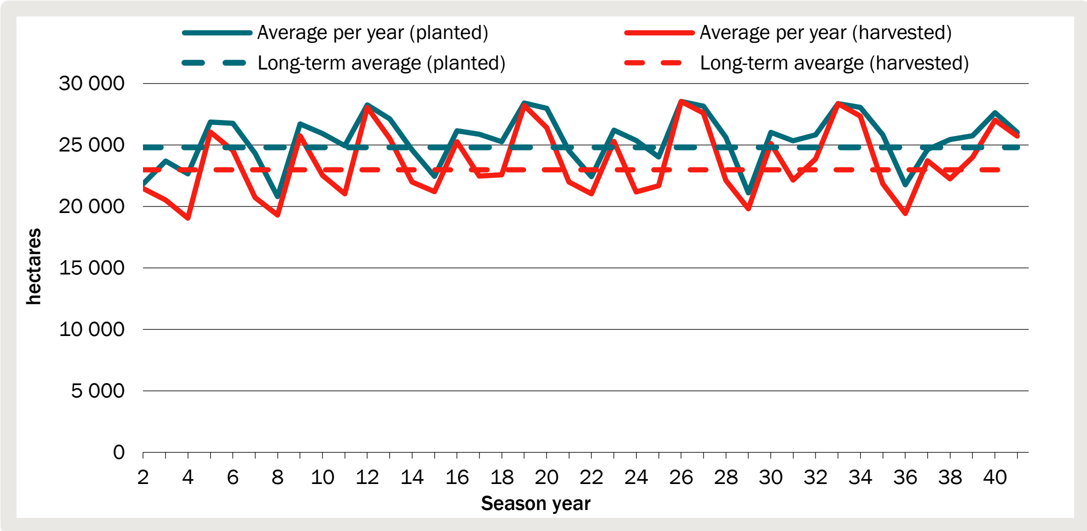
24 https://www.industry.nsw.gov.au/__data/assets/pdf_file/0003/509565/reasonable-excuse-report-for-bd-sdl-compliance-2020-21.pdf

7.5 Long-term average cotton and winter crops planted and harvested (base case) – Barwon-Darling

Crop type	Hectares planted (ha)	Hectares harvested (ha)	Value of crop planted ($m, real)	Value of crop harvested ($m, real)	Difference (per cent)
Cotton	24,783	22,924	166.6	154.1	- 7.5
Winter crops	2,722	2,147	3.9	3.0	- 21.2

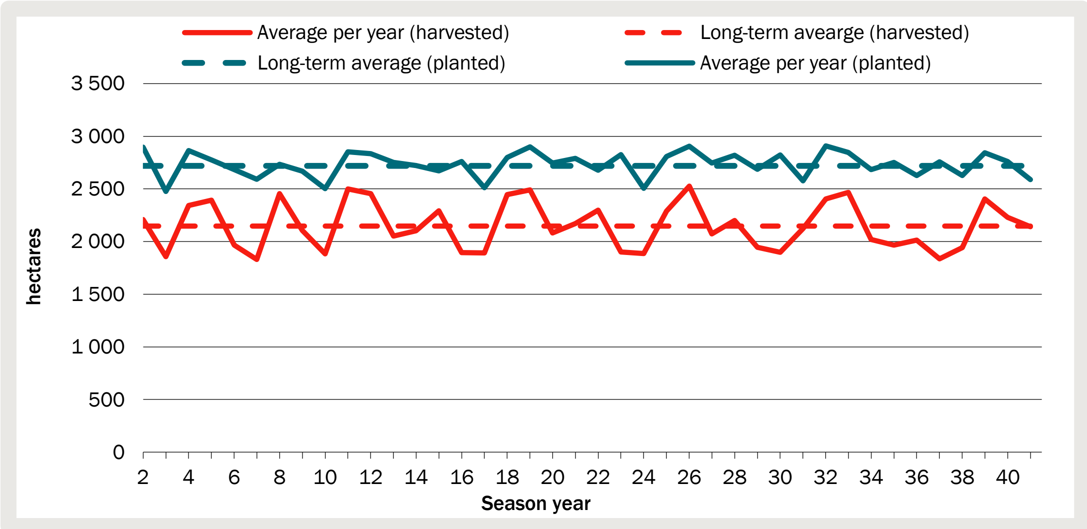
Source: CIE

7.6 Cotton planted versus harvested hectares (base case) – Barwon-Darling



Note: Season year 1 starts in April and ends in September; therefore, no cotton planting/harvesting is recorded
Data source: CIE

7.7 Winter Crops planted versus harvested hectares (base case) – Barwon-Darling



Note: Season year 1 starts in April and ends in September; therefore, no cotton planting/harvesting is recorded
Data source: CIE

Central case impacts

The central case compares outcomes of each proposed option against the economic base case outlined in the previous section. The central results are based on probability-weighted outcome for each year across all climate scenarios.

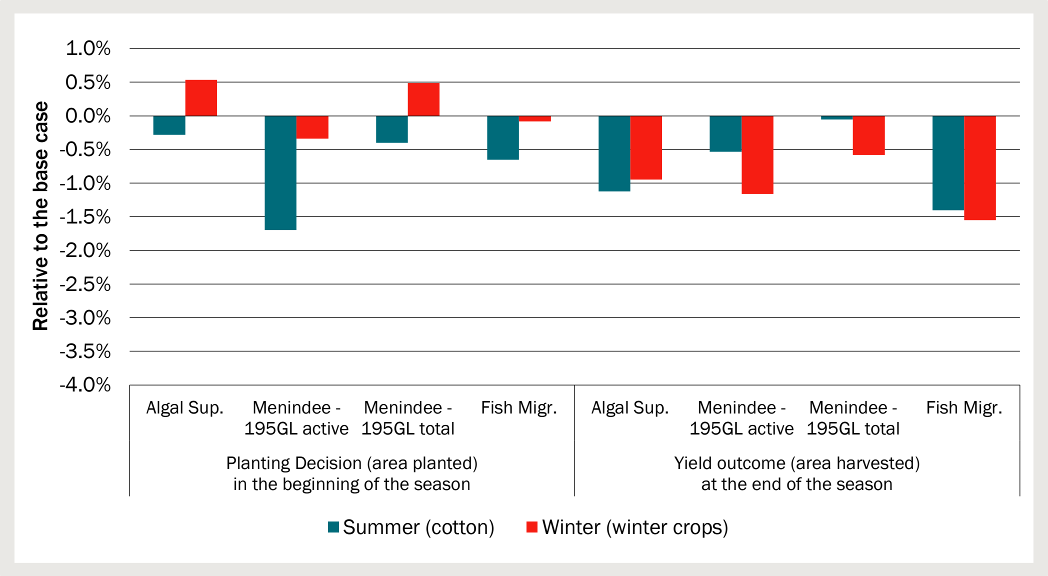
Chart 7.8 summarises the total probability-weighted impact over 40 years of each proposed option on the farmers planting decision in the beginning of the season and the yield loss at the end of the season for both crop types relative to the base case:

- The Algal Suppression option has the least impact on the total cotton area planted, reducing it by 0.3 per cent compared to the base case. On the other hand, total winter crop area planted increases by 0.5 per cent. For both crops we observe large negative impacts on yield. These results are largely driven by disproportionally many extreme events.
- The Menindee – 195GL active option has the largest negative impact across all assessed options.
  - The total cotton area planted experiences a reduction of 1.7 percent, while winter crops see a reduction of 0.3 percent relative to the base case.
  - In addition, due to restricted water access during the season winter crop yield is reduced by 1.2 per cent and a reduction in cotton yield by 0.5 per cent.
- The Menindee – 195GL total option sees a reduction of the total cotton area planted by 0.4 per cent, but an increase of 0.5 per cent for winter crops relative to the base case. In addition, due to restricted water access during the season winter crop yield is reduced by 0.6 per cent and cotton yield is only marginally affected.
- The Fish migration option has overall the seconds largest impact across all options. The option leads to a 0.7 per cent decrease in cotton planted and 0.1 per cent in winter crops planted. Overall, cotton yield loss is 1.4 per cent and 1.6 per cent for winter crops.

We observe relatively large impacts on cotton yield for the Algal suppression and Fish migration options. Those are the result of substantially lower water stress coefficient in those options compared to the base case in Dezember and January. Those months are critical for cotton growth, and water stress during this period results in disproportionally high yield reductions.

In addition, we observe for some options positive outcomes on the total winter crop area planted. This is a direct output from the hydrological modelling and driven by some extreme events in the data. It is important to note that 'winter crops' encompass various crops with different growth stages and season lengths.

7.8 Probability-weighted impact of options on planting decision and yield relative to base case – Barwon-Darling



Data source: CIE

The total economic impact of the assessed options has been estimated over a 40-year period, while for each year the probability-weighted result across the 13 climate scenarios has been taken. The present value has been calculated using a real social discount rate in accordance with the NSW Treasury Guidelines.[25]

All proposals are assessed against the economic base case. In summary:

- The economic impact on the farmer's planting decision is estimated as the change in the cropping area and valued at the net difference between forgone (or gained) value and avoided costs during the cropping season resulting from the proposals.
- The economic impact on the farmer's yield is estimated as the change in the harvested area resulting from changes is yield outcomes and valued at the crop value that has been forgone (or gained) due to the assessed proposals.

The total economic loss due to the proposed options ranges from -$11.2 million to -$100.1 million in undiscounted terms and -$1.3 million to -$44.4 million in present value terms (table 7.9).

The Algal Suppression and Fish migration options have the most impact compared to both Menindee – 195GL options. The main reasons are:

- More extreme events occur in the beginning of the sample (first 20 years) which distort the probability-weighted outcome for the Algal suppression and Fish migration options.

25 NSW Treasury (2023), TPG23-08 NSW Government Guide to Cost-Benefit Analysis, available at: https://www.treasury.nsw.gov.au/sites/default/files/2023-04/tpg23-08_nsw-government-guide-to-cost-benefit-analysis_202304.pdf

- Overall, the water stress coefficient is on average higher in the Menindee options relative to the base case from November to January. Those months are critical for cotton growth.
- Due to the nature of discounting, those events will have a higher weight in the present value results.

Charts 7.10 provides a comprehensive overview of the economic impact of each option compared to the economic base case, considering both impact measures and both crop types:

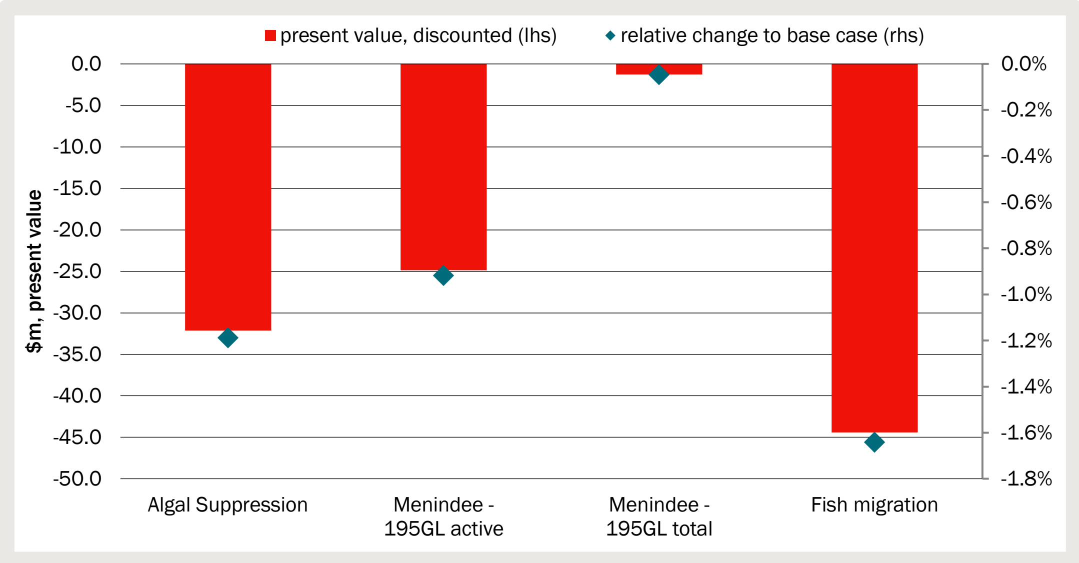
- The Algal Suppression option has the overall second highest economic loss, amounting to $32.1 million in present value terms. This is an overall reduction of 1.2 per cent relative to the base case.
- The Menindee – 195GL active option exhibits an economic loss totalling $24.8 million in present value terms. This is an overall reduction of 0.9 per cent relative to the base case.
- In contrast, the Menindee – 195GL total option leads to the overall lowest economic loss of $1.3 million in present value terms. This is an overall reduction of 0.0 per cent relative to the base case.
- The Fish migration option results in the overall largest economic loss of $44.4 million in present value terms. This is an overall reduction of -1.6 per cent relative to the base case.

7.9 Central case results, undiscounted and discounted – Barwon-Darling

Option	Central Case ($m, real undiscounted)	Central Case ($m, real discounted)	Central Case (per cent change)
Algal Suppression	-75.4	-32.1	-1.2
Menindee - 195GL active	-64.5	-24.8	-0.9
Menindee - 195GL total	-11.2	-1.3	-0.0
Fish migration	-100.1	-44.4	-1.6

Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

7.10 Summary of central case results relative to the base case ($m, present value) – Barwon-Darling



Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

Detailed results

Tables 7.11 and 7.12 summarise in detail the economic impact of each option against the base case by type of impact measured and crop type.

7.11 Economic impact on farmers' planting decision – Barwon-Darling

Option	Crop type	Total Value less of input cost ($m, PV)	Relative to base case ($m, PV)	Change (per cent)
Base Case	Cotton	765	NA	NA
	Winter Crop	10	NA	NA
	Total	**775**	**NA**	**NA**
Algal Suppression	Cotton	763	-1.9	-0.2
	Winter Crop	10	0.1	0.6
	Total	**773**	**-1.8**	**-0.2**
Menindee - 195GL active	Cotton	753	-11.6	-1.5
	Winter Crop	10	0.0	-0.2
	Total	**764**	**-11.6**	**-1.5**
Menindee - 195GL total	Cotton	763	-2.1	-0.3
	Winter Crop	10	0.0	0.4
	Total	**773**	**-2.1**	**-0.3**
Fish migration	Cotton	759	-5.6	-0.7
	Winter Crop	10	0.0	-0.2
	Total	**770**	**-5.6**	**-0.7**

Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

7.12 Economic impact on farmers' yield – Barwon-Darling

Option	Crop type	Total Value ($m, PV)	Relative to base case ($m, PV)	Change (per cent)
Base Case	Cotton	2,649	NA	NA
	Winter Crop	55	NA	NA
	Total	**2,704**	**NA**	**NA**
Algal Suppression	Cotton	2,619	-29.8	-1.1
	Winter Crop	55	-0.5	-0.8
	Total	**2,674**	**-30.3**	**-1.1**
Menindee – 195GL active	Cotton	2,636	-12.8	-0.5
	Winter Crop	55	-0.4	-0.8
	Total	**2,691**	**-13.3**	**-0.5**
Menindee – 195GL total	Cotton	2,650	1.0	0.0
	Winter Crop	55	-0.2	-0.3
	Total	**2,705**	**0.8**	**0.0**
Fish migration	Cotton	2,611	-38.1	-1.4
	Winter Crop	54	-0.7	-1.2
	Total	**2,665**	**-38.8**	**-1.4**

Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

Worst case economic loss

The central case results are based on the probability-weighted impact observed across the climate scenarios in the hydrologic output. In this section we report the worst-case economic loss. For some proposals the economic loss is largest in the years with higher water availability, but for other proposals the largest economic loss may occur in drought years. The worst case in this analysis is the worst replica observed across the 13 climate scenarios.

Charts 6.13 summarise the total economic impact for the central and worst case of each option against the economic base case for both impacts measured and both crop types and chart 6.14 shows the results for each replica ranked from worst to best.

In summary:

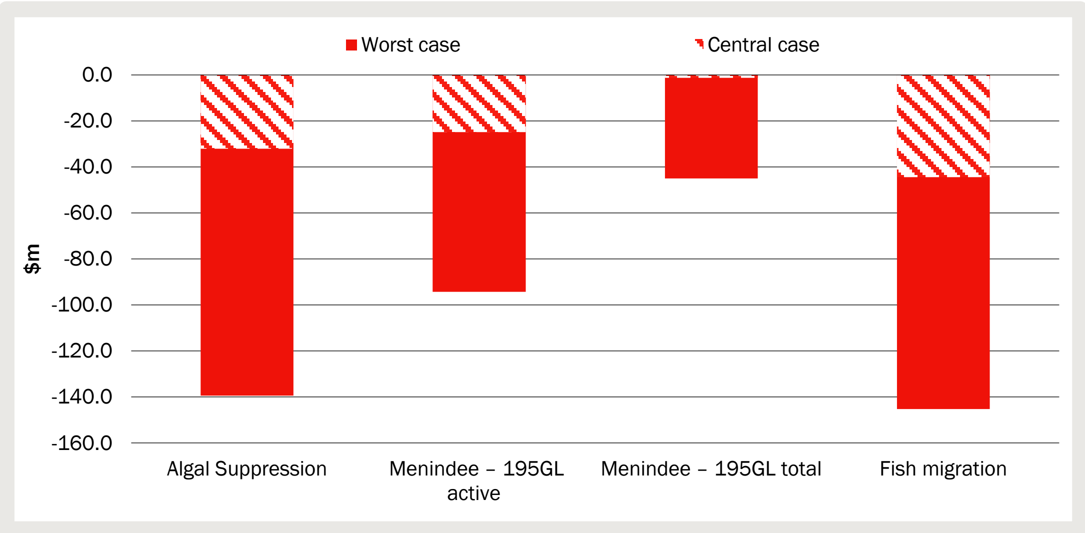
- All options demonstrate a large degree of variability in outcomes.[26] This is due to disproportionately high number of extreme events recorded in the sample.
- The Algal Suppression option's worst-case scenario results in the second largest overall economic loss among all options, totalling $139.5 million in present value terms. However, this represents more than a fourfold increase compared to the

26 The variability is measured by using the standard deviation across the results by replica.

central case. This option demonstrates the least variability in outcomes among all options.

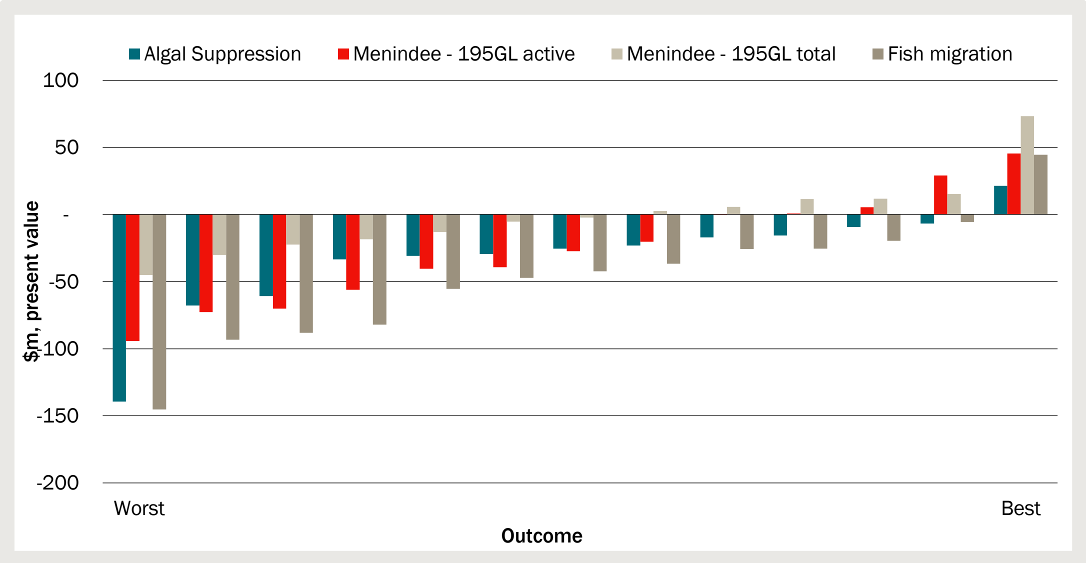
- The Menindee – 195GL active option presents an economic outcome exceeding $94.3 million in present value terms, ten times more than the central case. Notably, this option displays one of the widest range of outcomes across all options.
- The Menindee – 195GL total option results in a worst-case economic loss of $45.0 million in present value terms. This a large increase compared to central case results due to wide range of outcomes observed, both positive and negative.
- The Fish Migration option remains the worst option across all scenarios, with a worst-case economic loss of $145.3 million in present value terms.

7.13 Worst and central case results relative to the base case over 40 years ($m, PV) – Barwon-Darling



Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

7.14 Results for each replica over 40 years ($m, PV) – Barwon-Darling



Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

Sensitivity analysis

Overall, the ranking of the options does not change for the different sensitivity test, while the alternating discount rates have the largest impact on the results (table 6.15). Most noteworthy is the economic benefit observed for the Menindee - 195GL total option when using a 7 per cent discount rate. This gives outcomes in the beginning of the sample more weight compared to those in the future.

7.15 Sensitivity test results over 40 years ($m, present values) – Barwon-Darling

Option	Central Case ($m, PV)	3 per cent discount rate ($m, PV)	7 per cent discount rate ($m, PV)	+20 per cent value ($m, PV)	-20 per cent value ($M, PV)
Algal Suppression	-32.1	-43.8	-24.4	-38.6	-25.7
Menindee - 195GL active	-24.8	-35.2	-18.2	-29.8	-19.9
Menindee - 195GL total	-1.3	-3.8	0.2	-1.5	-1.0
Fish migration	-44.4	-59.3	-34.7	-53.3	-35.5

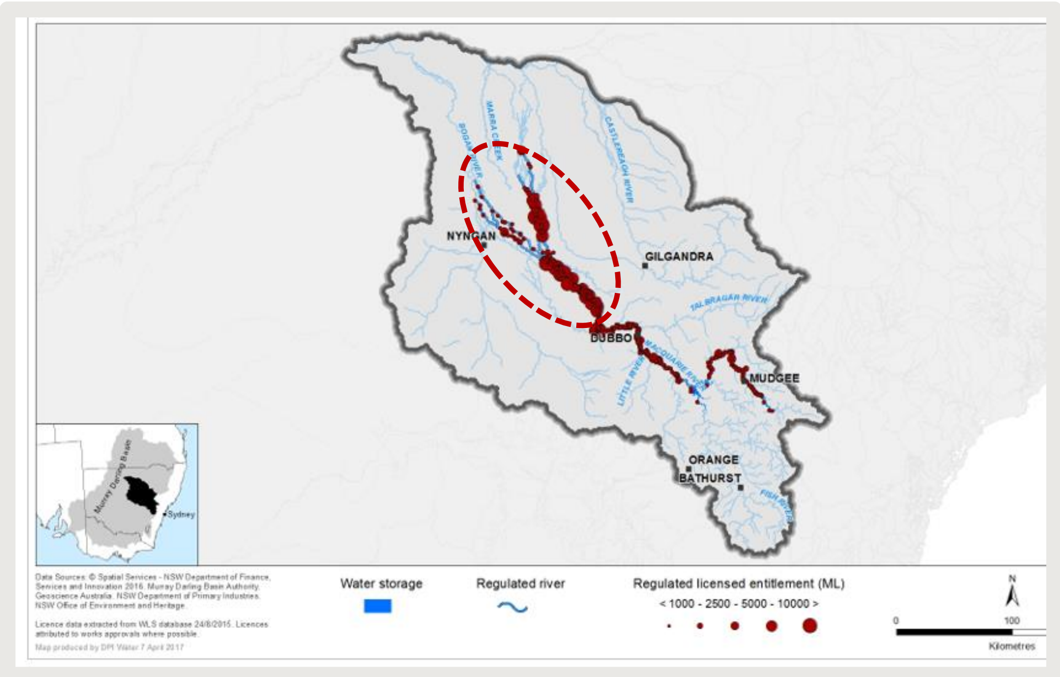
Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

8 Macquarie

The following chapter summarise the economic impacts of the proposed Menindee Lakes connectivity options across the Macquarie valley relative to the base case, i.e., business as usual. No results are reported for the algal suppression and fish migration options as the North West Flow Plan targets do not apply to the Macquarie valley. The reaches of the Macquarie valley where supplementary water access licenses are likely to be impacted by the Menindee proposals are indicated by the circled area in the map below

The economic analysis is based on the hydrological multi-replicate outputs and the methodology to estimate the economic impact outlined in the previous chapter. The hydrological modelling is based on the past 130 years and output results have been reshaped into 13 replicate outputs each covering a 40-year period.

8.1 Macquarie impacted reaches



Data source: The Water Group

Economic base case

The base case is a continuation of the current water-sharing plan rules and represents business-as-usual.

Value of planted crops at the beginning of the season

In the base case, a long-term average of 46 284 hectares of cotton are planted each season in October with a value of $311.2 million per season. Overall, the total average cotton area planted ranges between 30 988 and 57 830 hectares with a value of $208.3 to $388.8 million (chart 8.3).

For winter crops we observe a long-term average of 7 380 hectares are planted each season in May with a value of $10.5 million per season. Overall, the total average winter crops planted ranges between 5 509 and 9 009 hectares with a value of $7.8 to $12.8 million (chart 8.4).

This shows the large variability depending on the available water, in particular for cotton. However, there are also more extreme years recorded across the climate scenarios (table 8.2).

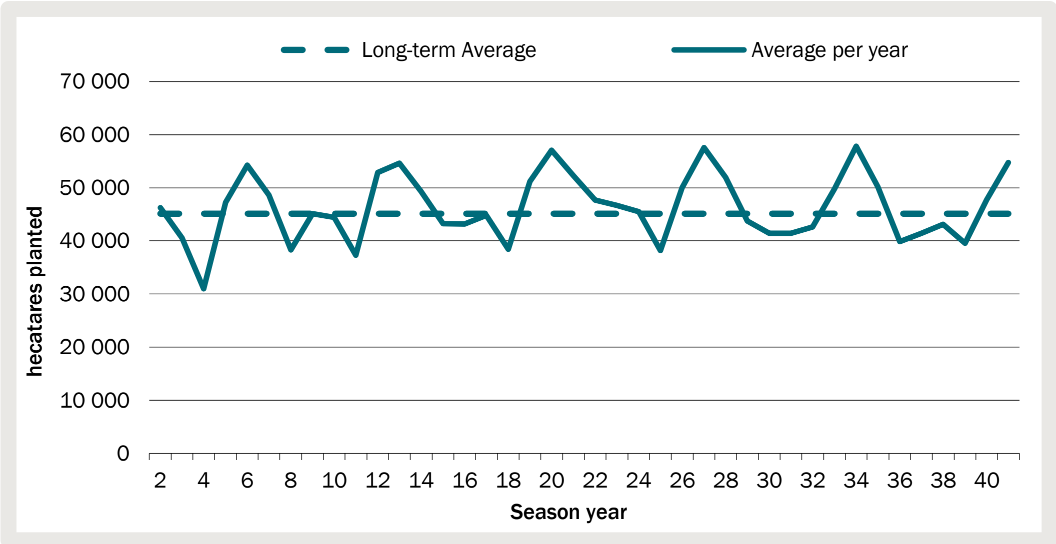
8.2 Summary statistics cotton and winter crops planted per season (base case) – Macquarie

Crop type		Hectares planted (ha)	Value of crop ($m, real)
Cotton	Min	30,988	208.3
	Long term average	46,284	311.2
	Max	57,830	388.8
Winter crops	Min	5,509	7.8
	Long term average	7,380	10.5
	Max	9,009	12.8

Note: Minimum and maximum values are based on the worst and best season recorded across years.

Source: CIE

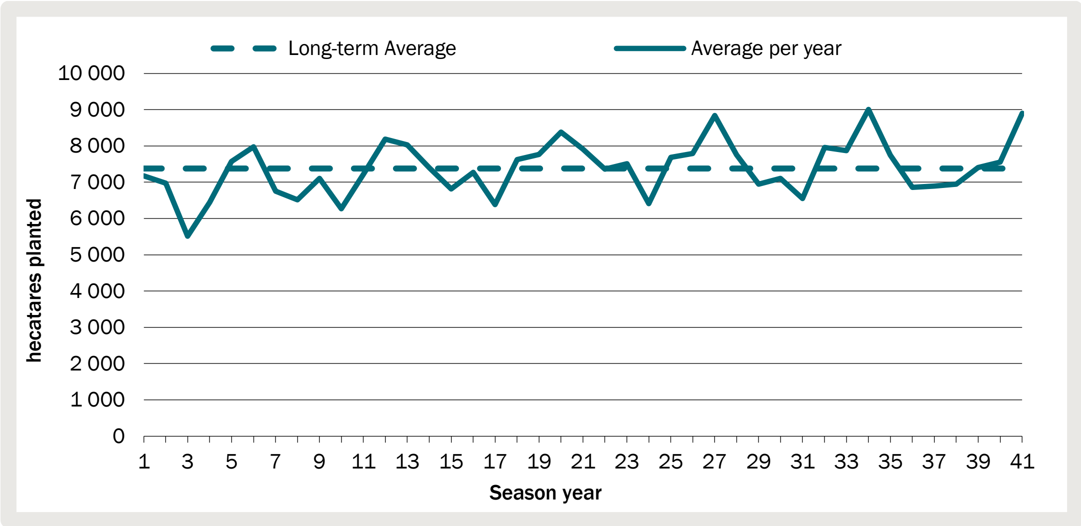
8.3 Cotton planted by season (base case) – Macquarie



Note: Season year 1 starts in April and ends in September; therefore, no cotton planting is recorded

Data source: CIE

8.4 Winter crops planted by season (base case) – Macquarie



Data source: CIE

Value of harvested crops at the end of the season

In the base case, a long-term average of 46 284 hectares of cotton are planted and 42 184 hectares harvested each season with a value of $283.6 million per season. This means that in years where cotton experiences water stress the probability-weighted outcome is 8.9 per cent lower (table 8.5 and chart 8.6). Across all years and climate scenarios, we observe that in one third of the observations some loss occurs due to water stress and in two thirds of the cases no loss is recorded. This is broadly in line with the expectation that farmers require more 'good' years to absorb losses from 'bad' years.

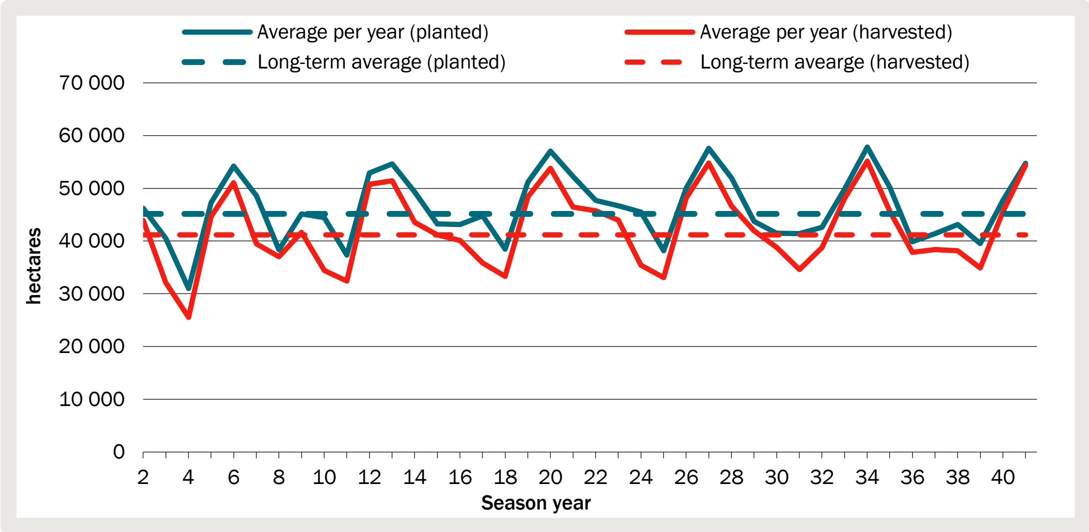
In the base case, a long-term average of 7 390 hectares are planted and 6 697 hectares are harvested each season with a value of $9.5 million per season. This means that in years where winter crops experience water stress the probability-weighted outcome is 8.9 per cent lower (table 8.5 and chart 8.7). This is similar compared to cotton.

8.5 Long-term average cotton and winter crops planted and harvested (base case) – Macquarie

Crop type	Hectares planted (ha)	Hectares harvested (ha)	Value of crop planted ($m, real)	Value of crop harvested ($m, real)	Difference (per cent)
Cotton	46,284	42,184	311.2	283.6	- 8.9
Winter crops	7,380	6,697	10.5	9.5	- 8.9

Source: CIE

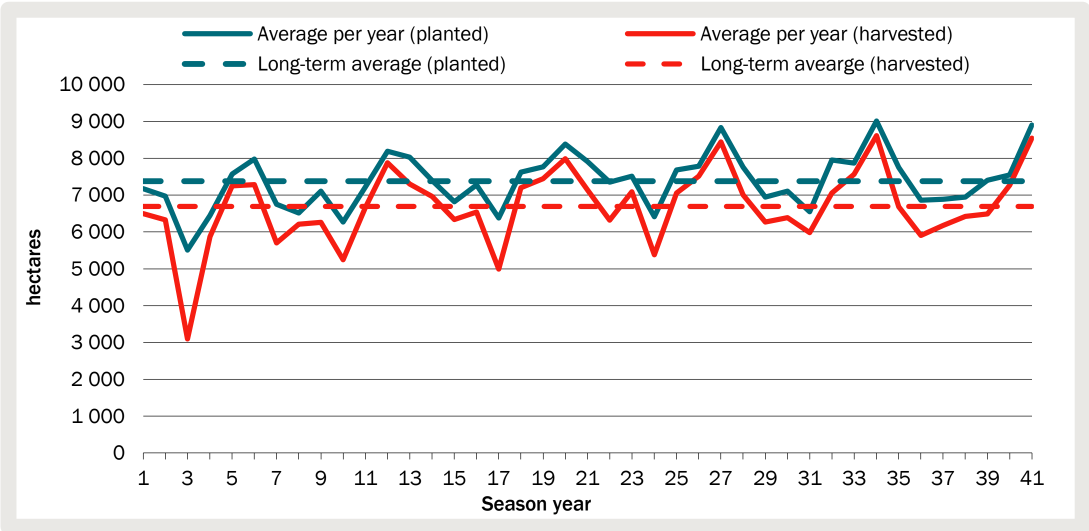
8.6 Cotton planted versus harvested hectares (base case) – Macquarie



Note: Season year 1 starts in April and ends in September; therefore, no cotton planting/harvesting is recorded

Data source: CIE

8.7 Winter crops planted versus harvested hectares (base case) – Macquarie



Data source: CIE

Central case impacts

The central case compares outcomes of each proposed option against the economic base case outlined in the previous section. The central results are based on probability-weighted outcome for each year across all climate scenarios.

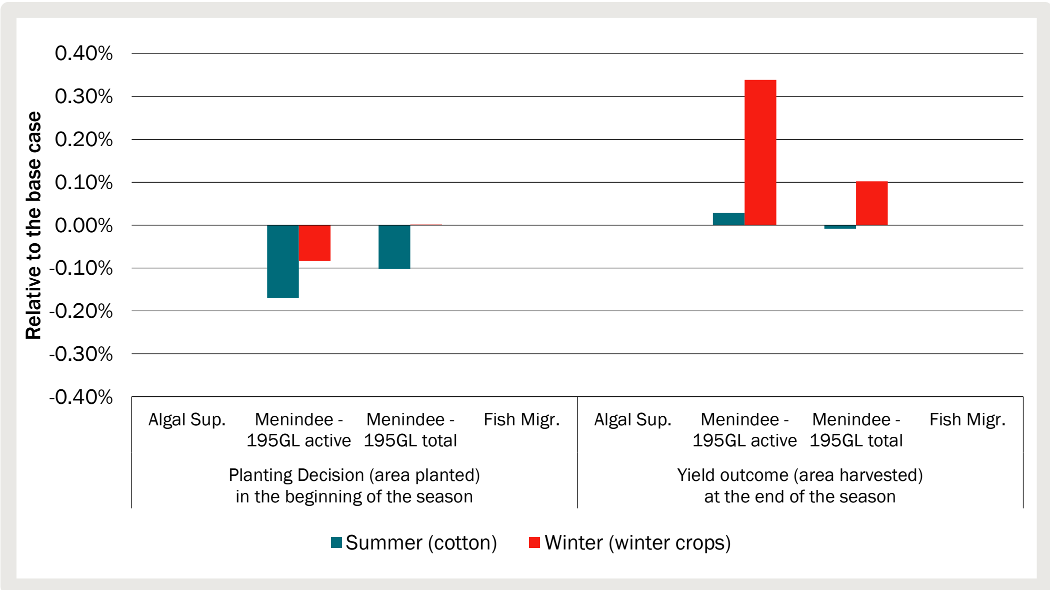
Chart 8.8 summarises the total probability-weighted impact over 40 years of each proposed option on the farmers planting decision in the beginning of the season and the yield loss at the end of the season for both crop types relative to the base case:

- No impacts are expected from the Algal suppression and Fish migration options.

- Overall, both Menindee – 195GL options have relatively small and similar economic outcomes.
- The Menindee – 195GL active option sees a reduction of the total cotton area planted by 0.2 per cent and 0.1 per cent for winter crops relative to the base case. In addition, due to restricted water access during the season cotton yield no significant impact is observed and winter crop yield increases slightly by 0.3 per cent.
- The Menindee – 195GL total option has similar economic outcomes but marginally less impact on total cotton planted (0.1 per cent reduction) and a sees a marginal increase in winter crop yield of 0.1 per cent.

We note that the somewhat marginal increase in probability-weighted yield outcome for winter crops is driven by a few extreme events where the water stress coefficient is higher than in the base case towards the end of the season. We note that winter crops are a basket of different crops with different growth cycle and planting and harvesting dates.

8.8 Probability-weighted impact of options on planting decision and yield relative to base case – Macquarie



Data source: CIE

The total economic impact of the assessed options has been estimated over a 40-year period, while for each year the probability-weighted result across the 13 climate scenarios has been taken. The present value has been calculated using a real social discount rate in accordance with the NSW Treasury Guidelines.[27]

All proposals are assessed against the economic base case. In summary:

27 NSW Treasury (2023), TPG23-08 NSW Government Guide to Cost-Benefit Analysis, available at: https://www.treasury.nsw.gov.au/sites/default/files/2023-04/tpg23-08_nsw-government-guide-to-cost-benefit-analysis_202304.pdf

- The economic impact on the farmer's planting decision is estimated as the change in the cropping area and valued at the net difference between forgone (or gained) value and avoided costs during the cropping season resulting from the proposals.
- The economic impact on the farmer's yield is estimated as the change in the harvested area resulting from changes is yield outcomes and valued at the crop value that has been forgone (or gained) due to the assessed proposals.

Table 8.9 shows the total economic loss due to the proposed options. The Menindee - 195GL active options has an economic loss of $1.1 million in undiscounted terms and $3.6 million in present value terms and the Menindee - 195GL total option an marginally higher loss of $3.9 million in undiscounted terms and $4.0 million in present value terms.

The present value losses are higher than the undiscounted losses as negative outcomes are primarily observed in the earlier years of the sample and significantly less pronounce in later years.

Charts 8.10 provides a comprehensive overview of the economic impact of each option compared to the economic base case, considering both impact measures and both crop types:

- No economic impacts were measured for the Algal suppression and Fish migration options.
- The Menindee – 195GL active option exhibits the lowest economic of both options, totalling $3.6 million in present value terms. This is an overall reduction of 0.1 per cent relative to the base case.
- The Menindee – 195GL total option leads to an economic loss of $4.0 million in present value terms. This is an overall reduction of 0.1 per cent relative to the base case.

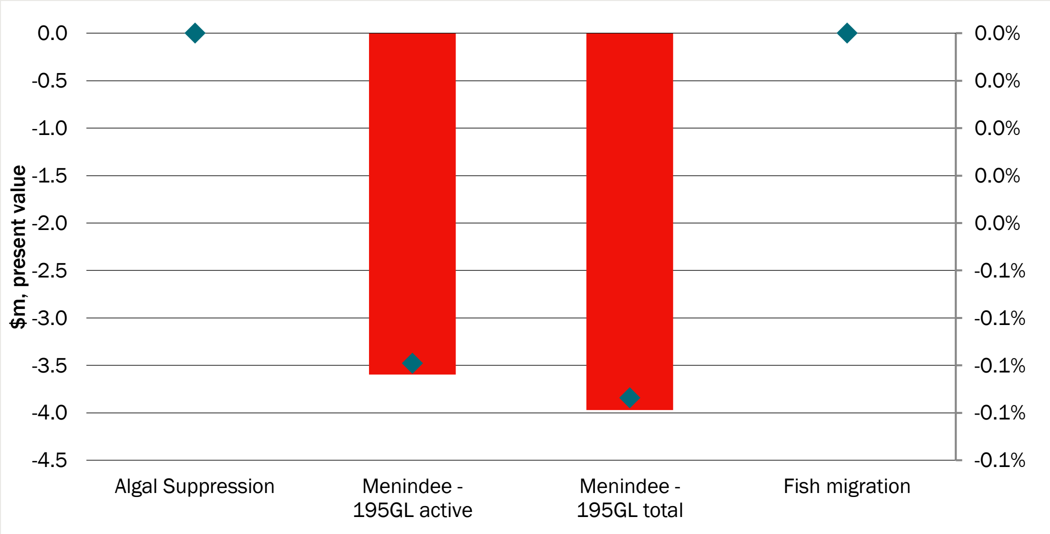
8.9 Central case results, undiscounted and discounted – Macquarie

Option	Central Case ($m, real undiscounted)	Central Case ($m present value discounted)	Central Case (per cent change)
Algal Suppression	NA	NA	NA
Menindee - 195GL active	-1.1	-3.6	-0.1
Menindee - 195GL total	-3.9	-4.0	-0.1
Fish migration	NA	NA	NA

Note: Present value figures are based on real social discount rate of 5 per cent.

Source: CIE

8.10 Summary of central case results relative to the base case ($m, present value) – Macquarie



Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

Detailed results

Tables 8.11 and 8.12 summarise in detail the economic impact of each option against the base case by type of impact measured and crop type.

8.11 Economic impact on farmers' planting decision – Macquarie

Option	Crop type	Total Value less of input cost ($m, PV)	Relative to base case ($m, PV)	Change (per cent)
Base Case	Cotton	1,473	NA	NA
	Winter Crop	28	NA	NA
	Total	**1,500**	**NA**	**NA**
Menindee - 195GL active	Cotton	1,470	-2.8	-0.19
	Winter Crop	28	-0.1	-0.25
	Total	**1,498**	**-2.9**	**-0.19**
Menindee - 195GL total	Cotton	1,471	-1.5	-0.10
	Winter Crop	28	0.0	-0.04
	Total	**1,499**	**-1.5**	**-0.10**

Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

8.12 Economic impact on farmers' yield – Macquarie

Option	Crop type	Total Value ($m, PV)	Relative to base case ($m, PV)	Change (per cent)
Base Case	Cotton	5,004	NA	NA
	Winter Crop	166	,NA	NA
	Total	**5,170**	**NA**	**NA**
Menindee - 195GL active	Cotton	5,003	-1.3	-0.03
	Winter Crop	167	0.6	0.36
	Total	**5,170**	**-0.7**	**-0.01**
Menindee - 195GL total	Cotton	5,002	-2.6	-0.05
	Winter Crop	166	0.1	0.08
	Total	**5,168**	**-2.5**	**-0.05**

Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

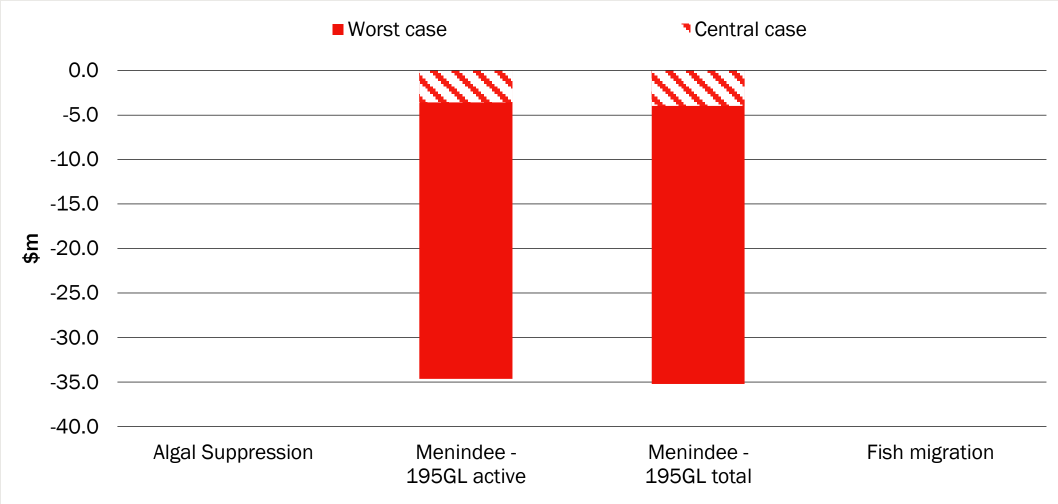
Worst case economic loss

The central case results are based on the probability-weighted impact observed across the climate scenarios in the hydrologic output. In this section we report the worst-case economic loss. For some proposals the economic loss is largest in the years with higher water availability, but for other proposals the largest economic loss may occur in drought years. The worst case in this analysis is the worst replica observed across the 13 climate scenarios.

Charts 8.13 summarise the total economic impact for the central and worst case of each option against the economic base case for both impacts measured and both crop types and chart 8.14 shows the results for each replica ranked from worst to best.

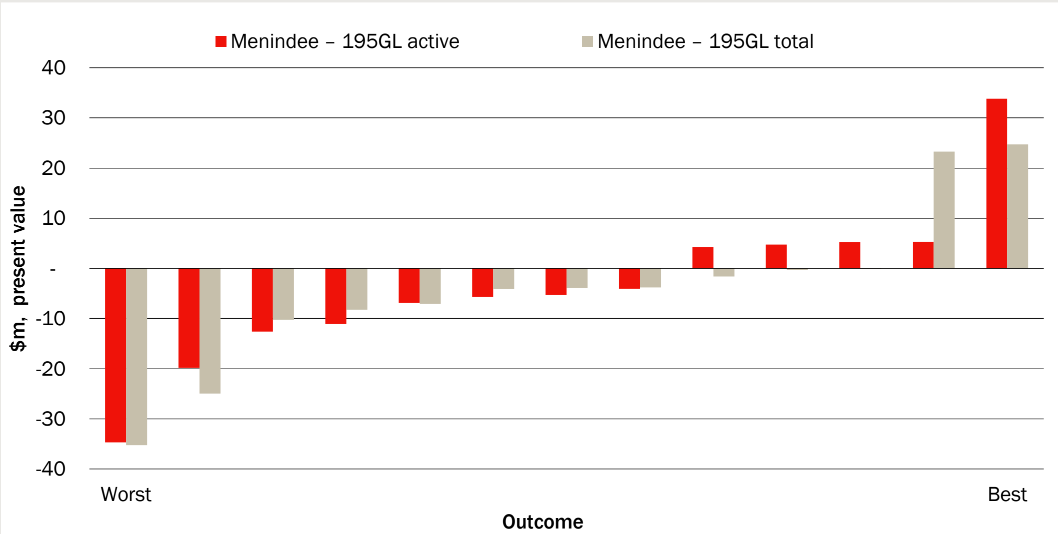
For both options is the worst-case economic loss approximately $35 million in present value terms. This is more than eight times higher than the central case estimate, which highlights the variability of the results at the extremes.

8.13 Worst and central case results relative to the base case over 40 years ($m, PV) – Macquarie



Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

8.14 Results for each replica over 40 years ($m, PV) – Macquarie



Note: Present value figures are based on real social discount rate of 5 per cent.
Source: CIE

Sensitivity analysis

Overall, the ranking of the options does not change for the different sensitivity test, while the alternating discount rates have the largest impact on the results (table 4.14).

8.15 Sensitivity test results over 40 years ($m, present values) – Macquarie

Option	Central Case ($m, PV)	3 per cent discount rate ($m, PV)	7 per cent discount rate ($m, PV)	+20 per cent value ($m, PV)	-20 per cent value ($m, PV)
Algal Suppression	NA	NA	NA	NA	NA
Menindee - 195GL active	-3.6	-2.9	-4.0	-4.3	-2.9
Menindee - 195GL total	-4.0	-4.1	-3.8	-4.8	-3.2
Fish migration	NA	NA	NA	NA	NA

Note: Present value figures are based on real social discount rate of 5 per cent if not otherwise stated.

Source: CIE

A Technical appendices

Methodology to understand the economic impact on farmers

For the Regional Water Strategies, the Water Group used an economic model that utilises daily hydrological modelling, which subsequently aggregates daily data into monthly data. Consequently, this approach results in the loss of certain valuable information, such as the ability to distinguish between periods of consecutive dry days, whether they occur, for example, as a continuous 10-day span or are spread out across the entire month.

In the previously used model, the valuation of water is based on a dollar per ML estimate. This approach is well suited to measure the benefits for town water supply (using the willingness to avoid water restrictions) and to agricultural/other commercial water use (using the marginal value of water for these users) but will be revisited under this model extension.

This translates into three main shortcomings which will be addressed by our revised model:

1. A monthly aggregation does not allow the analysis of the value of water at critical times of the growing cycle. For example, cotton needs the most water from the first flower until the first open boll which makes the crop most vulnerable at this point.
2. The model needs to better reflect economic decision making of agricultural users. The decision-making process will depend on a variety of parameters, such as water allocation, on farm water storage at the start of the season, expected rainfall and temperature throughout the season and willingness to take risks.
3. Decisions include questions like:

   Before the crop is planted, whether to

   a) plant a crop and also the area to plant, or

   b) sell the water.

   Once the crop is planted and water availability is less than expected, whether to

   c) partially water all the planted crop area,

   d) fully water part of the planted crop area, and partially water/stop watering the remainder, or

   e) sell the water.

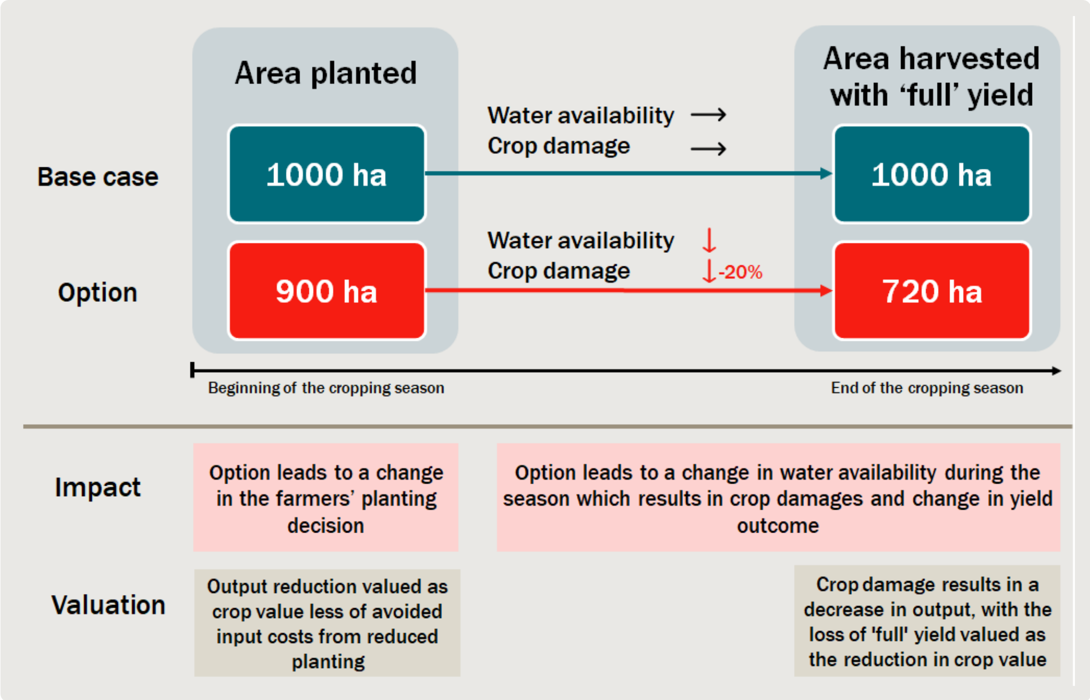
Decision rules will also differ by crop type, in particular, seasonal versus perennial crops. The main focus of the connectivity proposals are supplementary licences.

Those are 'opportunistic' licences and usually not used to irrigate perennial crops. This analysis, therefore, focuses on two main crop types:

- Cotton in summer, and
- Crops such as wheat in winter (hereafter: winter crops).

The economic value lost due to the changes in the dry conditions trigger can be narrowed down to two main components, **famers planting decision** at the beginning of the season and **water availability** during the season (chart A.1):

A.1 Illustrative example to estimate the impact of dry conditions trigger



Data source: CIE

1. The value of lost output due to changes in the planting decisions of farmers:
   a) This is a direct output of the hydrological modelling. The estimated total crop area planted at the beginning of the season incorporates a risk function of farmers, available water and expected available water.
   b) The value lost is then the difference between the crop area in the base case and the option times value of the crop less of avoided input costs from reduced planting
2. The value of lost output due to changes in water availability during the season affecting the yield of the crop.
   a) This is based on the water stress coefficient or soil moisture parameter estimated in the hydrological modelling. The water stress coefficient is based on the soil moisture content on a daily step and triggers crop water diversions in the hydrological model. We are using this water stress coefficient to make inferences about the yield of the crop at the end of the season.

b) This approach effectively measures the time value of water as the model applies a yield damage curve for different stages of the cropping cycle. The value lost is then the difference of the modelled yield after accounting for yield losses during time of water stress times the crop value.

c) The analysis is based on a regional level as actual yield data has been used to calibrate the outcomes of the hydrological model. We note that if actual yield data were available on a farm level, this analysis could be further refined.

In more detail the key components of the model include:

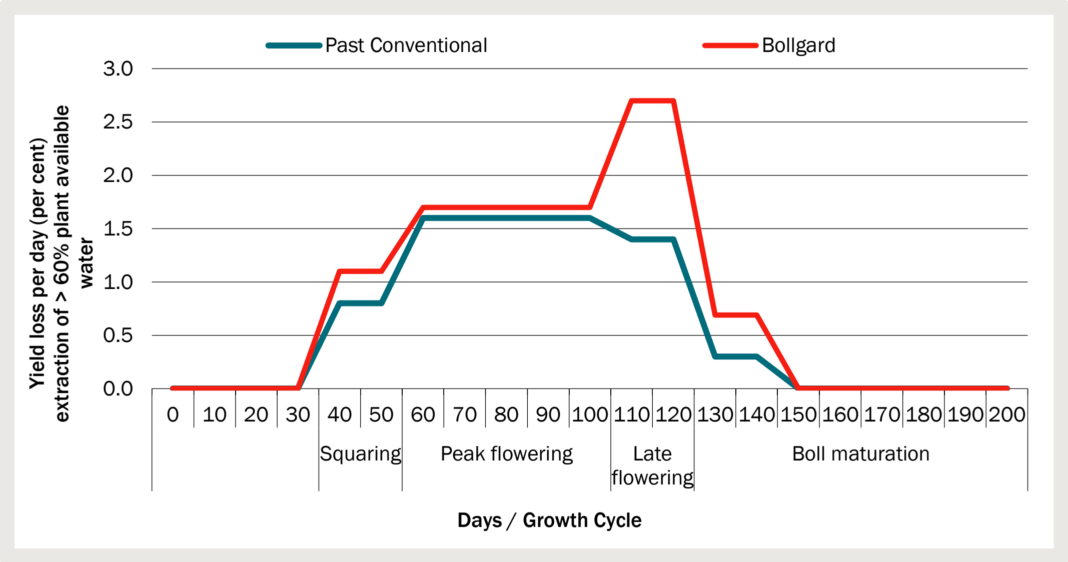
1 **Water availability.** This was provided by the Water Group. Data includes total water allocation, daily on-farm storage, rainfall and floodplain (harvesting), evaporation and losses, and the water stress coefficient. Water stress coefficient is more than any other variable linked to the specific farm, however, has been aggregated to a weighted average based on farm size.

2 **Decision Rules.** The farmers decision at the beginning of the season, but also during the season, will determine the crop area planted and how the crop is watered throughout the season. This will mainly depend on known water availability and willingness to take risk on expected water availability. Ultimately, we would assume an efficient market where farmers sell water to other farmers if they believe that is the profit maximising decision at the beginning of the season.

3 **Damage curve for crop.** We have developed **yield loss/damage curves** for cotton and winter crops. Those have been used to estimated how much more yield is lost during the season in the project case compared to the base case. Chart A.2 shows the yield damage curve for cotton and chart A.3 for winter crops (such as wheat).

   a) Cotton yield is permanently lost if cotton is not sufficiently irrigated. The magnitude of the loss varies by the time the irrigation deficit occurs. For example, the Bollgard cotton type is the most vulnerable during the late flowering period. Irrigation deficit is defined if more than 60 per cent of the plant available water in the soil has been extracted by the plant. This threshold has been calibrated to match actual yield data of the past 20 years (see calibration section below).

A.2 Yield loss under water stress by growth cycle for cotton

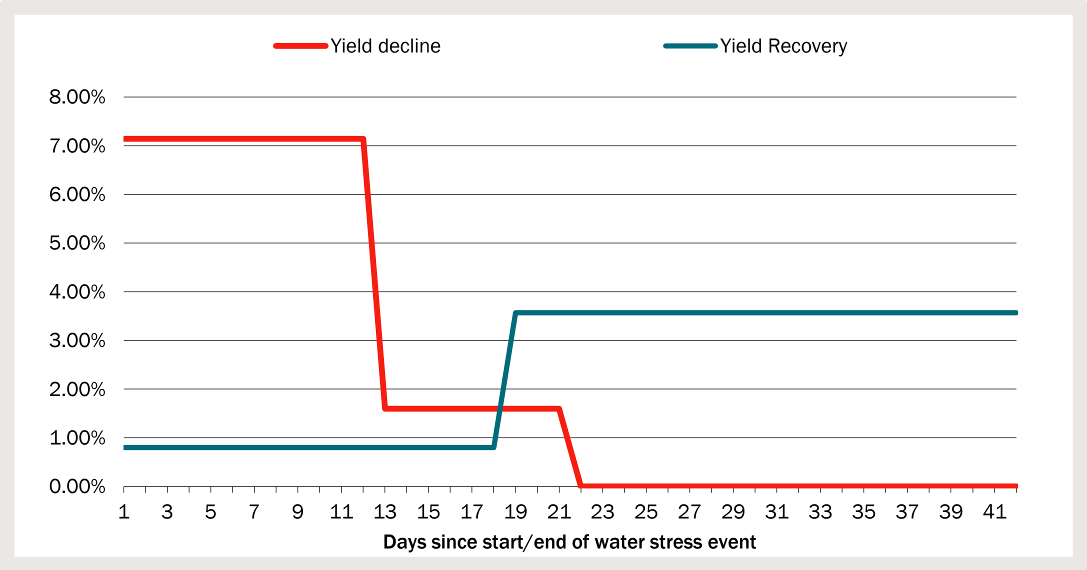


Data source: CIE, CRDC (2012) WATERpak – a guide for irrigation management in cotton and grain farming systems Table 3.1.3, p.246 based on Yeates et al. 2010; Hearn and Constable 1984

b) Yield loss for winter crops is usually *not* permanent if the crop has enough time to recover after irrigation deficit events. For water stress events up to 12 days the yield is reduced by 7.14 per cent per day and 1.60 per cent thereafter. It is assumed that if winter crops do not have sufficient water for more than 20 days the crop will die. As noted, winter crops can recover from water stress if sufficient water is available after water stress events. Crops will recover at a rate of 0.8 per cent per day for the first 17 days after a water stress event and at a rate of 3.6 per cent thereafter. This process takes 42 days if the crop was nearly dead.

c) We have chosen the same water stress coefficient threshold for winter crops as for cotton. In general, we would assume that winter crops are more drought resistant, which means our estimates will be more conservative.

A.3 Yield loss and recovery under water stress for winter crops



Data source: CIE, DPI (2012), Kangaroo River Water Sharing Plan - Socio-economic impact assessment of changes to the flow rules, p.14

4 **Valuing (remaining) output**. Lastly, attach a value to the measured differences between base case and project cases.

a) Total value of hectares of crop not planted at the start of the season:

For decision rules which will have an impact on the planting decision of farmers, the value lost will be equal to the average profit as the change in rules has caused this decision. The value lost is then the difference between the crop area in the base case and the option times value of the crop less of avoided input costs from reduced planting.

b) Total value of hectares of crop damaged (lower yield):

For farmers who have a (higher) yield loss due to water stress and less water availability during the growth season in the project case relative to the base case, the difference in yield will be valued at the crop value.

A.4 Crop value and input cost by crop type

Crop type	Source	Crop value ($2023/ha)	Input cost ($2023/ha)
Cotton	Weighted average of cotton income and input cost (2009-2021)	6,723	4,935
Winter Crop	Weighted average of NSW cropping income and input cost (1999-2021)	1,420	1,207

Source: CRDC and Boyce CA (2021), *Australian Cotton Comparative Analysis 2021;* CRDC and Boyce CA (2012) *Australian Cotton Comparative Analysis 2012*; ABARES (2021-22), *Financial performance of cropping farms*

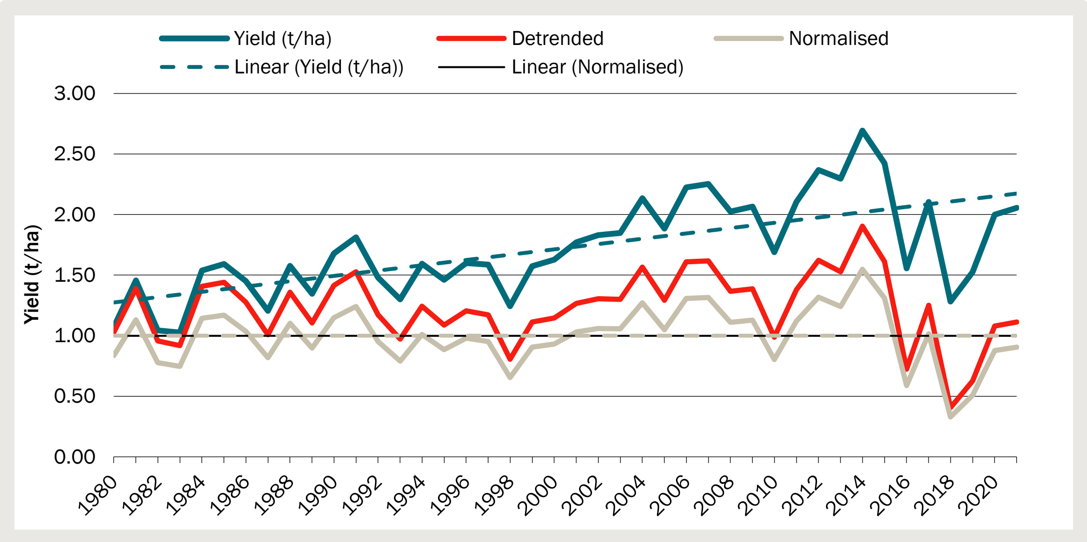
Calibration of water stress coefficient

The Water Group's hydrological modelling calculates a soil moisture index based on evaporation, rainfall and crop specific parameters. However, the model is not a crop model, i.e., the soil moisture index is calibrated so that water diversions for each farm are realistic. This means we cannot use the level of the soil moisture index or water stress coefficient reported alongside the hydrological output and our methodology has to account for that. For example, water stress coefficients range from 0 to 100, 100 meaning no water stress, <100 meaning water stress. In most of the cases this coefficient is below 100 in the hydrological output, which would imply that cotton would be under stress each day.

We have therefore calibrated a threshold for the water stress coefficient at which stress occurs for each valley. This threshold is based on actual yield data being observed and then compared to the base case data of each valley.

The chart below shows actual cotton lint yield in tonnes per hectare over the past 20 years in NSW. The yield data was first detrended to account for changes in crop types and technical advances which led to overall higher yield outcomes. The detrended data was then normalised. This process allows to compare yield outcomes in the past years with yield outcomes 40 years ago and creates a long enough sample to calibrate the threshold.

A.5 NSW Cotton Yield (1980 – 2021)



Data source: ABARES 2023, Australian crop report: September 2023, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra, September. CC BY 4.0.https://doi.org/10.25814/btrs-zg29; Agricultural Commodity Statistics 2022, Table 5.2

Since the water stress coefficient has an upper bound of 1, we can only observe below average yield outcomes in the economic analysis and not yield outcomes which are above the norm, for example, during high rainfall seasons. This shortcoming is less relevant as this analysis is focused on restricting supplementary water access which is most important during times of less water availability. Overall, in the past decades, we observe that if the yield outcome was below average this resulted on average in an 8 per cent yield reduction compared to the average. However, there are more extreme events like the 2019/20 season which saw a 49 per cent lower yield compared to the average or the 2016/17 season (41 per cent lower yield).

We also note that the yield data is based on NSW data and not valley specific data. The table below shows the calibrated thresholds used under which water stress for cotton occurs.

A.6 Calibrated water stress coefficient threshold

Valley	Threshold
Border Rivers	56.0
Gwydir	11.5
Namoi	31.0
Barwon Darling	24.0
Macquarie	18.2

Source: The Water Group

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