Department of Planning and Environment

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Far North Coast Regional Water Strategy

Detailed economic and ecological analysis

November 2022

Acknowledgement of Country

The NSW Government acknowledges Aboriginal people as Australia's first people and the traditional owners and custodians of the country's lands and water. Aboriginal people have lived in NSW for over 60,000 years and have formed significant spiritual, cultural, and economic connections with its lands and waters. Today, they practise the oldest living cultures on earth.

The NSW Government acknowledges the people of the Bunjalung and Githabul nations as having an intrinsic connection with the lands and waters of the Far North Coast Regional Water Strategy area. The landscape and its waters provide the people of the Bunjalung and Githabul nations with essential links to their history and help them to maintain and practise their culture and lifestyle.

The NSW Government recognises that the Traditional Owners were the first managers of Country and that incorporating their culture and knowledge into management of water in the region is a significant step for closing the gap.

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Far North Coast Regional Water Strategy

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Introduction

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

This report provides the detailed assessments, both economic and ecological, for the combined options outlined in the *Draft Far North Coast Regional Water Strategy: Far North Coast long list of options.* It outlines the results of the options assessment process for all relevant options for the Far North Coast.

This assessment is used to inform the risks and opportunities associated with different options being considered. The following combinations of options are subject to extensive hydrologic assessment in the Far North Coast:

- Combined option 1: Expand Rous County Council's bulk water system through Dunoon Dam
- Combined option 2: Maximise use of the proposed Clarrie Hall Dam augmentation
- Combined option 3: Maximise use of Toonumbar Dam
- Combined option 4: Incrementally augment the Richmond system through desalination
- Combined option 5: Connect the region to the Rous County Council water supply system.

The options considered for detailed analysis were informed by a series of rapid cost-benefit analyses. These rapid cost benefit analyses were evaluated based on the instrumental record rather than the more comprehensive stochastic and NSW and ACT regional climate modelling (NARCliM) models.

The options subject to a rapid assessment that did not progress to combined options without changes are:

- Option 1: Connect independent water supplies in the region to the Rous County Council network
- Option 2: Connect the Rous County Council and Tweed Shire Council bulk water supplies
- Option 3: Use Toonumbar Dam to augment town water supplies
- Option 7: Investigate indirect potable reuse of purified recycled water
- Option 8: Investigate direct potable reuse of purified recycled water
- Option 10: Investigate decentralised desalination
- Option 11: Investigate regional desalination
- Option 12: Raise Clarrie Hall Dam level
- Option 14: Construct a new Dunoon Dam on Rocky Creek
- Option 16: Provide purified recycled wastewater for industry and rural users
- Option 19: Raise Toonumbar Dam level
- Option 21: Establish and/or increase environmental water releases from major storages in the Far North Coast.

The rapid ecological assessment was applied to all options.

Purpose of the detailed economic and ecological analysis

The detailed economic and ecological analysis describes the results of the hydrologic modelling for the relevant options put forward in the draft Far North Coast Regional Water Strategy. Combined options subject to detailed analysis are evaluated according to new hydrologic modelling to examine economic outcomes for key extractive users and this outcome is compared with a base case.

A range of analyses were conducted on each of the combined options as well as a breakeven analysis that determines at what value of water the cost of the combined option equates to its benefits.

The hydrologic modelling in the Far North Coast region covers the observed historical, long-term paleoclimate (stochastic) and climate change (NARCliM) model projections. We have 10,000 years of data in each data set. This data has been split into 1,000 40-year segments. The analysis on each major water user is analysed using 1,000 40-year realisations or ‘windows’. Both the average and the extreme outcomes are examined in the detailed analysis.

The detailed economic and ecological analysis of the selected options examines:

- how each option will influence the use of water in the region
- the economic consequences of implementing the option
- how resilient the option will be to a more variable climate, or to a dry climate change scenario
- how the option impacts different water users and classes of licences
- the extent to which changes to the key assumptions influence the outcomes of the detailed assessment
- impacts on a range of flows including average annual flows, and flows that increase from zero flows to overbank flows, which flow across floodplains or fill wetlands
- whether changes to a set of flow parameters at several points were positive or negative relative to environmental water targets.

We currently do not have enough information to be able to include evidence about potential impacts and benefits for Aboriginal communities in the assessment of the shortlisted options. Our preliminary engagement with some Aboriginal communities in the Far North Coast region has identified that communities need specific information on how the shortlisted options will affect them. Some of this information will not be available until we begin to do more detailed analyses of specific options that remain in the final regional water strategy shortlist. Some of this additional analysis may be identified for early action in the strategy’s implementation plan, while other work would progress as part of the strategic business case for specific options.

Limitations of cost-benefit analysis

The analyses used in the regional water strategies follow the advice of NSW Treasury. This advice suggests using CBA to understand how well options meet the service need in each region.

CBA analysis provides a method of evaluating options across the state in a consistent and reliable way. It also lets us compare the performance of different options for improving town water reliability with a state-wide perspective.

There are two key challenges that we face when applying the CBA analysis to the Far North Coast:

- It is not possible to obtain an accurate cost for a major town running out of potable water because it has not happened to any major industrialised city.[1] This makes it difficult to accurately capture the cost of not having water available, which might bias the CBA.
- The CBA analysis assumes perfect knowledge of the hydrology. It assumes that if shortfalls justify it, action can be taken two years before an emergency augmentation is required.

These 2 challenges mean that if shortfalls occur very infrequently they are not valued in a way that is captured by the state-wide approach. This is true regardless of the costs incurred by the shortfalls.

None of our hydrologic models in the Far North Coast resulted in shortfalls that lasted for two years or more. However, the region does not have the same levels of water storage that many other regions have available. For example, Rocky Creek dam has just over 12 months supply with no restrictions. The dam has about 18 months supply if water restrictions are put in place.

The towns and communities in the Far North Coast are relatively large. This means that it can take a long time to make an emergency source of water available. Examples of emergency sources of water in the Tweed local government area are desalination and connecting to the City of Gold Coast or SeqWater networks. These supply options have high capital costs and operational costs. Additional considerations are:

- If the Tweed area is in drought, it is likely that southeast Queensland will also be in drought. This would make it challenging to connect to these other networks and would reduce their effectiveness.
- During a drought there is likely to be a scarcity of membranes available for desalination. This would increase the time it would take to have a desalination plan operational.
- Planning and implementing these emergency measures can take 12 months or more.

To avoid running out of water, councils need to plan for emergency augmentations early in a drought. With current storage conditions, councils need to start planning these augmentations when storages are still quite full. For example, to allow for a 12-month planning horizon, Tweed Shire Council currently needs to plan for emergency supplies once Clarrie Hall Dam drops to about 97% capacity. As demand increases and climate change reduces inflows, dam levels will drop faster and they will need to start planning augmentations much earlier. Some models suggest that by 2030

[1] Cape Town is frequently thought of as an industrialised town to run out of water. However, the 'Day Zero event' did not actually eventuate. It was only planned for.

Tweed Shire Council will need to start planning emergency augmentations when Clarrie Hall Dam is completely full.

There are many other factors to consider when assessing options for town water supplies. In particular, local councils have statutory requirements to provide certain levels of service for water provision. They also need to ensure that:

- communities are protected as much as possible from the risk of water system failure, and
- residents have continuous access to safe water for drinking and essential services.

Councils in the Far North Coast region are struggling to reduce the risks of these failures. To account for these factors in the Far North Coast, the department is progressing additional analyses that will better consider these risks and lead times. The analyses have not been completed in time for the release of this consultation paper. However, the results will be available to inform the final strategy.

Overview of the detailed analysis

The complete options assessment process is described in the *Options Assessment Process Overview*.[2] This complete assessment process comprises 5 stages. The current document describes stage 3 (detailed assessment of options based on new climate modelling) which follows the filtering of options and rapid economic and ecological assessments based on the 130-year historic climate record.

Combined options are evaluated against new datasets for hydrologic modelling to examine economic outcomes for key extractive users. The economic outcome is then compared with a base case. Different scenarios and a breakeven analysis were also examined on each of the combined options. This helps determine the regional value of water, where the cost of the combined option equates with its benefits.

The hydrologic modelling in the Far North Coast region is based on:

- long-term historic climate projections (stochastic data): these assume that our future climate is similar to what the science is indicating our long-term paleoclimate was like and are based on a 10,000-year dataset.
- a dry climate change scenario (NARCliM[3] modelling): this assumes that there is a dry, worst-case climate change scenario in the future and is also based on a 10,000-year dataset

Each 10,000-year dataset is split into 1,000 40-year segments. The impact to each major water user is analysed using 1,000 40-year realisations or 'windows'. The 40-year time horizon reflects NSW Treasury guidelines for a long period of time to measure the consequence of an option. More detail on the base case is available in the economic base case report for the Far North Coast.[4] The detailed analysis examines how much water is available to different licences under the base case and each option.

Our preliminary engagement with some Aboriginal communities in the Far North Coast region and assessment of the shortlisted options has not yet produced enough evidence of the potential impacts and benefits of the options for Aboriginal communities. These communities need specific information on how the shortlisted options will affect them. Some of this information will not be available until we begin to do more detailed analyses of specific options. Preparing the information

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[2] Department of Planning and Environment 2022, *Options Assessment Process: Overview*, www.dpie.nsw.gov.au/water/plans-and-programs/regional-water-strategies/identifying-and-assessing, accessed 15 November 2022.

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

[4] Department of Planning and Environment 2022, *Economic Base Case: Far North Coast Region*, water.dpie.nsw.gov.au/plans-and-programs/regional-water-strategies/public-exhibition/far-north-coast-regional-water-strategy

for consultation and analysis may be identified for early action in the strategy's implementation plan or may progress as part of the strategic business cases for specific options.

It should be noted that the detailed ecological analysis is more comprehensive than the rapid assessment and guides the strategic assessment of the option. More rigorous ecological assessments will be completed as options are progressed.

Overview of the detailed economic analysis

The key information that informed the cost-benefit analysis of each option included:

- **understanding what happens if we do nothing**, including hydrological modelling under the two different hydrologic models
- **high level cost estimates** prepared for each option including capital expenditure and operational expenditure for infrastructure options, and implementation costs for non-infrastructure options. These costs were very broad and high level. Further investigation of any option will require more detailed cost estimates.
- **benefit estimates** for the economic value of water for towns and industries that has been developed and used as the primary benefit to assess the costs against. This is referred to as the regional water value function. A summary of the value of water for each major water user is presented in the *Regional water value functions report*.[5]

Key outcomes of the detailed analysis are defined using two metrics or decision criteria: the net present value and the benefit-cost ratio. These terms and how they are applied are described in more detail in the *Options Assessment Process Overview.*[6]

In addition to these decision-supporting tools, the detailed analysis also uses:

- **sensitivity analysis** to identify the extent to which changes to the key assumptions influence the outcomes of the detailed analysis. The sensitivity analysis was carried out across:
  - the discount rate (3 and 10 per cent)
  - capital and operational expenditure (+30 per cent / -30 per cent)
  - the value of water assigned to each economic activity
  - reactive infrastructure solutions.
- **distributional impacts** to look at how the option impacts different water users and classes of licences
- **breakeven analysis**, which determines the price at which a megalitre of water would result in the costs being equivalent to the benefits. This analysis assumes the proposed option is viable on the balance of outcomes within the economic analysis framework presented.

[5] Marsdon Jacob Associates 2022, *Regional water value functions: Values for inclusion in the cost-benefit analysis to support NSW Regional Water Strategies*, Department of Planning and Environment, water.dpie.nsw.gov.au/plans-and-programs/regional-water-strategies

[6] Department of Planning and Environment 2022, *Options Assessment Process: Overview*, www.dpie.nsw.gov.au/water/plans-and-programs/regional-water-strategies/identifying-and-assessing, accessed 15 November 2022.

It is not always possible to determine a breakeven point, so some combined options may have no breakeven analysis described.

The detailed assessment was completed by applying the regional water value function to the outputs of the hydrologic modelling to determine the incremental change between the base case and the option, while taking into account the cost of the option.

Overview of the detailed ecological analysis

The ecological analysis used a quantitative method to understand the impacts of the options on different flows in the river systems. The analysis did not seek to monetise the costs and benefits of ecological impacts within the timeframe of the regional water strategies because these are difficult to determine and subject to several limitations.

We used standard ecological metrics which considered impacts on a range of flows, including average annual flow volumes; frequency of no-flow (cease-to-flow) events; and frequency of overbank flows, which flow across floodplains or fill wetlands (Figure 1). Each part of the flow regime plays an important role in supporting waterway health.

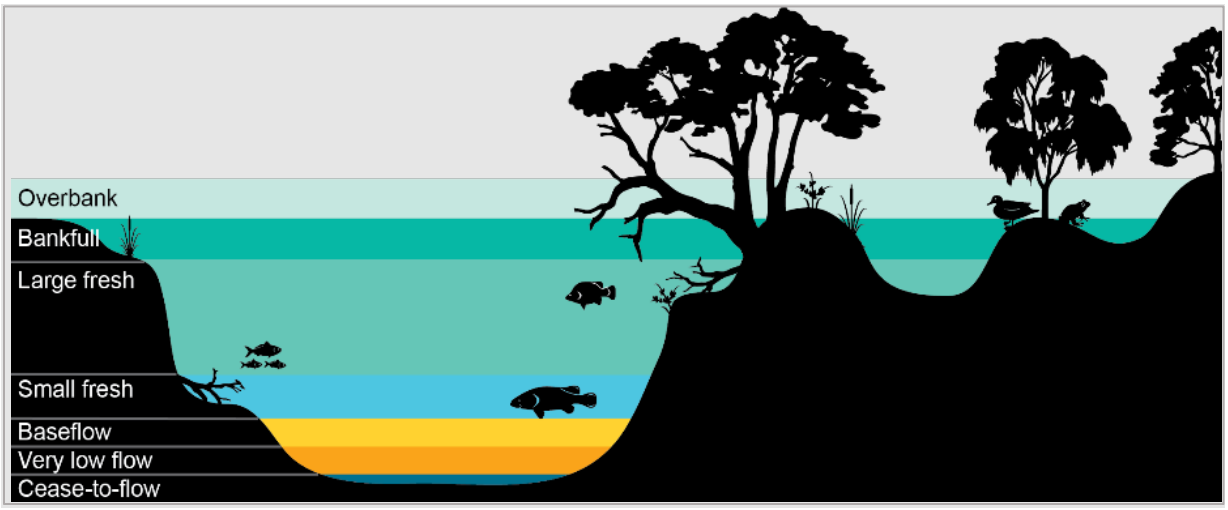

Figure 1. Conceptual model of the role of different flow regime components

These ecological metrics were evaluated from the outputs of the hydrologic models. In a similar way to the economic analysis, modelled flow data was generated for each water management option and climate scenario. We compared the results to the base case model outputs to identify changes in water delivery.

Modelled flows were output for several locations along the waterways.[7] In the Far North Coast, we assessed changes in standard ecological metrics for 30 locations in the Richmond River catchment

[7] The locations for modelled flow outputs were based on the locations of current and historic flow gauging stations. This allows us to compare model outputs to recorded flow data.

and for 17 locations in the Tweed region. These locations were chosen to represent the significant breadth of river habitat types across the region.

We used a categorisation system to rate the potential impacts or benefits to the environment. The results were categorised as having effects that ranged from 'extreme improvement' to 'extreme impact' (Table 1). The detailed assessment expands the 5-category system used for the rapid ecological assessment (stage 1) to a more comprehensive 11-category ranking (stage 2).

Table 1. Categories used in ecological assessment

Stage 1 category	Stage 2 category	Estimated percentage change in hydrology / ecology
Major/Extreme impact	Extreme impact	More than 30% change in a negative direction (i.e. < -30%)
	Major impact	More than 20% change in a negative direction (i.e. < -20%)
Minor/Moderate impact	Moderate impact	More than 10% change in a negative direction (i.e. < -10%)
	Minor impact	More than 3% change in negative direction (i.e. < -3%)
No/Little change	Little impact	Less than 3% change in a negative direction (i.e.< 0%)
	No change	0%, rounded to the nearest whole percentage point
	Little improvement	Less than 3% change in a positive direction (>0% and <3%)
Minor/Moderate improvement	Minor improvement	More than 3% change in a positive direction (i.e. >3%)
	Moderate improvement	More than 10% change in a positive direction (i.e. >10%)
Major/Extreme improvement	Major improvement	More than 20% change in a positive direction (i.e. >20%)
	Extreme improvement	More than 30% change in a positive direction (i.e. >30%)

Rapid analysis

Options that influence the supply and demand for water were initially put through a rapid assessment.

Options that seek to address the regional water strategy objectives for towns or economic activity were assessed through rapid cost-benefit analysis. Options that aim to improve environmental outcomes were assessed through a rapid ecological risk assessment.

These assessment criteria were used as a guide only for assessing whether there was merit in the option going through to the next stage of assessment. The rapid economic analysis and rapid ecological assessments are decision-supporting tools. An assessment outcome that is not strictly positive (with a benefit-cost ratio less than 1) or does not have a positive ecological assessment does not necessarily preclude an option from being progressed to a detailed assessment.

Rapid economic analysis

The rapid economic analysis involved assessing whether the benefits the option can generate are greater than the estimated costs. The key information that informed the rapid cost-benefit analysis of each option included understanding what happens if we do nothing. To do this, we used hydrological modelling of the observed historical data (130 years) and looked at how much water is available to different licences under the base case and each option. More detail on the base case is available in the economic base case report.[8]

A discount rate of 7% has been used in this analysis as required by NSW Treasury guidelines. All assessments took place over the length of the available historic record in the Far North Coast region, referred to as the instrumental record of 130 years (1890 to 2020). This allowed an analysis of the performance of an option over a known climate period. Within this period all infrastructure and policy settings are kept constant over the length of a hydrologic run.

Under this assessment, none of the considered options produced benefits greater than their estimated costs. This did not preclude several of the following options from being considered under the stochastic and NARCliM climate datasets. These datasets contain a higher degree of variability under which further benefits of considered options might be realised.

[8] Department of Planning and Environment 2022, *Economic Base Case: Far North Coast Region*, water.dpie.nsw.gov.au/plans-and-programs/regional-water-strategies/public-exhibition/far-north-coast-regional-water-strategy, accessed

Connect independent water supplies in the region to the Rous County Council network (*Draft Far North Coast Regional Water Strategy*, Option 1)

Byron Shire, Ballina Shire, Lismore City, and Richmond Valley councils all operate at least one town water supply that is not connected to the Rous County Council bulk water supply network. Connection of these towns into the regional Rous County Council network would increase their water security and resilience.

The regional water strategy assessed the connection of Casino, Kyogle, Mullumbimby and Nimbin/Channon water supplies to Rous County Council's bulk water supply network.

Table 2. Option 1 — summary model results

Average change in economic outcomes ($ million, over 40 years and % change)			Option cost ($ million, over 40 years)	Net present value ($ million, over 40 years)	Benefit to cost ratio
Towns	Perennial pasture	Total			
+0	+0	0.0	275	-274.5	<0.01

This option gives a very low benefit-cost ratio. However, this option may be worth considering if it can help improve the overall reliability of towns and communities in the region and delay alternative augmentation options.

The benefit to town water supplies is small because the instrumental record shows that water supply is relatively secure. This means the existing costs of economic shortfalls are less than the cost of the option.

Connect the Rous County Council and Tweed Shire Council bulk water supplies (*Draft Far North Coast Regional Water Strategy,* Option 2)

This option connects the Rous County Council and Tweed Shire Council bulk water supplies via a pipeline between Pottsville (Tweed) and Ocean Shores (Rous). This improves system resilience by increasing and diversifying the water supplies available in both the Tweed and Rous regions.

Two variations of this option were modelled:

- version 1 assumes the Tweed water supply system is operated to supply as much of the Rous bulk water demand as possible
- version 2 assumes the Tweed water supply system would only supply water to the Rous bulk water supply system to overcome supply shortfalls.

Table 3. Option 2 — summary model results — version 1

Average change in economic outcomes ($ million, over 40 years and % change)			Option cost ($ million, over 40 years)	Net present value ($ million, over 40 years)	Benefit to cost ratio
Towns	Perennial pasture	Total			
+0	+7.6 (1.4%)	7.6 (1.4%)	82	-82	0.1

Table 4. Option 2 — summary model results — version 2

Average change in economic outcomes ($ million, over 40 years and % change)			Option cost ($ million, over 40 years)	Net present value ($ million, over 40 years)	Benefit to cost ratio
Towns	Perennial pasture	Total			
+0	+7.6 (1.4%)	7.6 (1.4%)	82	-82	0.1

Version 1 produces a very low benefit-cost ratio. This option may be worth considering if it can help improve the overall reliability of water supply to towns and communities in the region and delay alternative augmentation options.

The benefit to town water supply is small because the instrumental record shows that Rous County Council's water supply is relatively secure. This means the existing costs of economic shortfalls are less than the cost of the option.

Version 2 of the option also produces a very low benefit-cost ratio. However, like the previous version, it may be worth considering if it can help improve the overall reliability of towns and communities in the region and delay alternative augmentation options.

Use Toonumbar Dam to augment town water supplies (*Draft Far North Coast Regional Water Strategy*, Option 3)

The draft regional water strategy identified several variations of this option. Two variations were assessed:

- version 1 supplies Casino from Toonumbar Dam by delivering water to Jabour Weir via the Richmond River
- version 2 supplements Rous County Council's bulk water supply by delivering water from Toonumbar Dam to a pipeline located upstream of Jabour Weir via the Richmond River.

Table 5. Option 3 — summary model results — version 1 & 2

Version	Average change in economic outcomes ($ million, over 40 years and % change)			Option cost ($ million, over 40 years)	Net present value ($ million, over 40 years)	Benefit to cost ratio
	Towns	Perennial pasture	Total			
1	+0	+0	+0	$1 (nominal)	-$1	<0.01
2	+0	-2 (-0.4%)	-2 (-0.4%)	$162	-164	< 0.01

Version 1 of the option produces a very low benefit-cost ratio. However, it may be worth considering if it can help improve the overall reliability of towns and communities in the region and delay alternative augmentation options.

The second version of the option also produces a very low benefit-cost ratio. However, like the previous version, it may be worth considering if it can help improve the overall reliability of towns and communities in the region and delay alternative augmentation options.

Investigate reuse of purified recycled water (*Draft Far North Coast Regional Water Strategy,* Options 7 and 8)

Highly-treated wastewater from sewage treatment plants has the potential to be a reliable, safe and mostly climate-independent water source. This option investigated the potential of existing wastewater sources for mitigating shortfalls in the Rous bulk water supply network. The sources modelled are shown in Table 6.

Table 6. Sources modelled

Lismore City	Ballina Shire	Byron Shire
East Lismore (3.25 ML/day)	Ballina (13.5 ML/day)	Byron Bay (13.1 ML/day)
South Lismore (3.25 ML/day)	Lennox Head (10.5 ML/day)	Brunswick Heads (7.2 ML/day)
Perradenya Estate (0.2 ML/day)	Alstonville (3.6 ML/day)	

Water for drinking requires higher levels of treatment and purification than water used by agriculture and industry.

Table 7. Option 7 and 8 — summary model results

Average change in economic outcomes ($ million, over 40 years and % change)			Option cost ($ million, over 40 years)	Net present value ($ million, over 40 years)	Benefit to cost ratio
Towns	Perennial pasture	Total			
+0	+0	+0	881	-881	<0.01

This option produces a very low benefit-cost ratio. The cost to treat the water is generally higher than the value of the water produced.

Investigate decentralised desalination (*Draft Far North Coast Regional Water Strategy*, Option 10)

Decentralised, small-scale, often modular desalination plants can be sited close to a water demand. It is possible to site several of these water plants across the region to supply local demands or to feed into the Rous County Council bulk water supply network. Decentralised desalination plants can be scaled up as the water demand of a town or region grows, or to respond to prolonged droughts or extreme events. Several sites have been identified as suitable for local-scale desalination, including Tyagarah and South Ballina.

The assessment assumed the plants introduced a constant supply of 10 ML/day of desalinated water to the Rous County Council system.

Table 8. Option 10 — summary model results

Average change in economic outcomes ($ million, over 40 years and % change)			Option cost ($ million, over 40 years)	Net present value ($ million, over 40 years)	Benefit to cost ratio
Towns	Perennial pasture	Total			
+0	+0	+0	1597	-1,597	<0.01

The option did not produce economic value, with a very low benefit-cost ratio. This may be due to the instrumental data having few town water supply shortfalls.

Investigate regional desalination (*Draft Far North Coast Regional Water Strategy*, Option 11)

Desalination offers a virtually unlimited, climate-independent source of water. A regional desalination facility would be able to supplement supply for the entire region, connected to the bulk water supply network.

A site south of Pottsville has been identified as a potential location, as it could service both the Rous and Tweed Shire Council systems.

Three variations of this option were assessed based on size: 10 ML/day, 20 ML/day and 30 ML/day.

Table 9. Option 11 — summary model results — version 1 (10 ML/day), version 2 (20 ML/day), version 3 (30 ML/day)

Version	Average change in economic outcomes ($ million, over 40 years and % change)			Option cost ($ million, over 40 years)	Net present value ($ million, over 40 years)	Benefit to cost ratio
	Towns	Perennial pasture	Total			
1	+0	+0	+0	582.8	-582.7	<0.01
2	+0	+0	+0	938.0	-938.0	<0.01
3	+0	+0	+0	1293.3	-1293.2	<0.01

All three variations of this option produced a very low benefit-cost ratio. Like the previous version, it may be worth considering if it can help improve the overall reliability of towns and communities in the region and delay alternative augmentation options.

Raise Clarrie Hall Dam level (*Draft Far North Coast Regional Water Strategy,* Option 12)

Raising Clarrie Hall dam, located on Doon Doon Creek 15 km south-west of Murwillimbah, will increase its capacity from 16 GL to 42.3 GL. Tweed Shire Council has identified this as the best option for augmenting its water supply.

Table 10. Option 12 — summary model results

Average change in economic outcomes ($ million, over 40 years and % change)			Option cost ($ million, over 40 years)	Net present value ($ million, over 40 years)	Benefit to cost ratio
Towns	Perennial pasture	Total			
+0	+0	+0	141	-140.9	0.0

The option does not appear to provide any benefits based on the instrumental climate record.

Construct a new Dunoon Dam on Rocky Creek (*Draft Far North Coast Regional Water Strategy,* Option 14)

A new dam at Dunoon was first proposed in 1995. The current proposed site is on Rocky Creek, downstream of the existing Rocky Creek Dam. Three different full-storage capacity variations have been proposed: 20 GL, 50 GL and 85 GL. Most recently, Rous County Council had assessed the 50 GL option. The Draft Far North Coast Regional Water Strategy also assessed the 50 GL variation.

Table 11. Option 14 — summary model results

Average change in economic outcomes ($ million, over 40 years and % change)			Option cost ($ million, over 40 years)	Net present value ($ million, over 40 years)	Benefit to cost ratio
Towns	Perennial pasture	Total			
+0	+0	+0	541	-540.6	< 0.01

Provide purified recycled wastewater for industry and rural users (*Draft Far North Coast Regional Water Strategy*, Option 16)

Highly purified recycled wastewater from sewage treatment plants has the potential to be a reliable, safe and climate-independent water source. The use of treated wastewater for industry and rural water users presents an opportunity to both support industry growth and reduce pressure on town water supplies and other water sources.

This option investigated supplying recycled water to industry and rural water users from Lismore City's three sewage treatment plants at East Lismore (3.25 ML/day), South Lismore (3.25 ML/day) and Perradenya Estate (0.2 ML/day). Sites in Ballina Shire and Byron Shire were not chosen due to model limitations.

Table 12. Option 16 — summary model results

Average change in economic outcomes ($ million, over 40 years and % change)			Option cost ($ million, over 40 years)	Net present value ($ million, over 40 years)	Benefit to cost ratio
Towns	Perennial pasture	Total			
+0	+0.9 (0.2)	+0.9	$100	-$99	<0.01

The cost of purifying recycled water to a level suitable for industry or rural users appears to outweigh the benefits associated with it.

Raise Toonumbar Dam level (*Draft Far North Coast Regional Water Strategy,* Option 19)

Toonumbar Dam is located on Iron Pot Creek in the Richmond Valley and is used to supply rural water users in the regulated Richmond River system. WaterNSW has investigated three different dam-raising levels in the past — 6 m, 10 m and 20 m — and determined 6 m to be the optimum level. The Draft Far North Coast Regional Water Strategy assessed the costs and benefits of a 6 m variation to regulated system water users.

Table 13. Option 19 — summary model results

Average change in economic outcomes ($ million, over 40 years and % change)			Option cost ($ million, over 40 years)	Net present value ($ million, over 40 years)	Benefit to cost ratio
Towns	Perennial pasture	Total			
+0	+0	+0	454	-453.6	< 0.01

This version of the option produces a very low benefit-cost ratio.

Establish and/or increase environmental water releases from major storages in the Far North Coast (*Draft Far North Coast Regional Water Strategy,* Option 21)

A 1,000 ML/year environmental contingency allowance was set aside in Toonumbar Dam for the first five years of the Richmond River Water Sharing Plan to help manage critical environmental events downstream and to maintain aquatic ecosystem health. However, the environmental contingency allowance provision was never used and expired in 2016.

The Far North Coast regional water strategy modelled the Toonumbar environmental contingency allowance as if it had not expired.

Table 14. Option 21 — summary model results

Average change in economic outcomes ($ million, over 40 years and % change)			Option cost ($ million, over 40 years)	Net present value ($ million, over 40 years)	Benefit to cost ratio
Towns	Perennial pasture	Total			
+0	+0	+0.5	-	0.5	-

This option aims to achieve environmental outcomes. As a consequence, no rapid cost-benefit was calculated since the ecological benefits have not been quantified.

Rapid ecological assessment

The rapid ecological assessment involved a high-level assessment of the ecological impact or improvement of each of the options in the long list of the *draft Far North Coast Regional Water Strategy* based on expert opinion of scientists from:

- Department of Planning and Environment — Water — Water Science
- Department of Planning and Environment — Environment, Energy and Science
- Department of Regional NSW, and
- Department of Primary Industries — Fisheries.

The ecological assessment was undertaken separately by each agency and then the assessments were combined for an overall result for each option. Due to the uncertainty in implementation and subsequent levels of impact from many options, the rapid ecological assessment column provides the average of these three assessments.

In developing their rankings, the scientists were asked to consider how the option might affect:

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

Table 16 summarises the rapid assessment of options in the *draft Far North Coast Regional Water Strategy*. The definitions of categories used in the rapid ecological assessment is provided in Table 15.

Table 15 Definitions of categories used in the rapid ecological assessment

Ecological change category	Estimated percentage change in hydrology / ecology	Symbol
Major / Extreme impact	More than 20% change in a negative direction	E-
Minor / Moderate impact	3-20% change in negative direction	M-
No/little change	Less than 3% change in any direction	N
Minor / Moderate improvement	3-20% change in a positive direction (i.e. >3%)	M+
Major / Extreme improvement	More than 20% change in a positive direction (i.e. >20%)	E+

Table 16 Assessment of the long list of options from the draft Far North Coast Regional Water Strategy

Draft strategy option	Rapid ecological assessments (with median impact)	Key points made in commentary
1. **Interconnection of independent water supplies in the region to the Rous County Council network**	Minor / Moderate impact	See proposed action 3.5: Support development of the regional water supply system This involves working collaboratively with local councils and WaterNSW to consider regional scale augmentations to bulk water systems, including: • connecting the regional water system into the South East Queensland water grid • accessing water from Toonumbar Dam for town water supplies improving understanding of Far North Coast water resources.
2. **Interconnection of Rous County Council and Tweed Shire Council bulk water supplies**	Minor / Moderate impact	See proposed action 3.5: Support development of the regional water supply system.
3. **Use Toonumbar Dam to augment town water supplies**	Major / Extreme impact	See proposed action 3.5: Support development of the regional water supply system.
4. **Connect the regional water system to the South East Queensland water grid**	Major / Extreme impact	See proposed action 3.5: Support development of the regional water supply system.

Draft strategy option	Rapid ecological assessments (with median impact)	Key points made in commentary
5. **Vulnerability of surface water supplies to sea level rise**	No/little change	Incorporated into: • proposed action 1.6: Assess the vulnerability of surface water supplies to sea level rise and saltwater intrusion proposed action 1.8: Characterise and plan for climate change and land use impacts on coastal groundwater sources.
6. **Remove impediments to water reuse projects**	Minor / Moderate improvement	This option is being progressed through option 6.7 of the NSW Water Strategy – Proactive support for water utilities to diversify sources of water.
7. **Indirect potable reuse of purified recycled water**	Minor / Moderate improvement	See proposed action 3.7: Recycled water plan for the Far North Coast.
8. **Direct potable reuse of purified recycled water**	No/little change	See proposed action 3.7: Recycled water plan for the Far North Coast.
9. **Managed aquifer recharge investigations and policy**	Major / Extreme impact	See proposed action 3.5: Managed aquifer recharge investigations.
10. **Decentralised desalination**	Minor / Moderate impact	This option has not been shortlisted at this time. However, economic assessments suggest that scaling up desalination over time may be more cost-effective than a large augmentation. This option will be reassessed in future reviews of the regional water strategy. See proposed option 3.4: Support development of the regional water supply system.
11. **Regional desalination**	Minor / Moderate impact	This option will be reassessed in future reviews of the regional water strategy.
12. **Raise Clarrie Hall Dam level**	Major / Extreme impact	Tweed Shire Council is progressing this project. Public consultation on the Ecological Impact Statement concluded in March 2021.

Draft strategy option	Rapid ecological assessments (with median impact)	Key points made in commentary
13. **New dam on Byrrill Creek**	Major / Extreme impact	This option has large ecological impacts and is no longer supported by the proponent (Tweed Shire Council).
14. **New Dunoon Dam on Rocky Creek**	Major / Extreme impact	See proposed action 3.4: Support development of regional water supply system.
15. **Increased harvestable rights**	Major / Extreme impact	See proposed action 2.8: Address catchment-based impacts of increased harvestable rights limits.
16. **Provide purified recycled wastewater for industry and rural users**	Minor / Moderate improvement	All options relating to recycled water have been merged into proposed action 3.7: Recycled water plan for the Far North Coast.
17. **Increased on-farm water storage**	Major / Extreme impact	See proposed action 3.3: Investigate increased on-farm water storage.
18. **A grid of off-stream storages in the Far North Coast region**	Major / Extreme impact	Does not effectively address a regional challenge. Feedback during public exhibition was that Option 17 Increased on-farm water storage provided a more realistic alternative.
19. **Raise Toonumbar Dam level**	Minor / Moderate impact	This option is not cost-effective at present. However, it may become more cost-effective if intensive horticulture increased in the regulated system, if Toonumbar Dam is accessed for town water supplies, or if a link to the Rous County Council bulk water supply system was pursued. This option will be reassessed in future reviews of the regional water strategy. See proposed action 3.4: Support development of regional water supply system.
20. **Establish sustainable extraction limits for Far North Coast surface water and groundwater sources**	Major / Extreme improvement	See proposed action 2.4: Establish sustainable extraction limits for surface water and groundwater sources.

Draft strategy option	Rapid ecological assessments (with median impact)	Key points made in commentary
21. **Establish and/or increase environmental water releases from major storages in the Far North Coast**	Major / Extreme improvement	This option has been incorporated into proposed action 1.7: Identify environmental water needs to support healthy coastal waterways.
22. **Convert low-flow water access licences to high-flow water access licences**	Minor / Moderate impact	See proposed action 2.6: Reduce the take on low flows.
23. **Improve stormwater management**	Minor / Moderate improvement	This option will be considered as part of Management Initiative 1 of the Marine Estate Management Strategy.
24. **Bringing back riverine and estuarine habitats and threatened species**	Major / Extreme improvement	Incorporated into proposed action 1.4: Deliver a river recovery program.
25. **Fish-friendly water extraction**	Major / Extreme improvement	See proposed action 2.2: Implement fish-friendly water extraction.
26. **Improve fish passage in the Far North Coast region**	Major / Extreme improvement	See proposed action 2.1: Improve fish passage.
27. **Addressing cold water pollution**	Major / Extreme improvement	See proposed action 2.3 Address cold water pollution.
28. **Characterising coastal groundwater resources**	Minor / Moderate improvement	See proposed action 1.8: Characterise and plan for climate change and land use impacts on coastal groundwater sources.
29. **Protecting ecosystems that depend on coastal groundwater resources**	Major / Extreme improvement	See proposed action 1.9: Protect ecosystems that depend on coastal groundwater resources.
30. **Northern Rivers Watershed Initiative**	Major / Extreme improvement	Funding for these types of works is progressed through existing programs such as the Marine Estate Management Strategy and Coastal Management Plans. Local councils may be supported to implement this option through proposed option : 1.3 Support improved governance Many of the aims of this option will be addressed through proposed action 1.4: Deliver a river recovery program.

Draft strategy option	Rapid ecological assessments (with median impact)	Key points made in commentary
31. **River Recovery Program for the Far North Coast: a region-wide program of instream works, riparian vegetation and sediment control**	Minor / Moderate improvement	See proposed action 1.4: Deliver a river recovery program.
32. **Improved data collection and information sharing**	Minor / Moderate improvement	Incorporated into: • Proposed action 1.10: Improve monitoring of water extraction Proposed action 3.1: Provide better information about water availability and climate risks.
33. **Active and effective water markets**	Major / Extreme impact	See proposed action 3.2: Review water markets.
34. **Regional Demand Management Program**	No/little change	Rous County Council supports regional demand management and drought planning for its constituent councils and the bulk supply system. Tweed Shire Council also actively implements demand management and drought planning. The barriers and opportunities for regional demand management planning identified by the Northern Rivers Water Group will largely be addressed through option 4.3 of the NSW Water Strategy – Improve drought planning, preparation and resilience and option 6.6 of the NSW Water Strategy — A new state-wide water efficiency framework and program.
35. **Regional network efficiency audit**	No/little change	This option will be considered through option 6.6 of the NSW Water Strategy — A new state-wide water efficiency framework and program.
36. **Apply the NSW Extreme Events Policy to the Far North Coast region**	Minor / Moderate impact	This option is being considered through option 4.3 of the NSW Water Strategy – Improve drought planning, preparation and resilience.

Draft strategy option	Rapid ecological assessments (with median impact)	Key points made in commentary
37. **Protecting coastal groundwater resources for town water supplies and rural water users**	Major / Extreme improvement	See proposed action 3.6: Protecting coastal groundwater resources for town water supplies and rural water users.
38. **Planning for climate change impacts on coastal groundwater resources**	Minor / Moderate improvement	Incorporated into proposed action 1.8: Characterise and plan for climate change and land use impacts on coastal groundwater sources.
39. **Planning for land use pressures on coastal groundwater resources**	Minor / Moderate improvement	See proposed action 1.12: Plan for land use pressures on coastal groundwater resources.
PE-1 Recognise and support Landcare programs that support volunteers and land managers to better manage the catchment in a whole range of issues.	Insufficient information to assess	Environmental outcomes will improve relative to scale of investment and how long term investment is. The Bagotville Barrage currently discharges large volumes of acidic water and has major ecological impacts. The Tuckean Swamp Restoration is being pursued by OzFish. As part of the restoration project, a detailed model of the Tuckean Swamp area has been developed by the UNSW Water Research Laboratory. This study assessed several hydrologic options for improving water quality and drainage outcomes for the Tuckean Swamp.

Draft strategy option	Rapid ecological assessments (with median impact)	Key points made in commentary
PE-2 Develop a whole-of-government position on historical floodplain drainage systems.	Insufficient information to assess	Environmental implications need to be considered in development of position, but does have the potential to lead to improved outcomes. This option would not be feasible based on the pipe and pumping costs compared to the benefit it would provide. Local councils identify additional water supplies for their local government areas. The department supports local councils' source additional water through several avenues including the integrated water cycle management planning process.
PE-3 Develop a detailed Richmond River catchment-wide flood model, including investigating and developing specific options for flood mitigation.	Insufficient information to assess	Environmental implications need to be considered in development of model, options and related actions, but does have the potential to lead to improved outcomes. This option will be considered through option 6.6 of the NSW Water Strategy — A new state-wide water efficiency framework and program.
PE-4 Renewable-powered solutions, such as Zero Mass Water, can roll out community by community, as needed, to solve drinking water shortage issues, with minimal environmental impact, at a cost which is now competitive with other solutions (for example, as used in Murrurundi, NSW).	Insufficient information to assess	Would need to investigate the interaction of option with existing water sharing arrangements to determine environmental implications from new practices (both direct and indirect). See proposed action 1.5: Create additional advisory services and projects that support landholder adoption of best practice land management.

Draft strategy option	Rapid ecological assessments (with median impact)	Key points made in commentary
PE-5 Raise Rocky Creek Dam wall by 1+ metres.	Major / Extreme impact	Increasing weir height also impacts on natural migration of salt wedge. Increase weir and weir pool upstream of it, will also likely drown out/impact on fringing riparian zone flora and fauna. This option will be considered through option 6.6 of the NSW Water Strategy — A new state-wide Water Efficiency Framework and Program.
PE-6 Increase height of Bray Park Weir to mitigate saltwater breaching the fresh water supply.	Insufficient information to assess	The regulation of mining exploration is managed under the Mining Act 1992, and any new mining leases require that a development consent under the Environmental Planning and Assessment Act 1979 be in place before any title is granted. Statutory requirements, which may include community consultation and an Environmental Impact Statement, would also apply during the development consent process.
PE-7 Remove the concrete drainage channels and restore a functioning vegetated ecosystem instead.	Minor / Moderate improvement	Remediating concrete channels does not reduce the impact of high intensity flows originating from hard-surfaced urbanised areas. Has the potential to improve water quality if remediation done well. Unlikely to reduce impact of litter. Needs further information and analysis to inform environmental implications, especially related to FM Act 1994, and legislative bound operational aspects associated with the infrastructure.
PE-8 Investigate a combined infrastructure solution in the Tuckean Swamp area - high quality modelling would facilitate the evaluation of a water attenuation device to store flooding rains and run off from the Alstonville Plateau and the continual release of water through the Bagotville drainage system.	Insufficient information to assess	Needs further information and analysis to inform environmental implications, especially related to FM Act 1994, and legislative bound operational aspects associated with the infrastructure.

Draft strategy option	Rapid ecological assessments (with median impact)	Key points made in commentary
PE-9 An off-creek storage in Byron Bay to supply Mullumbimby with water.	Minor / Moderate impact	
PE-10 A water audit of the area to see where water is being wasted. There are numerous leaking council mains.	No/little change	
PE-11 Invest in a research facility specifically for agricultural water security, focused on developing science and technologies for drought resilience.	Insufficient information to assess	
PE-12 Make it a requirement for any new or existing residential developments to use rainwater tanks in urban areas and recycled grey water systems; provide subsidies if appropriate.	Insufficient information to assess	Potential for greywater to impact on coastal and or highly connected river alluvial (groundwater). Potential groundwater impacts would need to consider existing water quality standards.
PE-13 Develop a map of mining to identify sensitive areas, drinking water catchments, heritage sites, and places of environmental significance, and scenic beauty, where mining simply should not occur, and declare them off-limits.	Insufficient information to assess	

Detailed economic analysis

Ecological valuations in the context of a cost-benefit analysis have a high level of uncertainty. As a result, we have conducted separate quantitative and qualitative ecological assessments on options that progress past the rapid cost-benefit analysis stage. These are presented in the section *Detailed ecological analysis* below.

The economic value of water for key user groups has been drawn from the regional water value function and is applied as a $/ML supplied. In the case of town water supplies and permanent agriculture, we have applied the water value function as $/ML *not* supplied. The economic base case report[9] outlines these values and what an analysis using the stochastic and NARCliM climate datasets predicts for the future of the region.

Population increases have been included in accordance with the NSW Government's Common Planning Assumptions medium population growth forecast.[10] We have also modelled population increase forecast by local government projections. Both population forecasts (Table 17) project significant growth in the Far North Coast, with the local government population forecasts being higher than the Common Planning Assumptions. Towns and communities forecast to experience declining populations by the Common Planning Assumptions, such as Uki, Kyogle, Casino and Nimbin, have been included using static demands. This provides a conservative estimate of their future demand. Their actual demand is likely to be less.

Table 17. Far North Coast population projections: Common Planning Assumptions and local government forecast growth 2020–2060

LGA	Common Planning Assumptions forecast increase	Local government forecast increase
Rous (Richmond Valley, Ballina, Byron and Lismore)	8%	31%
Tweed Shire Council and Murwillumbah	24%	83%

9 Department of Planning and Environment 2022, *Economic Base Case: Far North Coast Region*, water.dpie.nsw.gov.au/plans-and-programs/regional-water-strategies/public-exhibition/far-north-coast-regional-water-strategy

10 More information is available at www.treasury.nsw.gov.au/information-public-entities/nsw-common-planning-assumptions (accessed 8 November 2022)

Infrastructure option costings

The capital and operational expenditure for infrastructure options are derived from cost models built to allow a consistent comparative assessment across regions. They are not site-specific cost estimates and are not intended to be used beyond the scope of this study. The cost models rely on the relationship of physical characteristics of infrastructure — such as dam size or pipeline length — and the expected construction costs, with each category of infrastructure (dams, pipelines, desalination plants, etc.) having its own unique valuation method. These relationships are arrived at through analysis of past similar projects and professional assessment.

Capital and operational expenditure for options were discounted to present day values with the following assumptions:

- the option is constructed and fully operational from the start of the first year (that is, at Year 0 in the model), which means no discounting is applied to the capital expenditure
- operational costs occur annually for the full period of the cost-benefit analysis from Year 1.

A residual value for infrastructure was considered through the addition of capital expenditure discounted at a linear rate until the end of the analysis period.

Policy option costings

Policy options were calculated as the cost of full-time staff required to implement an option. The costs are incurred at the beginning of the first year (that is, at Year 0 in the model) and there is no annual cost associated with the option. It is assumed that there is no measurable change between the effort required to administer the region each year with and without the policy change implemented.

Combined option 1 — expand Rous County Council's bulk water system through Dunoon Dam

This combined option aims to improve water security for towns in the Richmond River catchment by augmenting Rous County Council's bulk water supply system and extending its service area to include towns that currently have independent water supplies. This option portfolio integrates the following options:

- construct a new Dunoon Dam on Rocky Creek (*Draft Far North Coast Regional Water Strategy,* Option 14)
- connect independent water supplies in the region to the Rous County Council network (*Draft Far North Coast Regional Water* Strategy, Option 1).

Detailed assessment was carried out for two demand projection variations based on the Common Planning Assumptions and local government population projections.

The cost of the combined option is estimated at approximately $815 million over the 40 years. The average net present value is approximately the same, giving a benefit-cost ratio of zero. This was the average outcome under both the stochastic and NARCliM climate projections, and under both the Common Planning Assumptions and local government population forecasts.

This option eliminates all cumulative shortfalls at the 95th percentile under the Common Planning Assumptions, and shortfalls for all town water supply systems except the Tweed Shire Council bulk supply under the NARCliM hydrology for the local government population forecasts. This indicates that the combined option has some benefits in eliminating town and community shortfalls under dry hydrologic realisations.

Under the Common Planning Assumptions there were no cumulative shortfalls for any town or community modelled in the stochastic or NARCliM forecasts. When the results are modelled under the local government population forecasts, the Tweed Shire Council experiences zero shortfalls at the median simulation, but at the 95th percentile it has a cumulative shortfall over 40 years of 580 ML, or 0.1% of the total demand over that timeframe. Similarly, the NARCliM results for the Tweed Shire Council show no cumulative shortfalls over the 40 years in the median outcome but 2,150 ML of cumulative shortfall at the 95th percentile. This represents shortfalls equivalent to 0.3% of total demand for the period.

Table 18. Combined option 1—benefit-cost ratio (BCR) results for Common Planning Assumptions (CPA) and local government (LGA) population projections

BCR	Stochastic		NARCliM	
	CPA	LGA	CPA	LGA
Lowest	0.00	0.00	0.00	0.00
Median	0.00	0.00	0.00	0.00
Highest	0.01	0.03	0.03	0.04

The hydrologic record includes a great deal of variation, with 1,000 realisations of each hydrologic dataset showing a range of potential outcomes for the option. Table 19 and Table 20 present the range of possible outcomes for the combined option's performance over any 40-year period. The 1st percentile is effectively the worst outcome while the 99th is the best.

The results in both tables (outcomes under Common Planning Assumptions and local government population assumptions) indicate there is little to no economic benefit for the region for the overwhelming majority of the 40-year hydrologic periods analysed. This is evidenced by benefit-cost ratios equal to zero and the net present value being equal to the cost of the combined option. Benefit is only realised in the extreme ranges of the outcomes. This is most visible in the 99th percentile of the NARCliM climate scenario of both population scenarios, with a benefit-cost ratio of 0.01.

Table 19 shows that the worst outcome would mean that the combined option produces results worse than those in the base case. Even under the most positive hydrologic realisation the combined option does not have a positive net present value or a benefit-cost ratio greater than one under any of the datasets. In fact, it only has a positive benefit-cost ratio in the 99th percentile under the

NARCliM dataset. That is the case in both the Common Planning Assumptions and the local government population forecasts.

Table 19. Decile and extreme centile results for combined option 1, Common Planning Assumptions (NPV: net present value, BCR: benefit-cost ratio)

Percentile	Stochastic NPV ($m)	Stochastic BCR	NARCliM NPV ($m)	NARCliM BCR
1%	-815.1	0	-815.1	0
10%	-815.1	0	-815.1	0
20%	-815.1	0	-815.1	0
30%	-815.1	0	-815.1	0
40%	-815.1	0	-815.1	0
50%	-815.1	0	-815.1	0
60%	-815.1	0	-815.1	0
70%	-815.1	0	-815	0
80%	-815	0	-814.9	0
90%	-814.3	0	-813.8	0
99%	-809.8	0.01	-807.3	0.01

Table 20. Decile and extreme centile results for combined option 1, local government population forecasts

Percentile	Stochastic NPV ($m)	Stochastic BCR	NARCliM NPV ($m)	NARCliM BCR
1%	-815.1	0	-815.1	0
10%	-815.1	0	-815.1	0
20%	-815.1	0	-815.1	0
30%	-815.1	0	-815.1	0
40%	-815.1	0	-815.1	0
50%	-815.1	0	-815.1	0

Percentile	Stochastic NPV ($m)	Stochastic BCR	NARCliM NPV ($m)	NARCliM BCR
60%	-815.1	0	-815.1	0
70%	-815.1	0	-815	0
80%	-815	0	-814.9	0
90%	-814.3	0	-813.8	0
99%	-809.8	0.01	-807.3	0.01

The tabulated data above is provided visually in two histograms below (Figure 2 and Figure 3). The histograms show each of the 1,000 realisations of both climate datasets.

Under both population assumptions the combined option performs worse under the stochastic climate dataset than the NARCliM dataset, as evidenced by the higher count of realisations that are on the lower end of the net present value (at approximately $815 million). This represents over 800, or 80%, of the realisations under Common Planning Assumptions and over 700, or 70%, of the realisations under local government population assumptions.

More realisations under the local government population assumption produce a net present value above the combined option cost of approximately $815 million. This indicates that the combined option provides larger and more frequent benefits if population growth is higher over the next 40 years.

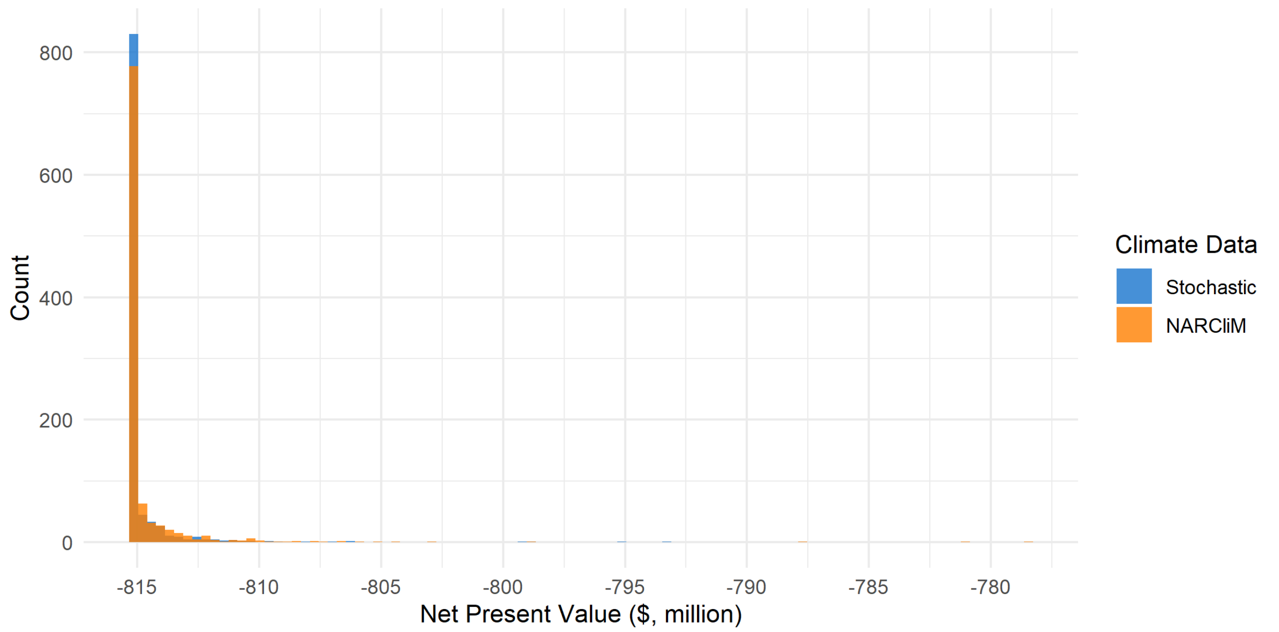

Figure 2. Combined option 1 Common Planning Assumptions net present value histogram

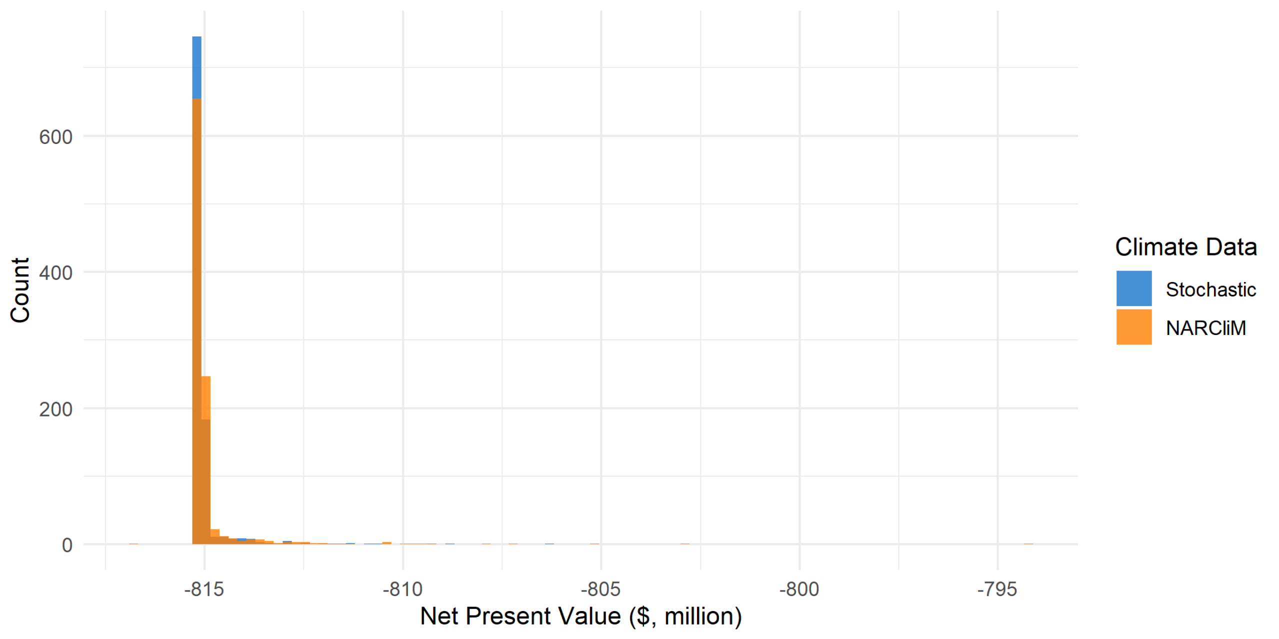

Figure 3. Combined option 1 local government population net present value histogram

Sensitivity analysis

Sensitivity analysis was undertaken for the combined option which included the following cases:

- higher (10%) and lower (3%) discount rates
- higher (+30%) and lower (-30%) combined option costs
- higher and lower economic costs, the magnitude of which varies depending on the marginal value altered.

Histograms of the results of the sensitivity analysis for the Common Planning Assumptions and local government population projections are provided in Figure 4 and Figure 5 respectively.

Trends relevant to each sensitivity case are the same under both population assumptions, none of which suggest that there may be a set of conditions under which the combined option produces economic benefits higher than its costs.

A higher discount rate of 10% lowers the value of future benefits and any residual value of the combined option, resulting in lower net present values. A lower discount rate has the opposite effect, raising the net present value of each realisation by a little over $100 million.

Varying the capital and operational expenditure by 30% in either direction has the predictable impact of considerably decreasing each realisation's net present value when the price is increased, and significantly increasing the realisation's net present value when the price is decreased. The movement in each direction is in the order of $200 million indicating a high level of sensitivity to the option cost, although a positive net present value is not achieved in any realisation.

Testing the marginal economic values of water for key users shows a low level of sensitivity to these assumptions.

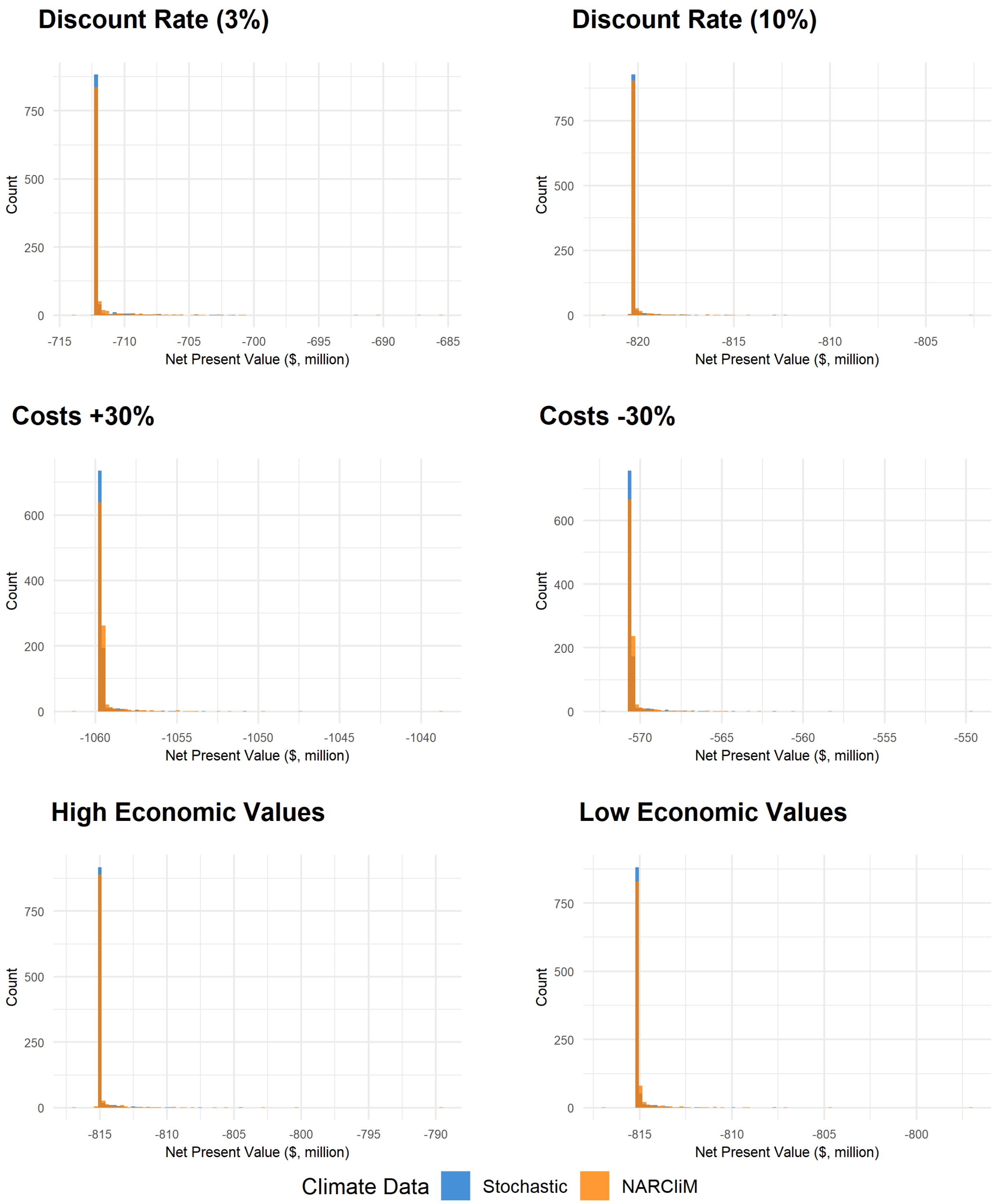

Figure 4. Combined option 1 Common Planning Assumptions sensitivity case net present value histograms

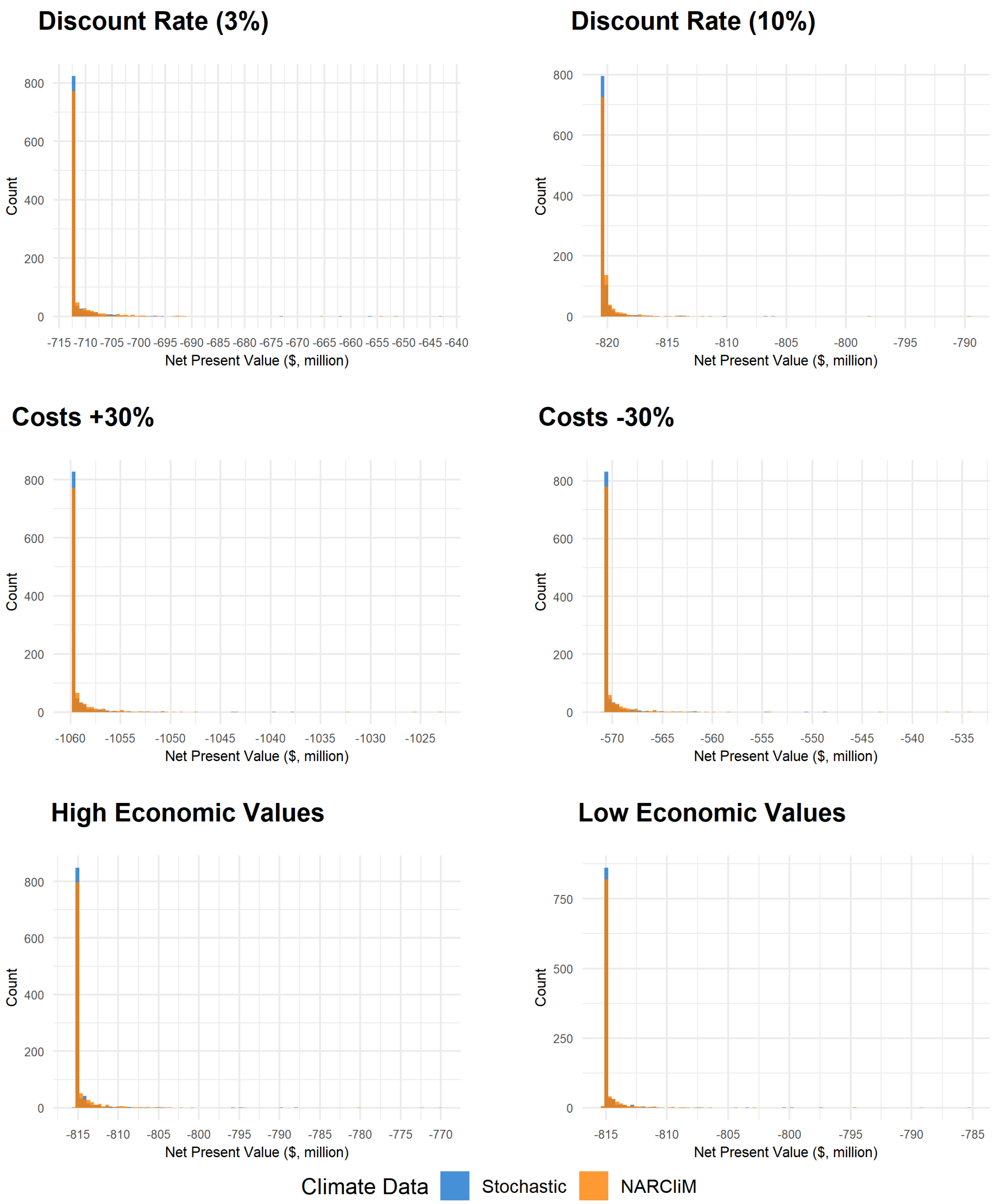

Figure 5. Combined option 1 local government population sensitivity case net present value histograms

Breakeven analysis

In this case the targeted primary beneficiary of the combined option is presumed to be regional town water security. The relevant price level for this beneficiary is the economic cost of water supply shortfalls. This cost was changed in both the stochastic and NARCliM economic analysis until the average, or expected value, of benefit-cost ratio outcomes for the 1,000 40-year runs of each dataset was equal to, or near to, 1.

The breakeven price level, and the calculated average benefit-cost ratio using this price level for combined option 1 for both climate datasets are given in Table 21.

Table 21. Breakeven price level combined option 1

Climate Dataset	Common Planning Assumptions		Local government population forecasts	
	BCR Average	Economic cost of town water supply shortfalls ($/ML)	BCR Average	Economic cost of town water supply shortfalls ($/ML)
Stochastic	1.0	$10,600,000	1.0	$4,600,000
NARCliM	1.0	$7,000,000	1.0	$3,200,000

For both climate datasets the marginal economic cost of a town water supply shortfall is required to be many orders of magnitude higher than the cost assumed within this study of carting water to a town (~$10,000/ML). For instance, under the Common Planning Assumptions the economic cost of each megalitre of shortfall must be worth $10,600,000 under the stochastic dataset. This is more than 1,000 times higher than the estimated cost of carting. Under the NARCliM dataset, the breakeven cost is 700 times higher than the estimated costs. While they are lower under the local government population forecasts, they are still many hundreds of times higher than the estimated costs of carting. These results agree with the economic value sensitivity runs that vary all price levels in tandem, which suggest that the average outcome of this combined option is not particularly sensitive to these price level changes.

The required marginal economic cost of a town water supply shortfall under the NARCliM climate dataset is much lower than that of the stochastic dataset. This is because shortfalls in the climate change scenario are longer and occur more frequently.

Combined option 2 — maximise use of the proposed Clarrie Hall Dam augmentation

The second combined option involves augmenting the Tweed Shire Council water supply system and linking it with the Rous County Council bulk water supply system. The aim is to increase water security for towns across the whole Far North Coast region. This combined option includes the following options:

- raise Clarrie Hall Dam level (*Draft Far North Coast Regional Water Strategy,* Option 12)
- connect the Rous County Council and Tweed Shire Council bulk water supplies (*Draft Far North Coast Regional Water Strategy,* Option 2)
- connect independent water supplies in the region to the Rous County Council network (*Draft Far North Coast Regional Water Strategy,* Option 1).

Table 22. Combined option 2 — outcomes under Common Planning Assumptions

Towns	Cumulative shortfall over 40 years (stochastic)		Cumulative shortfall over 40 years (NARCliM)	
	Median total shortfall volume (ML) (% of total demand)	95th percentile total shortfall volume (ML) (% of total demand)	Median total shortfall volume (ML) (% of total demand)	95th percentile total shortfall volume (ML) (% of total demand)
Kyogle, Casino, Tweed Shire Council bulk, Uki, Nimbin	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Rous County Council bulk	0 (0%)	1,470 (0.3%)	0 (0%)	2,260 (0.4%)
Mullumbimby	0 (0%)	20 (0.1%)	0 (0%)	50 (0.3%)

Table 23. Combined option 2 — outcomes under local government population assumptions

Towns	Cumulative shortfall over 40 years (stochastic)		Cumulative shortfall over 40 years (NARCliM)	
	Median total shortfall volume (ML) (% of total demand)	95th percentile total shortfall volume (ML) (% of total demand)	Median total shortfall volume (ML) (% of total demand)	95th percentile total shortfall volume (ML) (% of total demand)
Kyogle, Casino, Tweed Shire Council bulk, Uki, Nimbin	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Rous County Council bulk	0 (0%)	4380 (0.8%)	0 (0%)	5750 (1%)
Mullumbimby	0 (0%)	80 (0.5%)	0 (0%)	100 (0.6%)

Table 24. Combined option 2 — benefit-cost ratio (BCR) results for both population scenarios

Towns	Stochastic		NARCliM	
	CPA	LGA	CPA	LGA
Lowest	0.00	0.00	0.00	0.00
Median	0.00	0.00	0.00	0.00
Highest	0.01	0.02	0.02	0.03

The cost of this option is estimated to be approximately $357 million over the 40-year timeframe. The average net present value is the same under both the stochastic and NARCliM hydrologic projections and using the Common Planning Assumptions and local government population forecasts. The cost-benefit ratio is barely more than zero under the driest hydrologic realisations.

This option eliminates cumulative shortfalls under the Common Planning Assumptions in the driest realisations in all towns and communities except for Mullumbimby and the Rous County Council bulk water supply. In the 95th worst percentile, the cumulative deficits experienced by these towns increase by between 74–85% for Mullumbimby and by 30% for the Rous County Council bulk water supply system.

Table 25. Decile and extreme centile results for combined option 2, Common Planning Assumptions

Percentile	Stochastic NPV ($m)	Stochastic BCR	NARCliM NPV ($m)	NARCliM BCR
1%	-356.7	0	-356.7	0
10%	-356.7	0	-356.7	0
20%	-356.7	0	-356.7	0
30%	-356.7	0	-356.7	0
40%	-356.7	0	-356.7	0
50%	-356.7	0	-356.7	0
60%	-356.7	0	-356.7	0
70%	-356.7	0	-356.7	0
80%	-356.7	0	-356.7	0

Percentile	Stochastic NPV ($m)	Stochastic BCR	NARCliM NPV ($m)	NARCliM BCR
90%	-356.6	0	-356.6	0
99%	-355.7	0	-355.2	0

Table 26. Decile and extreme centile results for combined option 2, local government population forecasts

Percentile	Stochastic NPV ($m)	Stochastic BCR	NARCliM NPV ($m)	NARCliM BCR
1%	-356.7	0	-356.7	0
10%	-356.7	0	-356.7	0
20%	-356.7	0	-356.7	0
30%	-356.7	0	-356.7	0
40%	-356.7	0	-356.7	0
50%	-356.7	0	-356.7	0
60%	-356.7	0	-356.7	0
70%	-356.7	0	-356.6	0
80%	-356.6	0	-356.6	0
90%	-356.4	0	-356.1	0
99%	-354.7	0.01	-353.2	0.01

The combined option only begins to have a measurable benefit in the 99th percentile under local government population forecasts. In this case it returns a benefit-cost ratio of 0.01 in both climate scenarios.

The tabulated data above is provided visually in two histograms below (Figure 6 and Figure 7). The histograms show each of the 1,000 realisations of both climate datasets.

The combined option typically performs more favourably under local government population assumptions with more realisations providing a higher net present value. However, the net present value is not positive in any realisation.

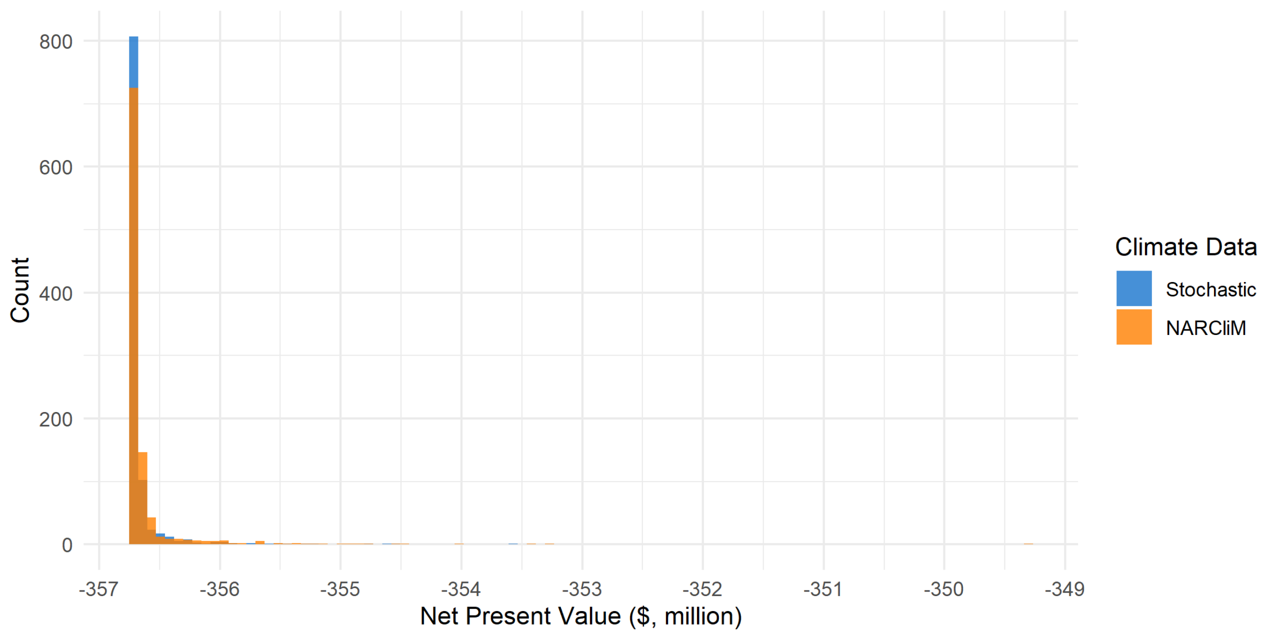

Figure 6. Combined option 2 Common Planning Assumptions net present value histogram

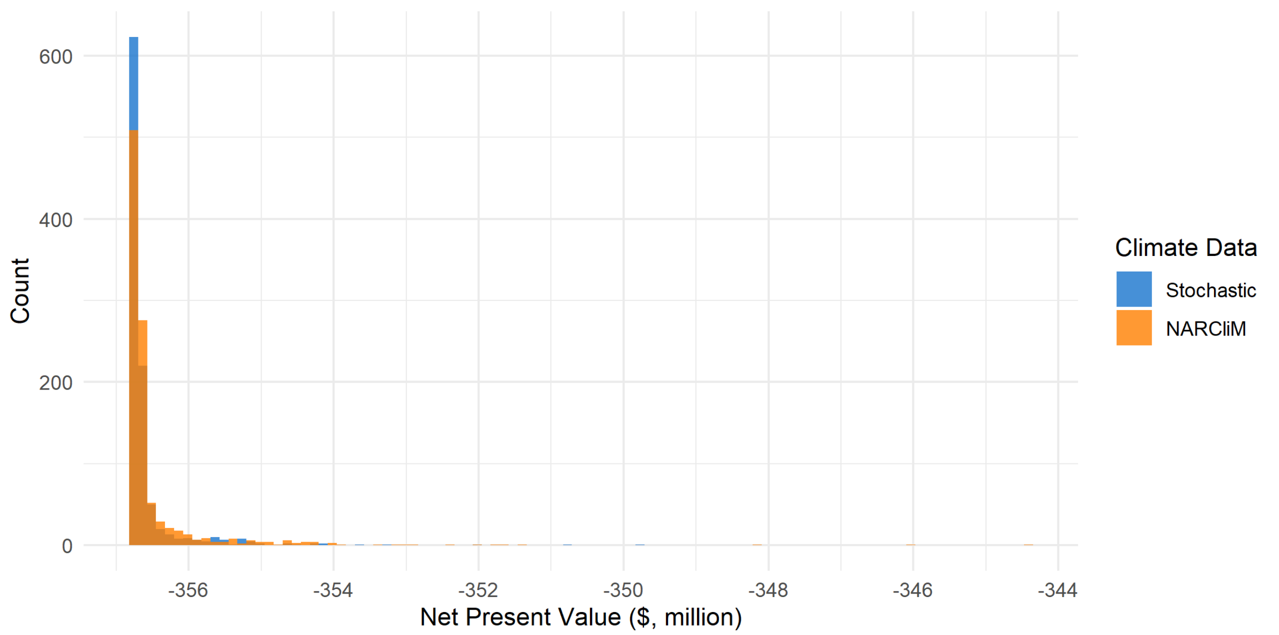

Figure 7. Combined option 2 local government population net present value histogram

Sensitivity analysis

Histograms of the sensitivity analysis results for the common planning and local government population assumptions can be seen in Figure 8 and Figure 9 respectively.

Trends relevant to each sensitivity case are the same under both population assumptions, none of which suggest that there may be a set of conditions under which the combined option produces economic benefits higher than its costs.

A higher discount rate of 10% lowers the value of future benefits and any residual value of the combined option, resulting in lower net present values. A lower discount rate has the opposite effect, raising the net present value of each realisation. The difference between a 10% and a 3% discount rate is a little over $100 million, which is not enough to make the project viable.

Consideration of the combined option costs, varying the capital and operational expenditure by 30% in either direction has the predictable effet of considerably decreasing each realisation's net present value when the price is increased, and significantly increasing the realisation's net present value when the price is decreased. The movement in each direction is in the order of approximately $400 million. This suggests a high level of sensitivity to the option cost, although a positive net present value is not achieved in any realisation.

Testing the marginal economic values of water for key users shows a low level of sensitivity to these assumptions.

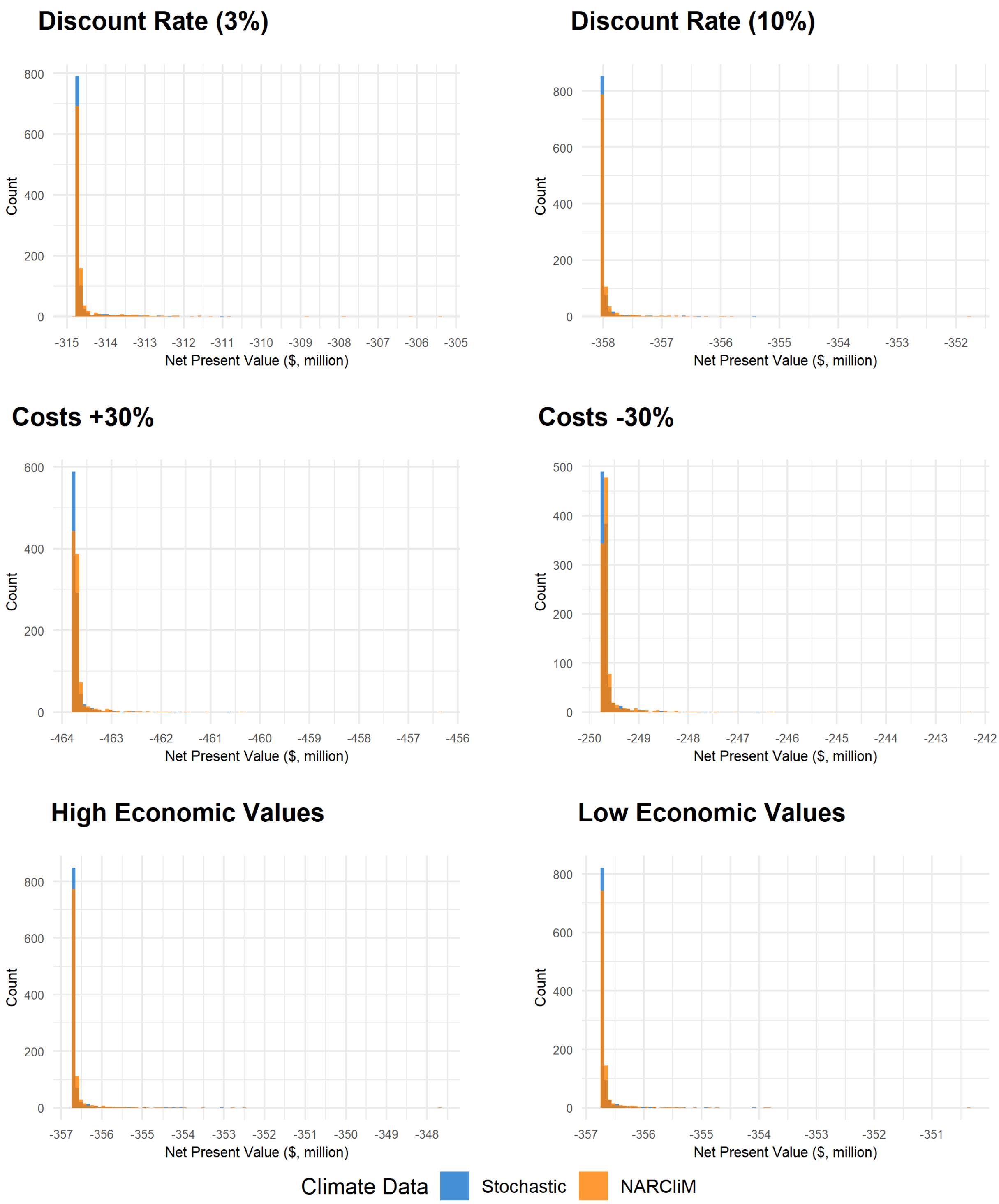

Figure 8. Combined option 2 Common Planning Assumptions sensitivity case net present value histograms

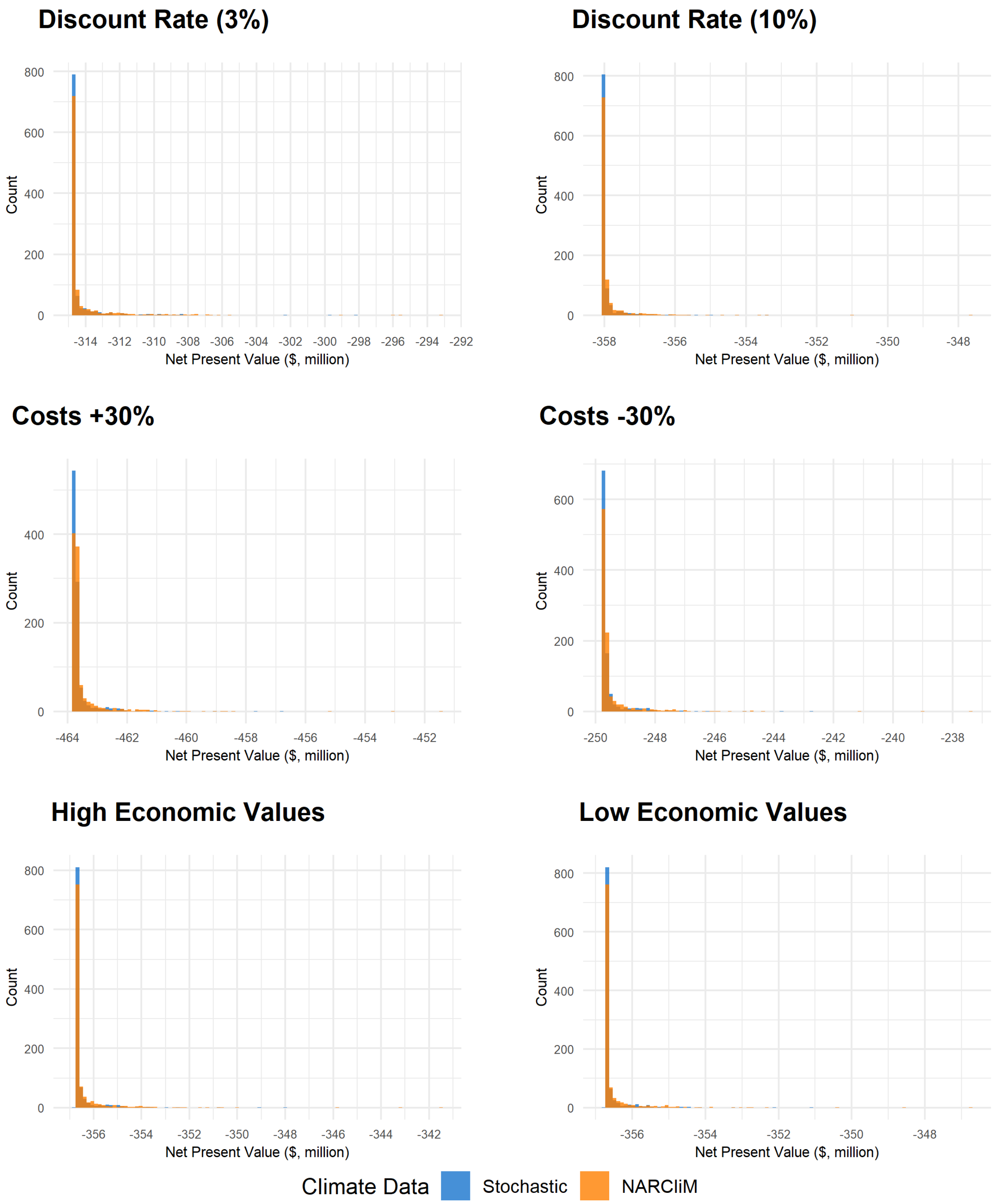

Figure 9. Combined option 2 local government population sensitivity case net present value histograms

Breakeven analysis

In this case the targeted primary beneficiary of the combined option is presumed to be regional town water security. The relevant price level for this beneficiary is the economic cost of water supply shortfalls. This cost was changed in both the stochastic and NARCliM economic analysis until the average, or expected value, of benefit-cost ratio outcomes for the 1,000 40-year runs of each dataset was equal to, or near to, 1.

A key assumption is that the raising of the dam wall at Clarrie Hall Dam is assumed to be progressing independently of this study and is not included in the cost of the combined option. The resultant increase in the capacity of Clarrie Hall Dam is assumed to bring the full storage to 42.3 GL. The maximum capacity of the pipeline connecting the Tweed Shire Council and Richmond catchments is 11.25 ML/day. It is also assumed that additional water from the Rous County Council bulk water supply system cannot be stored in Clarrie Hall Dam.

The breakeven price level and the calculated average benefit-cost ratio using this price level for combined option 2 for both climate datasets are given in Table 27.

Table 27. Breakeven price level combined option 2

Climate Dataset	Common Planning Assumptions		Local government population forecasts	
	BCR Average	Economic cost of town water supply shortfalls ($/ML)	BCR Average	Economic cost of town water supply shortfalls ($/ML)
Stochastic	1.0	$10,700,000	1.0	$4,400,000
NARCliM	1.0	$7,200,000	1.0	$2,700,000

For both climate datasets the marginal economic cost of a town water supply shortfall is required to be many orders of magnitude higher than the cost assumed within this study of carting water to a town (~$10,000/ML). For instance, under the Common Planning Assumptions the economic cost of each megalitre of shortfall has to be over 1,000 times higher than under the detailed assessment assumed cost. While they are lower under the local government population forecasts, they are still many hundreds of times higher than the estimated costs of carting. These results agree with the economic value sensitivity runs that vary all price levels in tandem, which suggest that the average outcome of this combined option is not particularly sensitive to these price level changes.

The breakeven analysis is fairly consistent between combined options 1 and 2.

Combined option 3 — maximise use of Toonumbar Dam

This combined option involves augmenting Toonumbar Dam to increase water security for the town of Casino and water users on the regulated Richmond River system and reinstate the ecological contingency allowance from Toonumbar Dam. This combined option integrates the following options:

- use Toonumbar Dam to augment town water supplies — version 1 (*Draft Far North Coast Regional Water Strategy,* Option 3)
- raise Toonumbar Dam level (*Draft Far North Coast Regional Water Strategy,* Option 19)

- establish and/or increase ecological water releases from major storages in the Far North Coast (*Draft Far North Coast Regional Water Strategy,* Option 21).

This combined option was only modelled using the Common Planning Assumptions population projections.

Table 28. Combined option 3 — outcomes under Common Planning Assumptions

Towns	Cumulative shortfall over 40 years (stochastic)		Cumulative shortfall over 40 years (NARCliM)	
	Median total shortfall volume (ML) (% of total demand)	95th percentile total shortfall volume (ML) (% of total demand)	Median total shortfall volume (ML) (% of total demand)	95th percentile total shortfall volume (ML) (% of total demand)
Kyogle, Casino, Tweed Shire Council bulk, Uki	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Rous bulk	0 (0%)	2,100 (0.4%)	0 (0%)	3,190 (0.6%)
Nimbin	0 (0%)	20 (0.3%)	0 (0%)	30 (0.4%)

The cost of this option is estimated to be approximately $454 million over the 40-year timeframe, with an average net present value of approximately negative $452 million under both the stochastic and NARCliM hydrologic forecasts. Even under the hydrologic realisation, which achieves the highest benefits, the cost-benefit ratio is barely more than zero.

This option eliminates cumulative shortfalls under the median outcomes using both the stochastic and NARCliM climate scenarios in all towns and communities except for Mullumbimby. However, under the 95th worst percentile realisation, the Rous bulk water supply system, Nimbin and Mullumbimby all experience cumulative deficits over the 40 years. These cumulative shortfalls are the same as those seen in the base case.

Table 29. Combined option 3 — benefit-cost ratio (BCR) results for both population scenarios

BCR	Stochastic		NARCliM	
	CPA	LGA	CPA	LGA
Lowest	0.00	N/A	0.00	N/A
Median	0.00	N/A	0.00	N/A
Highest	0.02	N/A	0.02	N/A

The results (Table 30) show that the combined option only produces benefit-cost ratios with a measurable benefit at the 90th percentile in the stochastic dataset and at the 80th percentile under the NARCliM dataset. However, the low benefit-cost ratio indicates that the benefits generated remain much lower than the cost of the combined option. Even at the extreme 99th percentile, the cost of the option is still greater than its benefits.

Table 30. Decile and extreme centile results for combined option 3, Common Planning Assumptions

Percentile	Stochastic NPV ($m)	Stochastic BCR	NARCliM NPV ($m)	NARCliM BCR
1%	-453.6	0	-453.5	0
10%	-453.4	0	-453.2	0
20%	-453.2	0	-453	0
30%	-453	0	-452.8	0
40%	-452.8	0	-452.5	0
50%	-452.6	0	-452.3	0
60%	-452.4	0	-451.9	0
70%	-452	0	-451.5	0
80%	-451.5	0	-450.8	0.01
90%	-450.6	0.01	-450	0.01
99%	-446.9	0.01	-445.8	0.02

Figure 10 is a histogram that illustrates the net present value outcome of each of the 1,000 realisations for both climate datasets. It reinforces the data in Table 30., showing that all realisations give negative net present value. A net present value of 0 is the point at which the benefits of the combined option balance its benefits. The population of both datasets is skewed to the left, indicating that in most cases only low benefits are produced, although the histogram shows that the combined option performs more favourably under the NARCliM dataset than the stochastic.

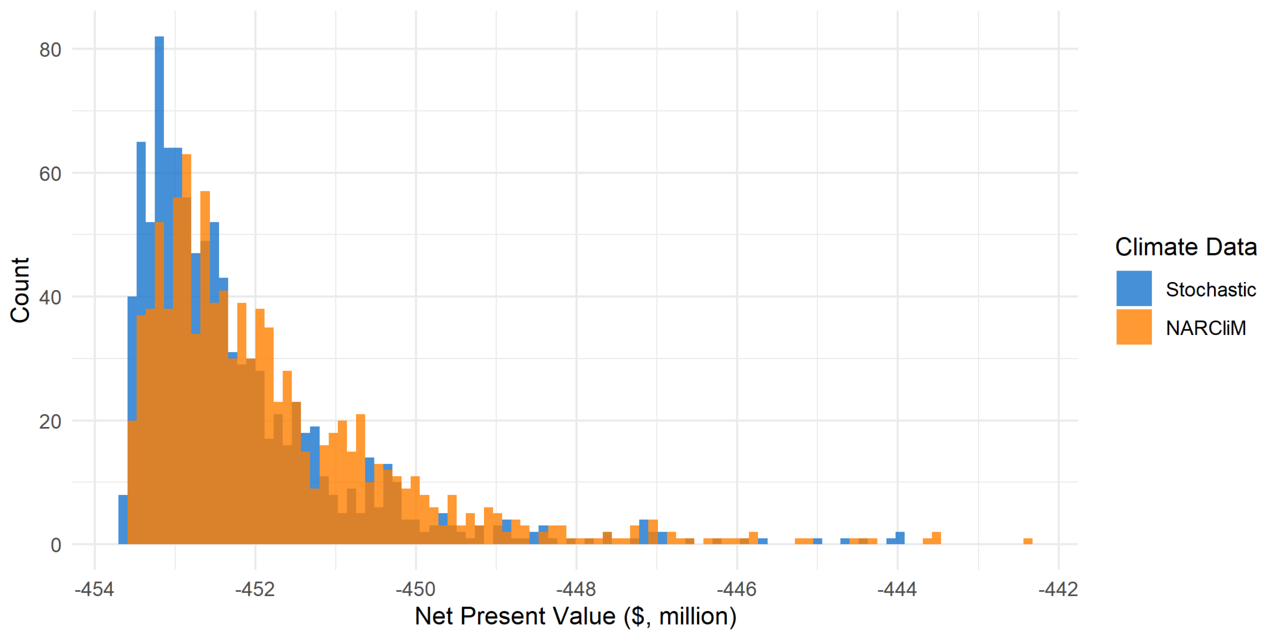

Figure 10. Combined option 3 Common Planning Assumptions net present value histogram

Sensitivity analysis

Histograms outlining the results of the sensitivity analysis for the combined option can be seen in Figure 11.

Trends relevant to each sensitivity case are the same under both climate scenarios, none of which suggest that there may be a set of conditions under which the combined option produces economic benefits higher than its costs.

A higher discount rate of 10% lowers the value of future benefits and any residual value of the combined option, resulting in lower net present values. A lower discount rate has the opposite effect, raising the net present value of each realisation by a little over $80 million.

Varying the capital and operational expenditure by 30% in either direction has the predictable effect of considerably decreasing each realisation’s net present value when the price is increased and significantly increasing the realisation’s net present value when the price is decreased. The movement in each direction is in the order of $200 million indicating a high level of sensitivity to the option cost, although a positive net present value is not achieved in any realisation.

Testing on the sensitivity of the marginal economic values of water to key users shows a low level of sensitivity to these assumptions.

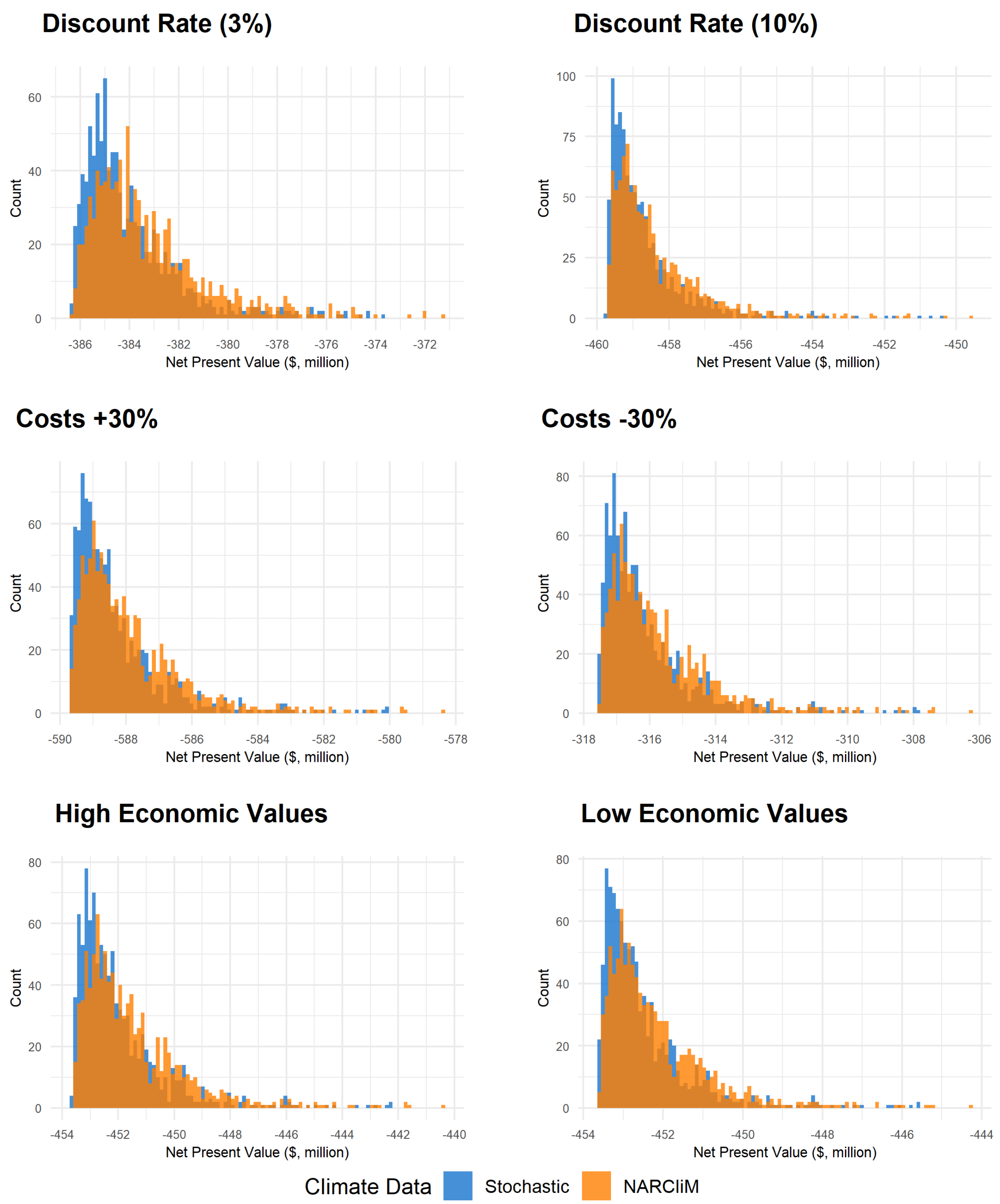

Figure 11. Combined option 3 Common Planning Assumptions sensitivity case net present value histograms

Breakeven analysis

In this case the targeted beneficiaries of augmenting Toonumbar Dam are the town of Casino and water users on the regulated Richmond River system, so the relevant price level is the economic cost of water supply shortfalls. This cost was changed in both the stochastic and NARCliM economic analysis until the average, or expected value, of benefit-cost ratio outcomes for the 1,000 40-year runs of each dataset was equal to, or near to, 1.

The breakeven price level and the calculated average benefit-cost ratio using this price level for combined option 3 for both climate datasets is given in Table 21.

Table 31. Breakeven price level combined option 3 (Common Planning Assumptions)

Climate Dataset	BCR Average	Economic cost of town water supply shortfalls ($/ML)
Stochastic	1.03	$900,000,000
NARCliM	1.10	$140,000,000

For both climate datasets, the marginal economic cost of a town water supply shortfall is required to be many orders of magnitude higher than the cost assumed within this study of carting water to a town (~$10,000/ML). For this combined option, the cost of each megalitre of shortfall has to be 90,000 times higher than was assumed in the initial assessment under the stochastic dataset. This falls dramatically for the NARCliM dataset but would still need to be 14,000 times higher.

Combined option 4 — incrementally augment the Rous County Council system through desalination

This combined option is a variation on decentralised desalination (*Draft Far North Coast Regional Water Strategy,* Option 10). It considers progressively introducing desalinated water into the Rous County Council bulk water supply system over time as the impacts of population growth and climate change increase.

The water would be sourced from decentralised desalination plants situated near to increasing water demands.

The assessment assumed the plants introduced constant supplies into the Rous County Council system of:

- 5 ML/day from year 5 onwards
- 10 ML/day from year 10 onwards
- 15 ML/day from year 15 onwards.

This combined option is expected to cost approximately $128 million over the 40-year forecast period. On average the option does not return high economic value for the Rous County Council bulk water supply. The total benefits are less than $50,000 on average using the Common Planning Assumptions population projections, and $100,000 using the local government population projections. Accounting for the benefit it produces, the average net present value of the combined option in both cases is approximately negative $128 million, which is essentially the cost of the option. This results in a cost-benefit ratio of effectively zero under the stochastic and NARCliM climate scenarios and for both population forecasts.

Table 32. Combined option 4 — outcomes under Common Planning Assumptions

Towns	Cumulative shortfall over 40 years (stochastic)		Cumulative shortfall over 40 years (NARCliM)	
	Median total shortfall volume (ML) (% of total demand)	95th percentile total shortfall volume (ML) (% of total demand)	Median total shortfall volume (ML) (% of total demand)	95th percentile total shortfall volume (ML) (% of total demand)
Kyogle, Casino, Tweed Shire Council bulk, Uki	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Rous bulk	0 (0%)	1,290 (0.3%)	0 (0%)	2,020 (0.4%)
Nimbin	0 (0%)	20 (0.3%)	0 (0%)	30 (0.4%)
Mullumbimby	10 (0.1%)	150 (1.0%)	30 (0.2%)	200 (1.2%)

Table 33. Combined option 4 — outcomes under local government population assumptions

Towns	Cumulative shortfall over 40 years (stochastic)		Cumulative shortfall over 40 years (NARCliM)	
	Median total shortfall volume (ML) (% of total demand)	95th percentile total shortfall volume (ML) (% of total demand)	Median total shortfall volume (ML) (% of total demand)	95th percentile total shortfall volume (ML) (% of total demand)
Kyogle, Casino	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Rous bulk	0 (0%)	3,960 (0.7%)	0 (0%)	5,020 (0.9%)
Nimbin	0 (0%)	20 (0.3%)	0 (0%)	30 (0.4%)
Mullumbimby	10 (0.1%)	150 (1%)	30 (0.2%)	200 (1.2%)
Tweed Shire Council bulk	0 (0%)	580 (0.1%)	0 (0%)	2,150 (0.3%)
Uki	0 (0%)	0 (0.1%)	0 (0%)	0 (0.2%)

The hydrologic variability shows that it is only in the most extreme realisations that the combined option produces a measurably positive benefit-cost ratio for both climate datasets and both population projections (Table 34). The benefit does not outweigh the cost of the combined option in any realisation. The benefits of combined option 4 are only measurable through the benefit-cost ratio in the 99th percentile in both the stochastic and NARCliM datasets for each population growth scenario (Table 35 and Table 36).

Table 34. Combined option 4 — benefit-cost ratio (BCR) results for both population scenarios

BCR	Stochastic		NARCliM	
	CPA	LGA	CPA	LGA
Lowest	0.00	0.00	0.00	0.00
Median	0.00	0.00	0.00	0.00
Highest	0.02	0.04	0.05	0.09

Table 35. Decile and extreme centile results for combined option 4, Common Planning Assumptions

Percentile	Stochastic NPV ($m)	Stochastic BCR	NARCliM NPV ($m)	NARCliM BCR
1%	-128.2	0	-128.2	0
10%	-128.2	0	-128.2	0
20%	-128.2	0	-128.2	0
30%	-128.2	0	-128.2	0
40%	-128.2	0	-128.2	0
50%	-128.2	0	-128.2	0
60%	-128.2	0	-128.2	0
70%	-128.2	0	-128.2	0
80%	-128.2	0	-128.2	0
90%	-128.2	0	-128.1	0
99%	-127.2	0.01	-126.7	0.01

Table 36. Decile and extreme centile results for combined option 4, local government population forecasts

Percentile	Stochastic NPV ($m)	Stochastic BCR	NARCliM NPV ($m)	NARCliM BCR
1%	-128.2	0	-128.2	0
10%	-128.2	0	-128.2	0
20%	-128.2	0	-128.2	0
30%	-128.2	0	-128.2	0
40%	-128.2	0	-128.2	0
50%	-128.2	0	-128.2	0
60%	-128.2	0	-128.2	0
70%	-128.2	0	-128.2	0
80%	-128.2	0	-128.1	0
90%	-127.9	0	-127.8	0
99%	-126.5	0.01	-125.7	0.02

The low benefits are also evident in the histograms of the net present value outcomes for each population growth scenario. Under Common Planning Assumptions (Figure 12) the net present value is mostly equal to the cost of the option. This indicates that there are limited benefit to the region, although under the NARCliM dataset there are more instances of generated benefits.

These benefits increase when using the local government population assumptions (Figure 13). The histogram shows more instances where the calculated net present value is greater than the net present cost of the combined option in both the stochastic and NARCliM datasets.

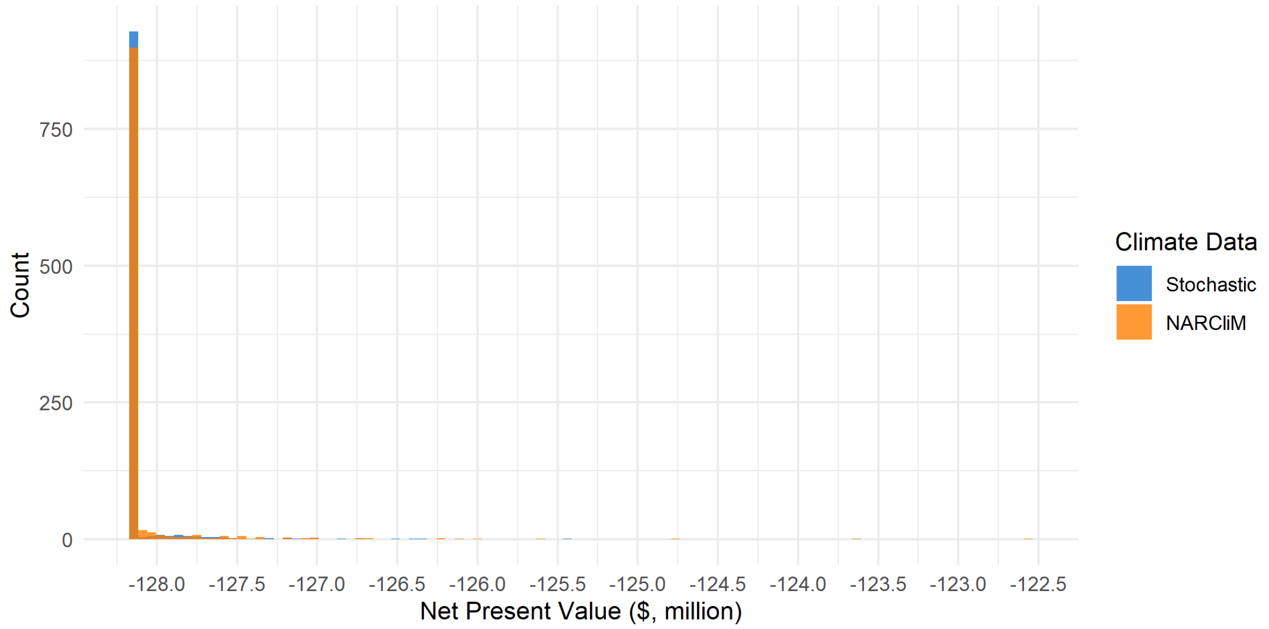

Figure 12. Combined option 4 Common Planning Assumptions net present value histogram

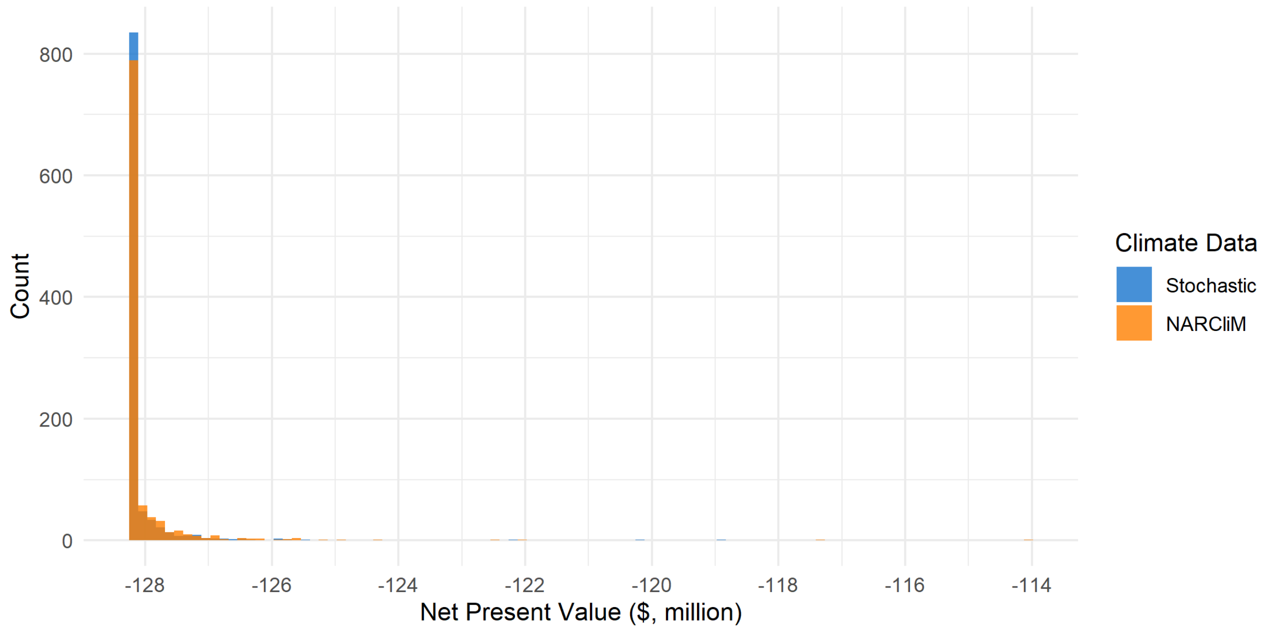

Figure 13. Combined option 4 local government population net present value histogram

Sensitivity analysis

The histograms in Figure 14 and Figure 15 show the results of the sensitivity analysis undertaken for the combined option using the two population projections.

Trends relevant to each sensitivity case are the same under both population assumptions. None of the results suggest that there may be a set of conditions under which the combined option produces economic benefits higher than its costs.

Typically, a higher discount rate of 10% would lower the value of future benefits and any residual value of the combined option, resulting in lower net present values. A lower discount rate has the opposite effect, raising the net present value of each realisation. However, in this case where there are few benefits, the higher discount rate reduces the annually incurred operational expenditure costs, resulting in a lower net present cost and therefore a higher net present value. The opposite is true for the lower 3% discount rate.

Varying the capital and operational expenditure by 30% in either direction has the predictable effect of significantly decreasing each realisation's net present value when the price is increased, and significantly increasing the realisation's net present value when the price is decreased.

Testing the sensitivity of the marginal economic values of water for key users shows a low level of sensitivity to these assumptions.

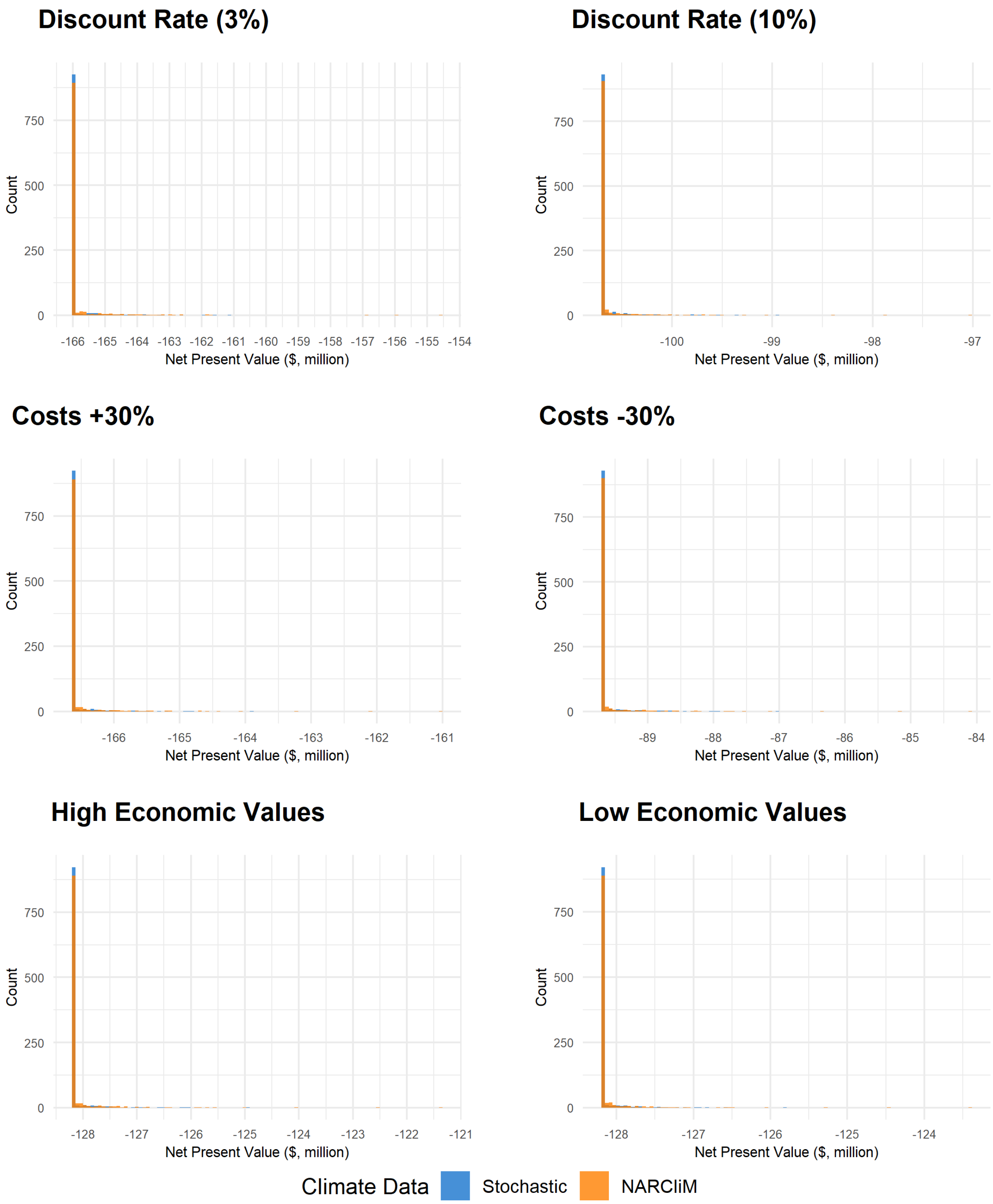

Figure 14. Combined option 4 Common Planning Assumptions sensitivity case net present value histograms

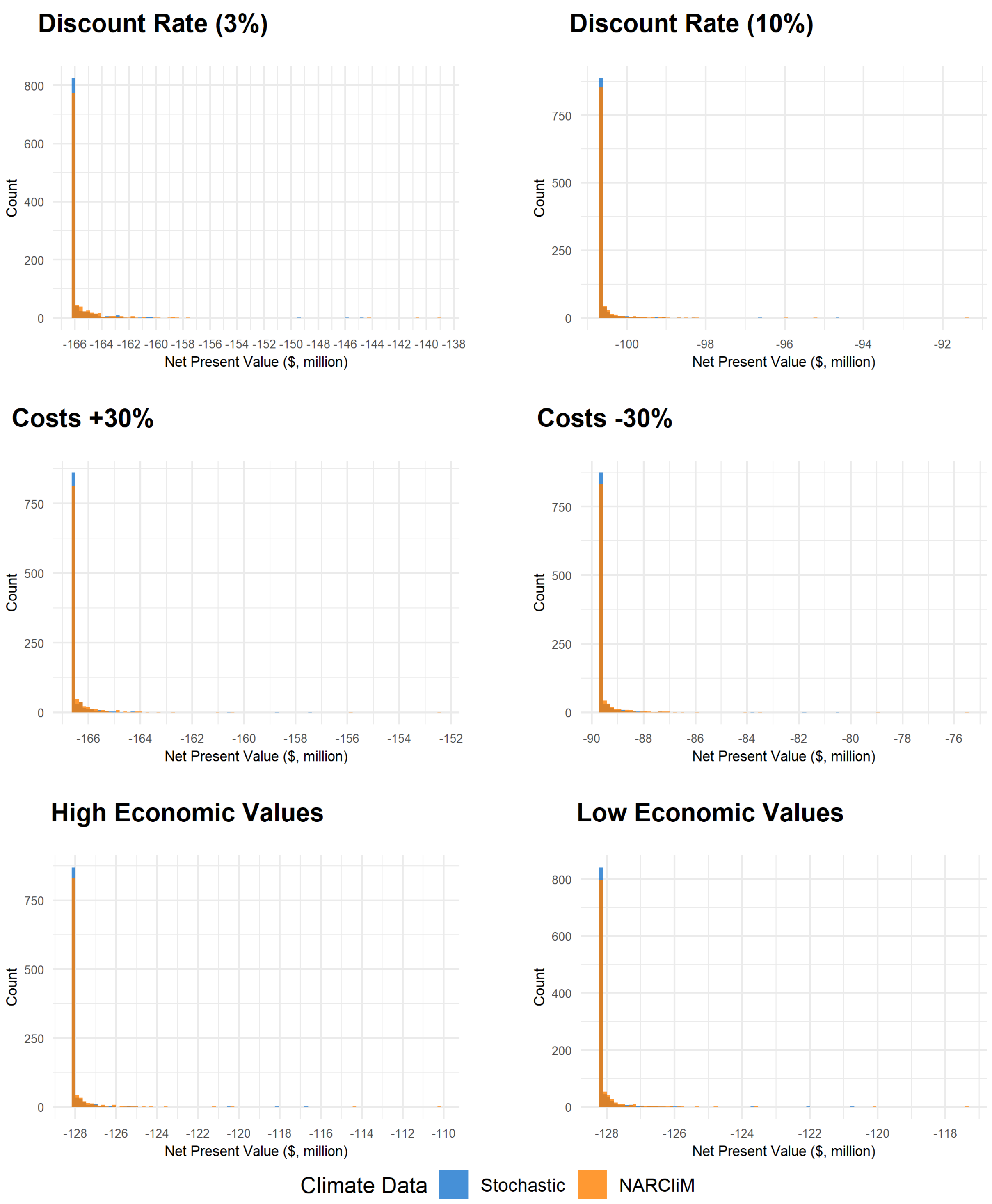

Figure 15. Combined option 4 local government population sensitivity case net present value histograms

Breakeven analysis

Where desalination is used to incrementally augment water supply, the relevant price level is the economic cost of water supply shortfalls. This cost was changed in both the stochastic and NARCliM economic analysis until the average, or expected value, of benefit-cost ratio outcomes for the 1,000 40-year realisations of each dataset was equal to, or near to, 1.

The breakeven price level and the calculated average benefit-cost ratio using this price level for combined option 4 for both climate datasets are shown in Table 37. Breakeven price level combined option 4.

Table 37. Breakeven price level combined option 4

Climate Dataset	Common Planning Assumptions		Local government population forecasts	
	BCR Average	Economic cost of town water supply shortfalls ($/ML)	BCR Average	Economic cost of town water supply shortfalls ($/ML)
Stochastic	1.0	$12,500,000	1.0	$5,000,000
NARCliM	1.0	$5,000,000	1.0	$3,400,000

For both climate datasets and both population forecasts, the marginal economic cost of a town water supply shortfall is required to be many orders of magnitude higher than the cost assumed within this study of carting water to a town (~$10,000/ML). While the costs under the local government population forecasts are approximately half of what they are under the Common Planning Assumptions, they are still at least 340 times higher than the cost assumed in the initial analysis.

Combined option 5 — Connect the region to the Rous County Council water supply system

Combined option 5 considers a series of options that look at linking the Rous County Council bulk water supply network with several independent supplies for towns in the Far North Coast. Towns considered for connection were Mullumbimby, Casino, and Nimbin. This may help improve supply security for these systems during extended dry periods by giving them access to water from Rocky Creek Dam and other future network improvements and augmentations that Rous County Council may implement. Kyogle has been excluded from this combined option as the hydrologic analysis showed no water supply shortfalls for this town using either climate dataset.

Modelling this combined options assumed that:

- the towns only rely on water from the Rous County Council system when they are unable to meet demands using their existing unregulated water supplies
- the demands of Nimbin and Mullumbimby are individually too small to materially impact the supply of the Rous County Council bulk water supply (that is, any impact on the Rous County Council system is considered to be zero)
- the demand of Casino is assumed to have an effect on the supply of water from the Rous County Council bulk water supply network.

The benefit-cost ratios of these combined options are generally close to zero, even under the highest benefit 95th percentile outcomes.

While the benefit-cost ratio does not reach the breakeven point, even under the driest years, these combined options almost eliminate their targeted cumulative shortfalls in the Far North Coast. The cumulative shortfalls are presented in Table 38 and Table 39. Benefit-cost ratios for the 3 system connections are presented in Table 40–Table 42.

Table 38. Combined option 5 — outcomes under Common Planning Assumptions

Towns	Cumulative shortfall over 40 years (stochastic)		Cumulative shortfall over 40 years (NARCliM)	
	Median total shortfall volume (ML) (% of total demand)	95th percentile total shortfall volume (ML) (% of total demand)	Median total shortfall volume (ML) (% of total demand)	95th percentile total shortfall volume (ML) (% of total demand)
Casino, Nimbin	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Mullumbimby	0 (0%)	20 (0.1%)	0 (0%)	50 (0.3%)

Table 39. Combined option 5 — outcomes under local government population assumptions

Towns	Cumulative shortfall over 40 years (stochastic)		Cumulative shortfall over 40 years (NARCliM)	
	Median total shortfall volume (ML) (% of total demand)	95th percentile total shortfall volume (ML) (% of total demand)	Median total shortfall volume (ML) (% of total demand)	95th percentile total shortfall volume (ML) (% of total demand)
Casino, Nimbin	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Mullumbimby	0 (0%)	80 (0.5%)	0 (0%)	100 (0.6%)

Table 40. Combined option 5 — benefit-cost ratio (BCR) results for both population scenarios (Mullumbimby)

BCR	Stochastic		NARCliM	
	CPA	LGA	CPA	LGA
Lowest	0.00	0.00	0.00	0.00
Median	0.00	0.00	0.00	0.00
Highest	0.08	0.08	0.06	0.06

Table 41. Combined option 5 — benefit-cost ratio (BCR) results for both population scenarios (Casino)

BCR	Stochastic		NARCliM	
	CPA	LGA	CPA	LGA
Lowest	-0.01	-0.07	-0.02	-0.01
Median	0.00	0.00	0.00	0.00
Highest	0.01	0.01	0.01	0.01

Table 42. Combined option 5 — benefit-cost ratio (BCR) results for both population scenarios (Nimbin)

BCR	Stochastic		NARCliM	
	CPA	LGA	CPA	LGA
Lowest	0.00	0.00	0.00	0.00
Median	0.00	0.00	0.00	0.00
Highest	0.03	0.03	0.02	0.02

Histograms showing the full range of calculated net present values for each realisation of this combined option for all climate datasets and population scenarios are given below:

- Mullumbimby: Figure 16 and Figure 17
- Casino: Figure 18 and Figure 19
- Nimbin: Figure 20 and Figure 21

In contrast to other combined options, the histograms show that this combined option typically performs more favourably under Common Planning Assumptions population growth assumptions than those of local government. This is because the combined option targets towns with water supply systems that are independent of the Rous system. Under local government population assumptions the Rous system becomes more stressed and is unable to provide the same level of water supply support to other townships within the catchment.

Negative effects are possible when Casino is connected to the Rous County Council system. Histograms showing the range of results of Rous providing Casino with additional water security show negative outcomes for the region before taking into account the cost of the option. Casino is assumed to be the only town with a large enough demand to materially impact on the supply of the Rous system. In some instances, Casino attempts to draw on the Rous system at times of limited water availability, weakening the overall water security within the system. The additional demand assumed on Rous bulk water under this scenario is the sum of the remaining towns considered within the catchment.

Similar to other combined options investigated, the net present value of each option is largely dependent on the cost of the combined option, indicating little benefit in each case.

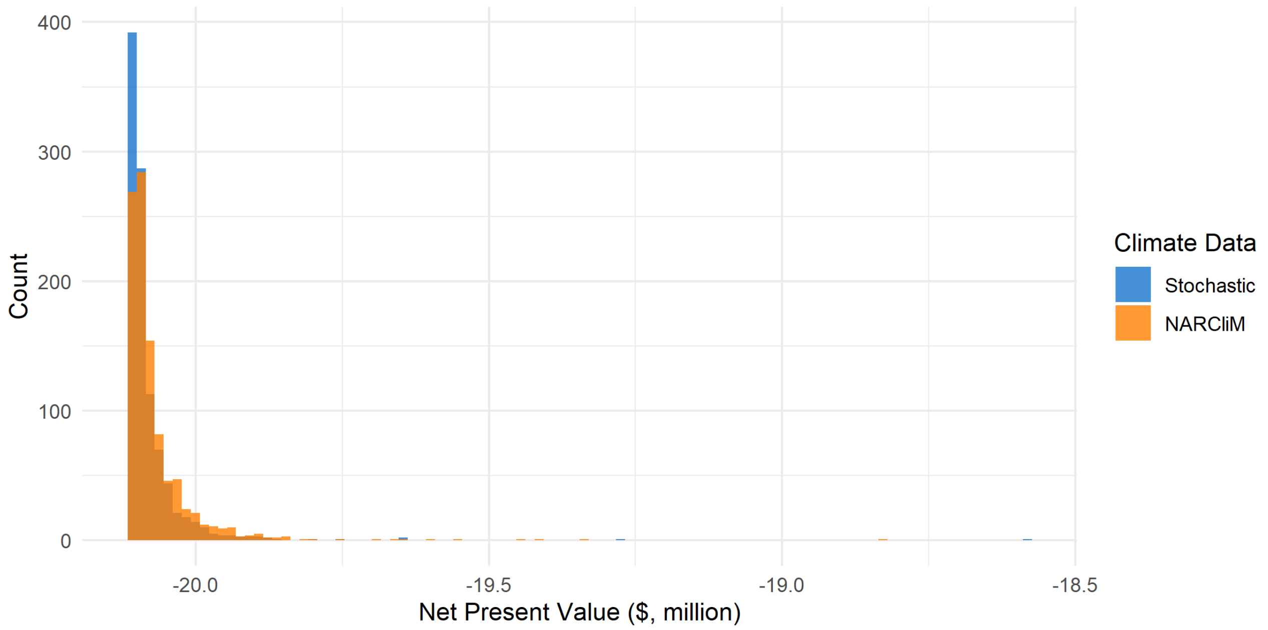

Figure 16. Combined option 5 (Mullumbimby) Common Planning Assumptions net present value histogram

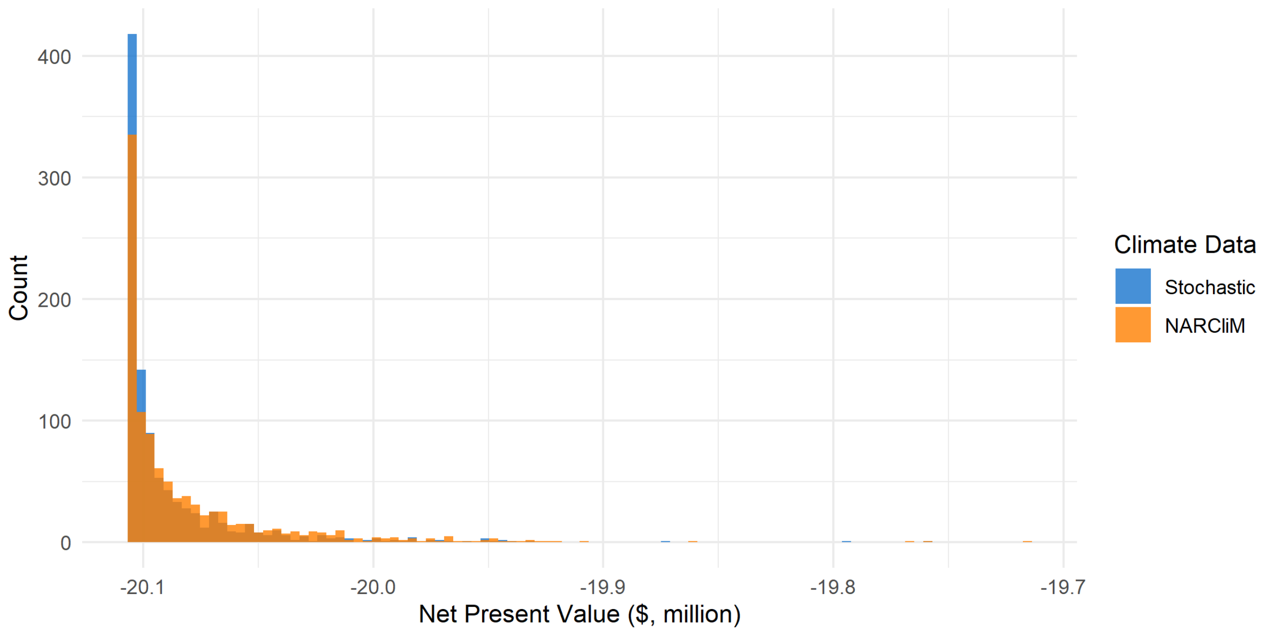

Figure 17. Combined option 5 (Mullumbimby) local government population net present value histogram

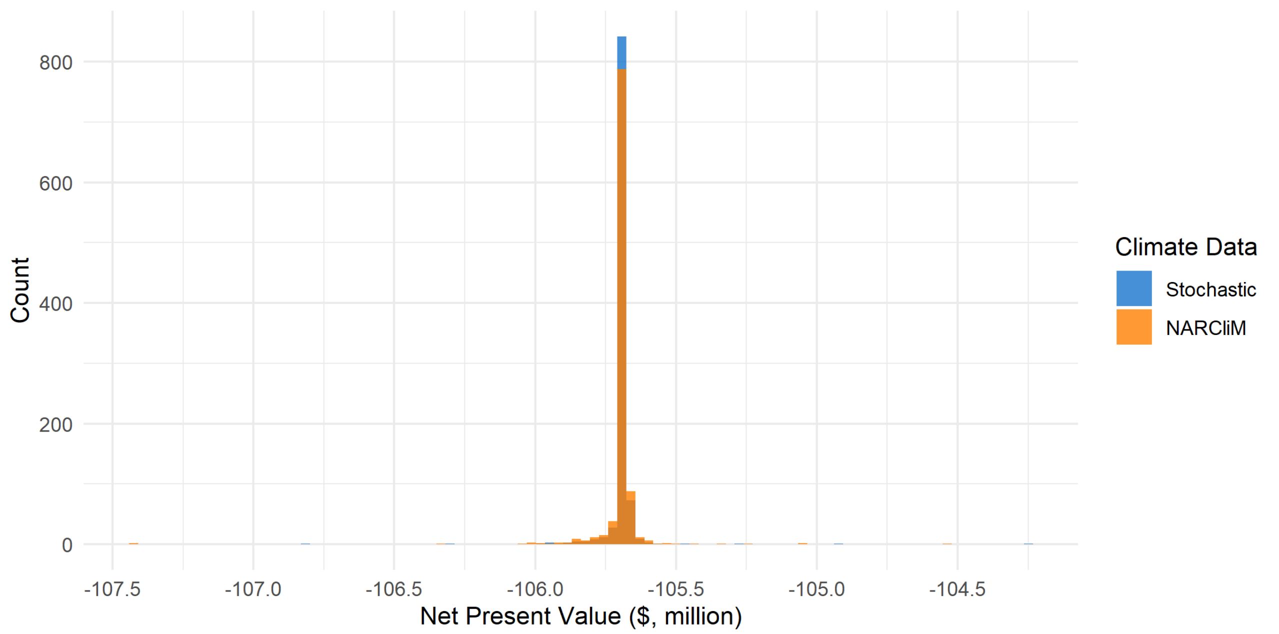

Figure 18. Combined option 5 (Casino) Common Planning Assumptions net present value histogram

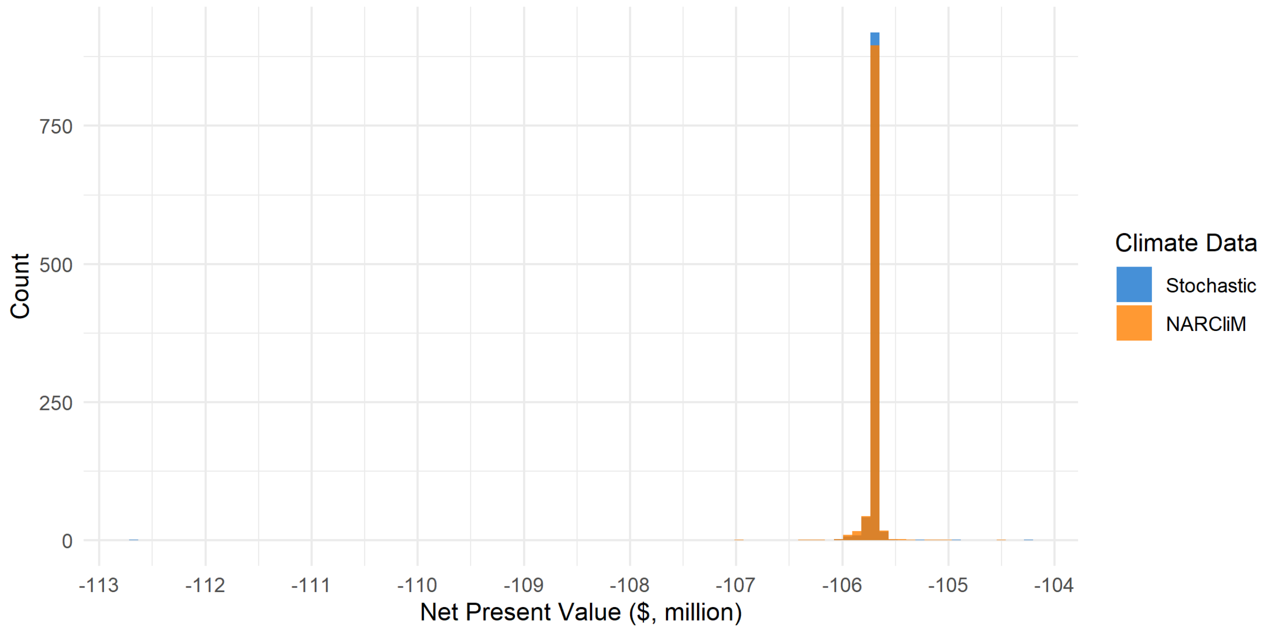

Figure 19. Combined option 5 (Casino) local government population net present value histogram

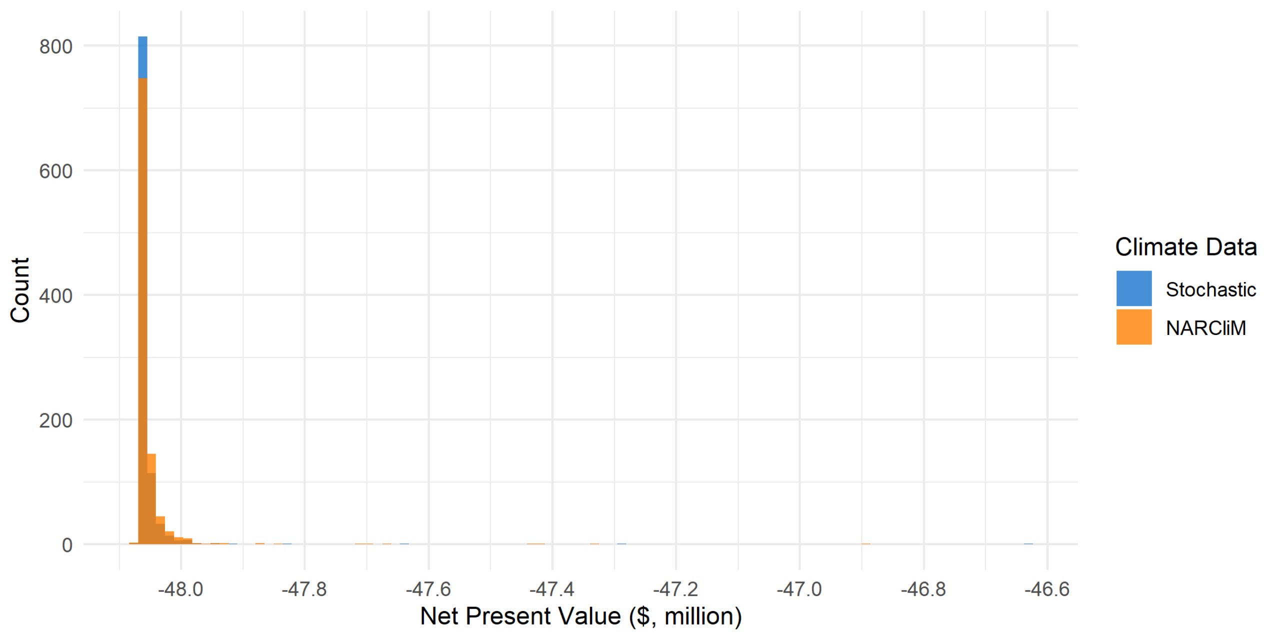

Figure 20. Combined option 5 (Nimbin) Common Planning Assumptions net present value histogram

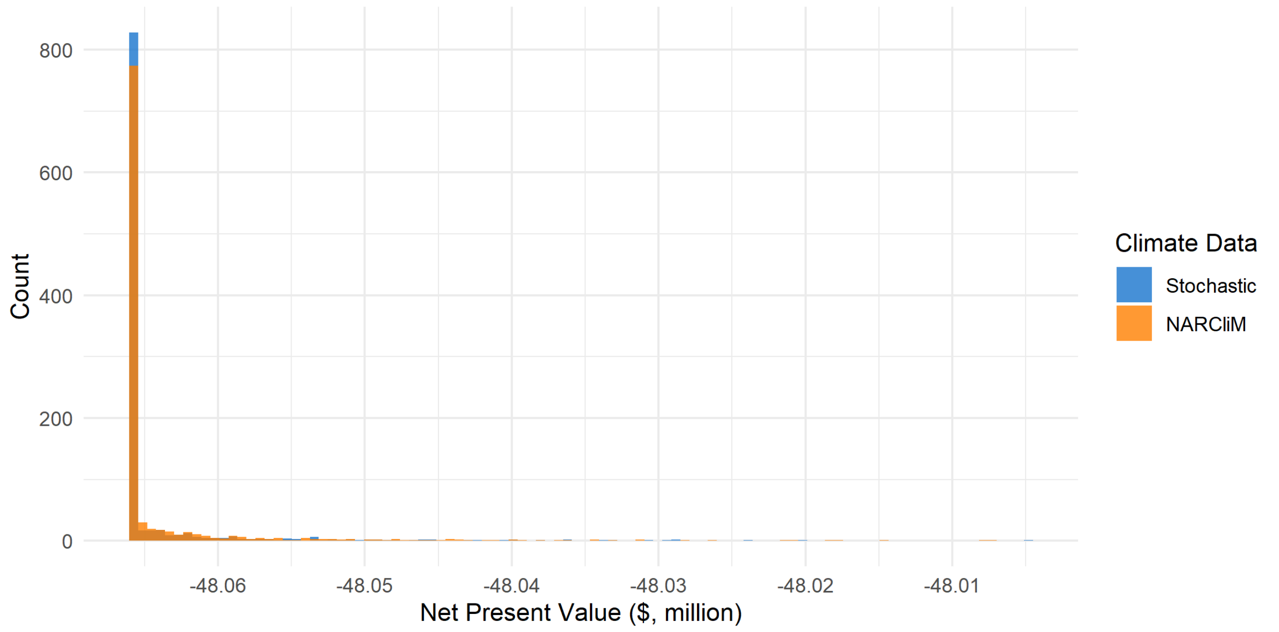

Figure 21. Combined option 5 (Nimbin) local government population net present value histogram

Sensitivity analysis

The histograms for the sensitivity analysis, for both the Common Planning Assumptions and local government population assumptions, are provided in the following figures:

- Mullumbimby: Figure 22 and Figure 23
- Casino: Figure 24 and Figure 25
- Nimbin: Figure 26 and Figure 27

Trends relevant to each sensitivity case are the same under both population assumptions for all four versions of combined option 5. None of these trends suggest that there may be a set of conditions under which the combined option produces economic benefits higher than its costs.

A higher discount rate of 10% lowers the value of future benefits and any residual value of the combined option, resulting in lower net present values. A lower discount rate has the opposite effect, raising the net present value of each realisation.

Varying the capital and operational expenditure by 30% in either direction has the predictable effect of considerably decreasing each realisation’s net present value when the price is increased, and significantly increasing the realisation’s net present value when the price is decreased.

Testing the sensitivity of the marginal economic values of water for key users shows a low level of sensitivity to these assumptions.

The sensitivity analysis for Kyogle did not result in different values and so the results are not presented.

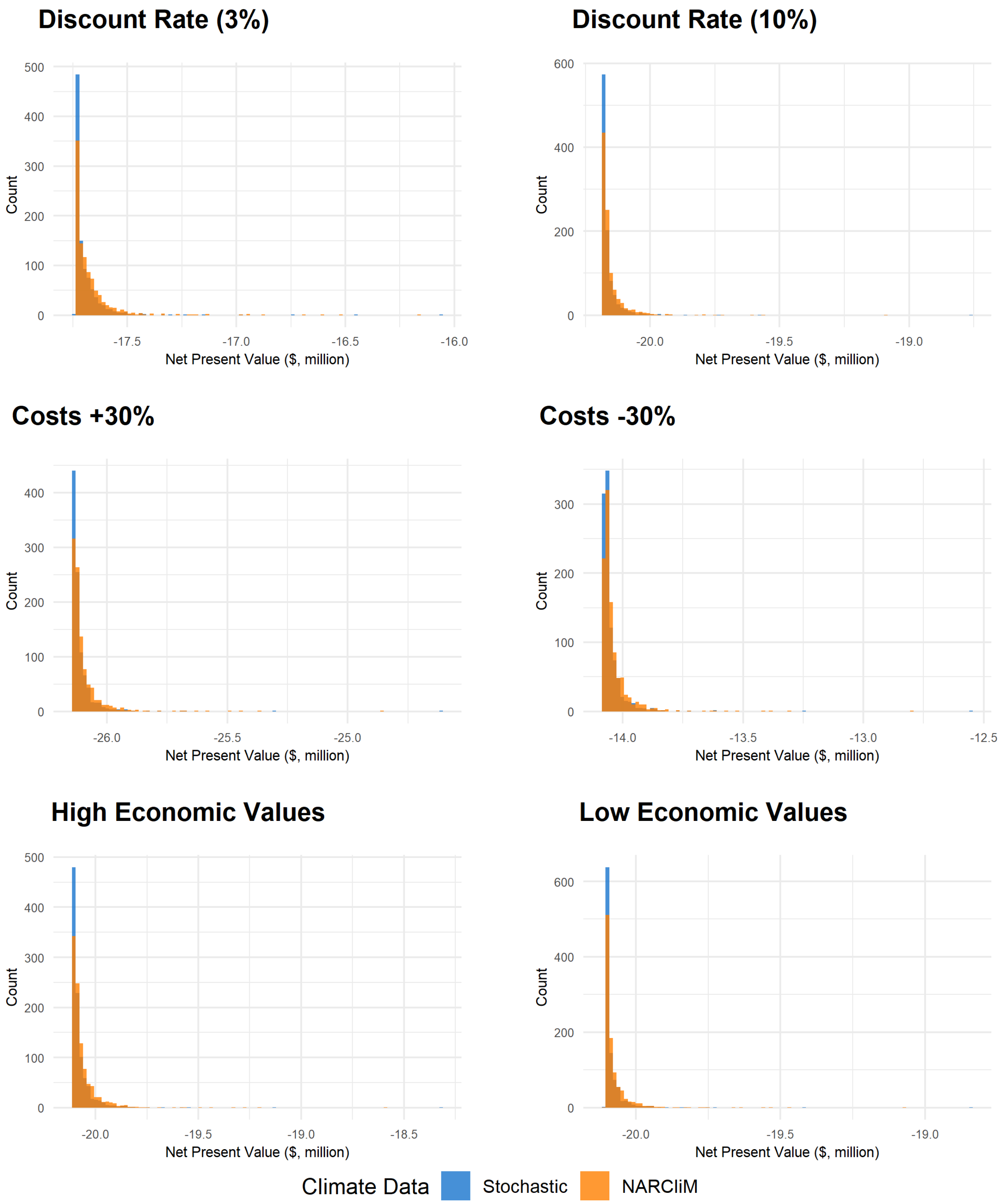

Figure 22. Combined option 5 (Mullumbimby) Common Planning Assumptions sensitivity case net present value histograms

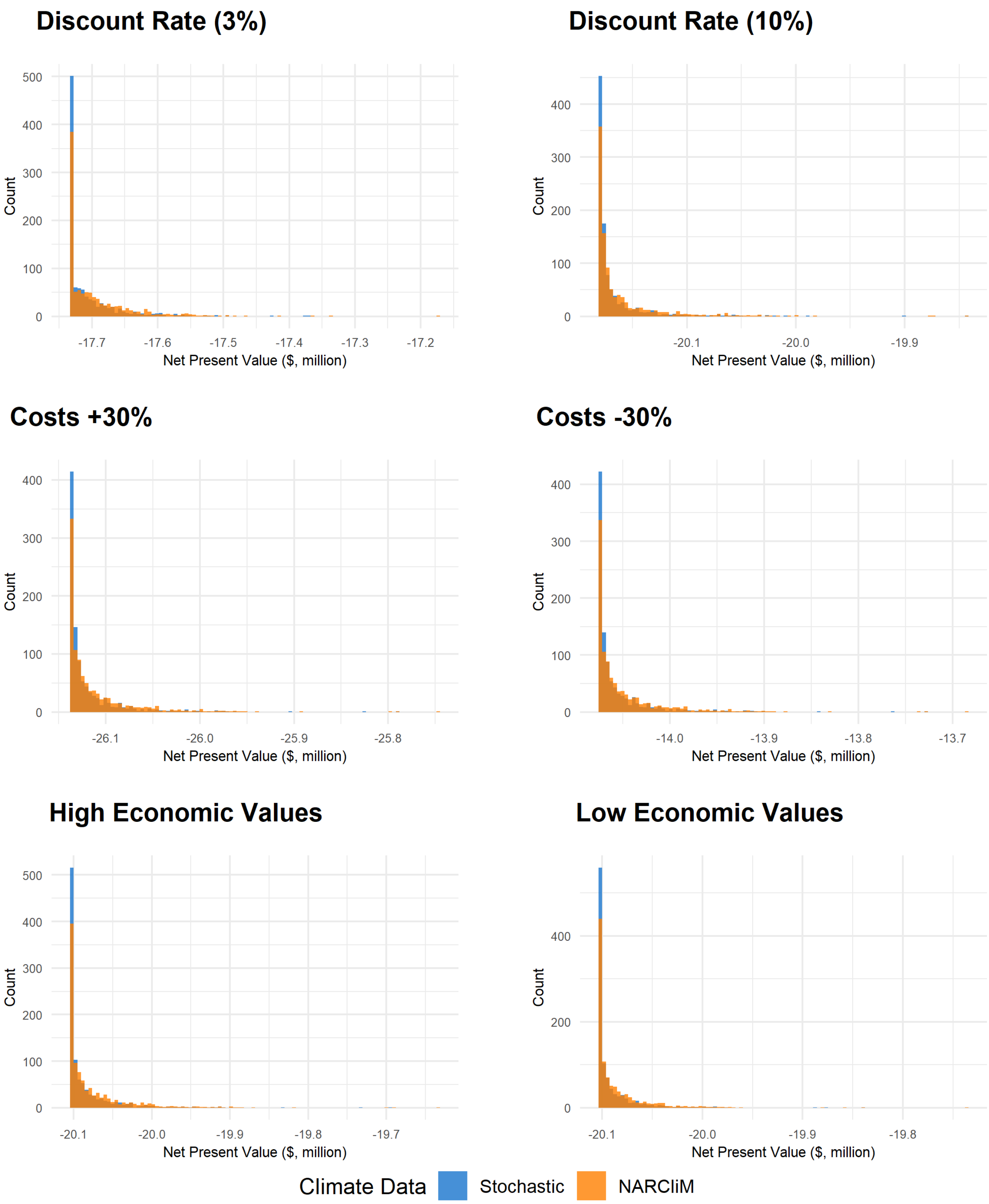

Figure 23. Combined option 5 (Mullumbimby) local government population sensitivity case net present value histograms

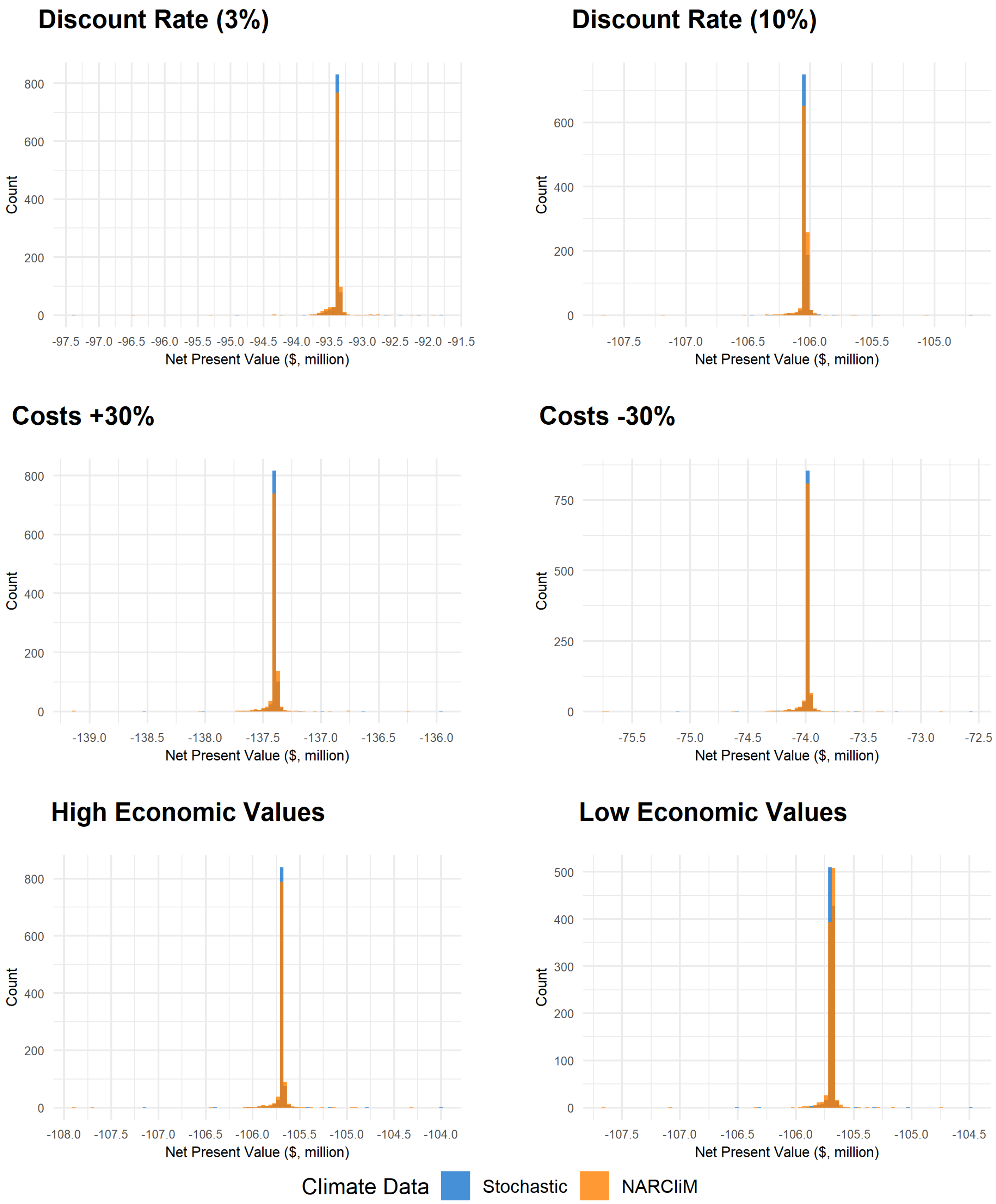

Figure 24. Combined option 5 (Casino) Common Planning Assumptions sensitivity case net present value histograms

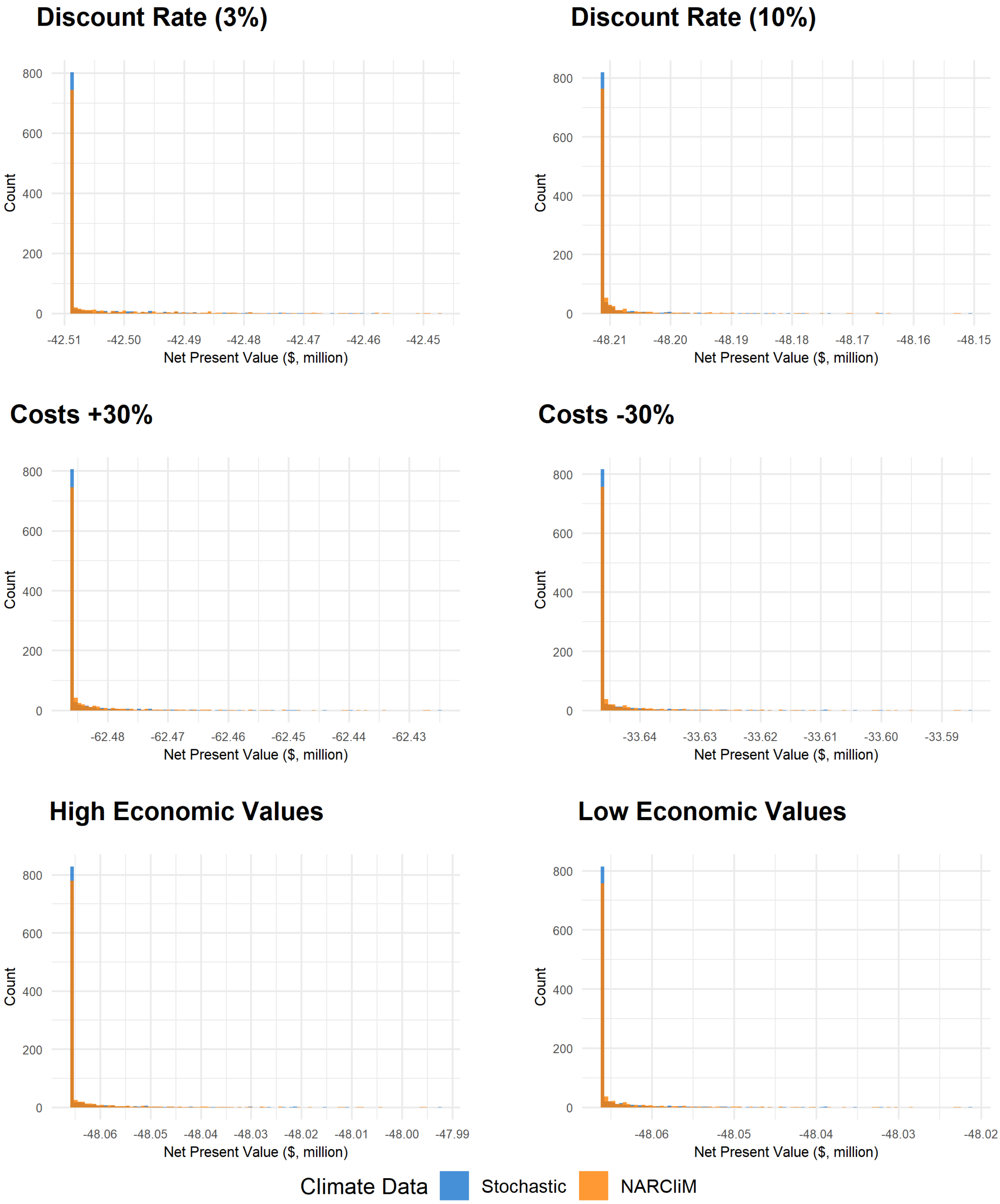

Figure 25. Combined option 5 (Casino) local government population sensitivity case net present value histograms

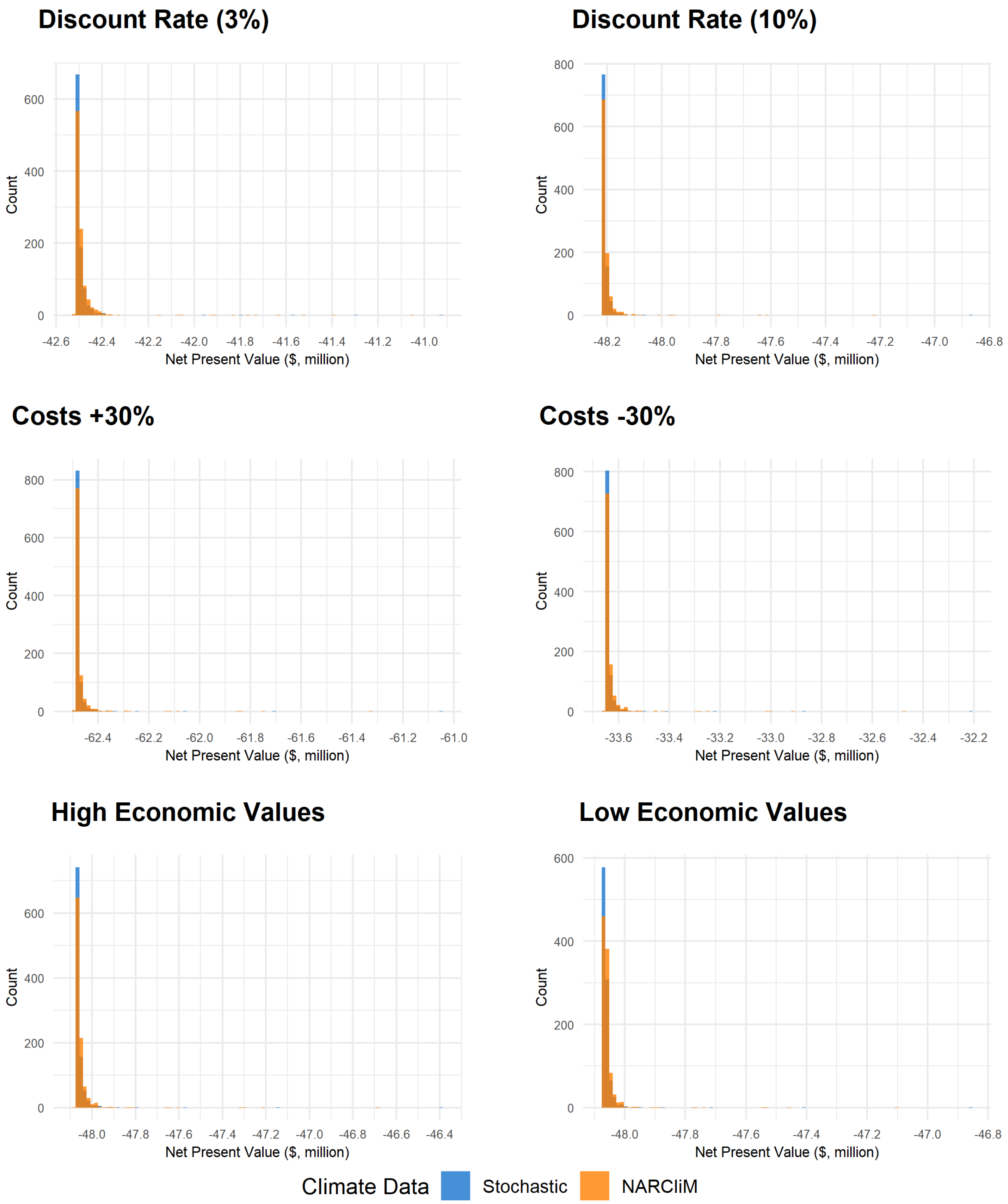

Figure 26. Combined option 5 (Nimbin) Common Planning Assumptions sensitivity case net present value histograms

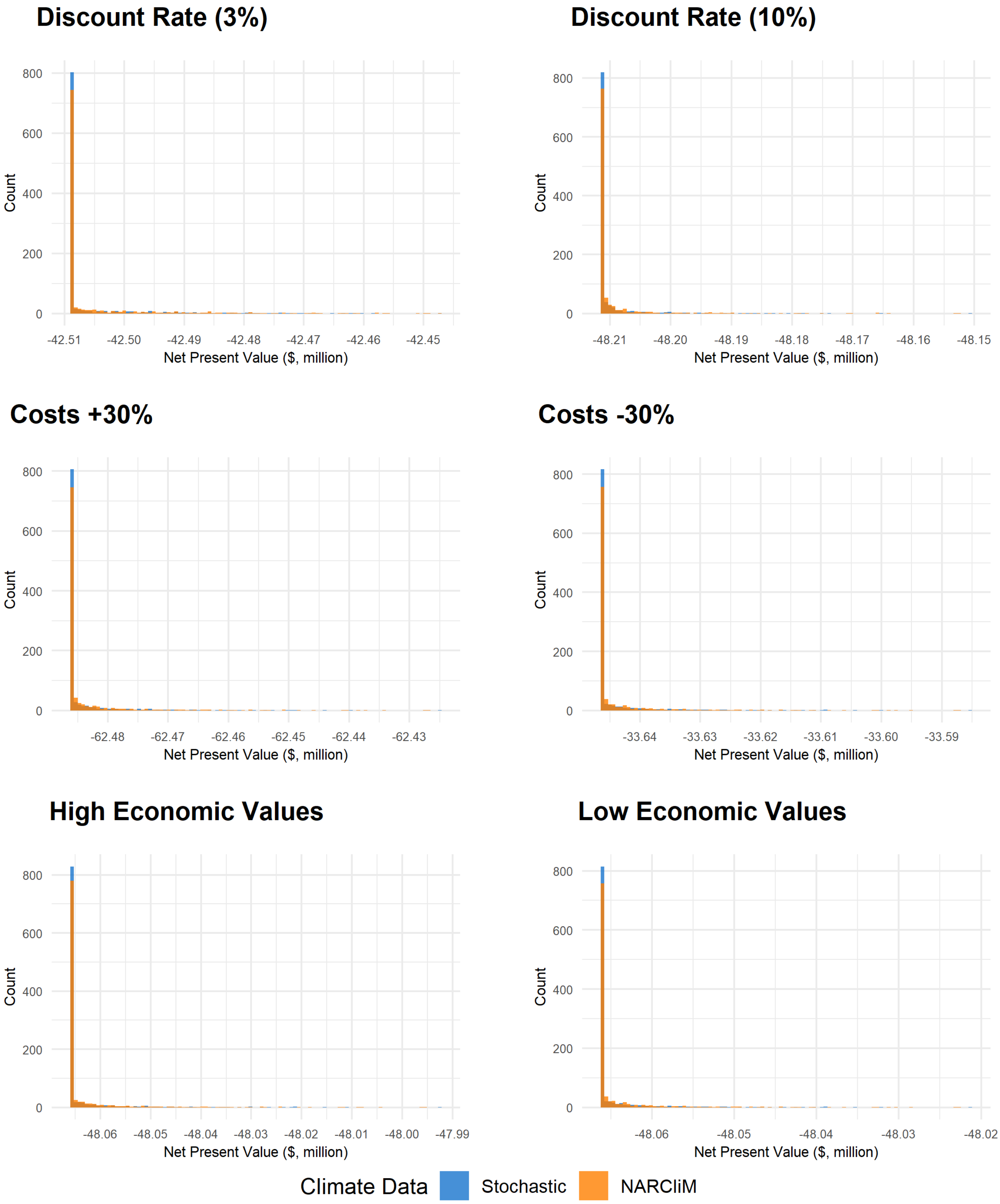

Figure 27. Combined option 5 (Nimbin) local government population sensitivity case net present value histograms

Breakeven analysis

The relevant price level for this combined option is the economic cost of water supply shortfalls. This cost was changed in both the stochastic and NARCliM economic analysis until the average, or expected value, of benefit-cost ratio outcomes for the 1,000 40-year runs of each dataset was equal to, or near to, 1. It was only possible to evaluate the breakeven point for Mullumbimby and Nimbin.

The breakeven price level and the calculated average benefit-cost ratio using this price level for the Mullumbimby connection for both climate datasets are given in Table 43.

Table 43. Breakeven price level combined option 5: Mullumbimby

Climate Dataset	Common Planning Assumptions		Local government population forecasts	
	BCR Average	Economic cost of town water supply shortfalls ($/ML)	BCR Average	Economic cost of town water supply shortfalls ($/ML)
Stochastic	1.0	$1,900,000	1.0	$2,100,000
NARCliM	1.0	$1,300,000	1.0	$1,400,000

The marginal economic cost of a town water supply shortfall for both climate scenarios needs to be many orders of magnitude higher than the cost assumed within this study of carting water to a town (~$10,000/ML). While the local government population forecasts result in breakeven value for water shortages much smaller than under the Common Planning Assumptions, it is 140 times higher than the estimate used in the initial analysis.

Table 44. Breakeven price level combined option 5: Nimbin

Climate Dataset	Common Planning Assumptions		Local government population forecasts	
	BCR Average	Economic cost of town water supply shortfalls ($/ML)	BCR Average	Economic cost of town water supply shortfalls ($/ML)
Stochastic	1.1	$50,000,000	1.0	$50,000,000
NARCliM	1.1	$35,000,000	1.0	$35,000,000

For the Nimbin connection, there is no difference between the breakeven analysis for the Common Planning Assumptions and the local government population forecasts. The breakeven value is much higher than the value used in the initial assessment under both climate scenarios and population projections.

Detailed ecological analysis

Key ecological values and assets

The Far North Coast region supports one of the most biologically diverse areas in Australia, partly because it supports both temperate and tropical species. This diversity is also supported by a range of water-dependent ecosystems. These include instream aquatic habitats, coastal floodplains, coastal saltmarsh, lowland rainforest on floodplains, and freshwater wetlands. The region includes ecological reserves around Brunswick Heads and Byron Bay.

The region contains many nationally important wetlands including the Tuckean Swamp, Stotts Island Nature Reserve, Cudgen Nature Reserve, Billinudgel Nature Reserve and the Lower Bungawalbin Catchment Wetland Complex. These wetlands are important coastal freshwater habitats and support large populations of migratory waterbirds. They also support many threatened wetland bird species including the vulnerable Comb-crested Black Bittern, Freckled Duck, Mangrove Honeyeater and the endangered Black-necked Stork. Clarrie Hall Dam and Cumbebin Swamp support several significant species, including the Comb-crested Jacana and Black-necked Stork. The Tweed River supports the region’s most diverse mangrove community, with five species of mangrove.

The waterways of the region also support a diverse range of native and endemic fish, including the endangered Eastern Freshwater Cod, Purple-spotted Gudgeon, and the threatened Oxleyan Pygmy Perch, along with crayfish, freshwater mussels and freshwater snails. The downstream sections of rivers and creeks in the region transition from freshwater to estuarine ecosystems. Some fish species require access to both freshwater and estuarine environments during their life cycles, including several eel species which also have cultural and commercial fishing values.

The Wilson’s River and Rocky, Terania and Coopers Creeks provide vital habitat for the remaining viable populations of the endangered Eastern Freshwater Cod in the upper river sections of the region. The Eastern Freshwater Cod spawns during August to October and then presumably need stable flows when they provide paternal care for about three weeks after that.

Purple-spotted Gudgeon is found in a variety of habitats with slow-flowing or still waters such as:

- rivers, creeks, streams and billabongs
- where aquatic vegetation and overhanging riparian vegetation provide cover, along with leaf litter, rocks or snags
- where hard substrates can be used for spawning.

In these relatively unimpacted habitats it is vulnerable to fluctuations in water levels, and especially no-flow events. This is because it cannot disperse long distances, which reduces its ability to recolonise where local extinctions have occurred.

Oxleyan Pygmy Perch have similar requirements to the Purple-spotted Gudgeon, as they mostly occur in the swamps, creeks and lakes of coastal 'wallum' (Banksia-dominated coastal heath). Both species have been reduced in distribution by the introduced minnow plague. Oxleyan Pygmy Perch appear to have much more limited tolerances in temperature and water quality, and hence are restricted to northern NSW and southern Queensland. Therefore they are probably at even greater risk under any no-flow events.

Ecological Water Requirements

Like other NSW rivers the ecological condition of the Far North Coast region's water-dependent ecosystems is largely driven by flows that support the specific requirements of species and ecological communities. Flows also support a wide breadth of ecological values by:

- enabling organic carbon transfer and nutrient cycling
- triggering the movement and breeding of native fish and waterbirds, and
- maintaining vegetation condition and estuarine habitat quality.

A key component of the flows that deliver these services is river flow variability, which is an important driver of condition and diversity in river habitats. Although many species have specific flow requirements, the different requirements across species and ecosystems tends to mean that variability in timing (seasonality), frequency and duration of flow pulses is required so that the benefits of these flows support high diversity stream ecosystems. Additionally, because flows affect river channel shape, flow diversity is also important for maintaining a diversity of habitats across and along streams.

The viability of water-dependent species and their ecosystems depends on both maintenance of appropriate flow regimes and land management practices that ensure protection and maintenance of river habitat. Clearing of riparian vegetation and stock access to waterways has accelerated erosion of streambanks of many river reaches in the Far North Coast region. In degraded streams, the maintenance of low flows for water-dependent species is less effective in ensuring population survival. Sediment eroded from streambanks has negatively affected instream habitat quality, which has reduced populations and caused localised extinctions of native fish, platypus, and other plants and animals that depend on these rivers. While land management is the main factor in protecting river habitat, flow management can mitigate poor habitat to a small extent. For example, river flows capable of flushing accumulated sediment from streambeds and estuaries throughout the Far North Coast are important for protecting critical habitats.

Approach to flow assessment

The ecological flow assessment included assessing the effects of water management options under future flow regime models. This included the hydrologic models run using the long-term climate variability (stochastic) and long-term dry climate change (NARCliM) datasets described earlier.

The assessment also assumed that the human population remains close to current levels. Modelling undertaken for the Far North Coast regional water strategy started with different assumptions about town water demands that included human population growth. The economic assessments therefore assumed different town water demands under the local government and Common Planning Assumptions population projections. However, the ecological analyses assume the human population is close to current levels. Different levels of population growth were only modelled in the Far North Coast. As a result, this difference in population estimates between the economic and ecological models only appears in the Far North Coast assessments. This assumption probably has a negligible effect on the ecological results. This is because different population assumptions will mostly affect modelled water demands in towns rather than water volumes or distribution in rural water management areas.

Once the flow scenarios were developed, the next step was to assess how the ecological components of the flow regime have changed. We identified key ecological characteristics of the flow regime and compared these characteristics to the base case. We selected 20 hydrological metrics, including mean annual flow and the number of years with a cease-to-flow event. This assessment provided information on hydrological changes in the flow regime for a subset of 9 metrics from this list. Preliminary analyses showed that the other 11 metrics did not add much information because many of them were interdependent.

Ecological water requirement metrics were not used in the coastal regions because they are currently only available for inland regions. Ecological water requirements that are best suited to the regional water strategy assessments need to be developed collaboratively with agency experts. They partly address the challenge that the flow-dependent species and communities have different and detailed needs. However, neither the generic metrics nor the ecological water requirements can capture all potential effects of interventions. There will always be other external and long-term hydrological and ecological effects associated with river management that will affect the viability of aquatic species and populations.

The current generic metrics attempt to capture the same intent as ecological water requirements for these flow events:

- **cease-to-flow** or **no flow** events, which are known to be a major influence on physical habitat for aquatic biota, water quality and water availability for vegetation
- **freshes,** which influence riparian habitat, food web dynamics and opportunities for fish movement and recruitment
- **overbank flows,** which provide critical connectivity with the floodplain, sustain wetland habitats and floodplain vegetation communities, and provide large-scale productivity pulses in river channels. We assumed that the threshold for overbank flows for any particular reach is likely to be within the range of 2.5- to 10-year average recurrence interval.

Where there were large changes how an ecological metric was met, it was assumed that these changes posed the greatest potential impact or improvement. Results for this detailed ecological assessment are categorised using 11 categories, ranging from 'extreme improvement' to 'extreme impact' (stage 2, Table 45). The assessment rating system is based upon that used by Department of Planning and Environment — Environment and Heritage Group to assess the potential ecological impacts from the implementing individual daily extraction limits in the Barwon-Darling system.[11] We

[11] Department of Planning, Industry and Environment (2019). Potential ecological outcomes from the implementation of IDELs in the Barwon – Darling River. Preliminary Assessment. September 2019.

assumed that flow changes had the greatest potential impact or improvement where the changes in metric values from the base case were large.

Table 45. Categories to be used in ecological assessment

Stage 1 category	Stage 2 category	Estimated percentage change in hydrology / ecology
Major/Extreme impact	Extreme impact	More than 30% change in a negative direction (i.e. < -30%)
	Major impact	More than 20% change in a negative direction (i.e. < -20%)
Minor/Moderate impact	Moderate impact	More than 10% change in a negative direction (i.e. < -10%)
	Minor impact	More than 3% change in negative direction (i.e. < -3%)
No/Little change	Little impact	Less than 3% change in a negative direction (i.e.< 0%)
	No change	0%, rounded to the nearest whole percentage point
	Little improvement	Less than 3% change in a positive direction (>0% and <3%)
Minor/Moderate improvement	Minor improvement	More than 3% change in a positive direction (i.e. >3%)
	Moderate improvement	More than 10% change in a positive direction (i.e. >10%)
Major/Extreme improvement	Major improvement	More than 20% change in a positive direction (i.e. >20%)
	Extreme improvement	More than 30% change in a positive direction (i.e. >30%)

The results in the tables below summarise the effects of the proposed combined option by impact category, observed within that environmental flow class and across multiple representative river flow gauges. All results are from averaged effects over time for each site. This means that the ranges represent the range of time-averaged values across sites, not the entire variability represented over time at the site, or regional level. The changes in the range 'little impact' to 'little improvement' correspond to changes at or less than 3% and are not considered significant.

Summary of ecological results

This section summarises the ecological results of the flow modelling using the stochastic and NARCliM climate datasets for 3 of the combined options.

Richmond catchment effects under combined option 1 — expand Rous County Council's bulk water system through Dunoon Dam

A summary of the ecological assessment results are shown in Table 32 for the effects on the Richmond River catchment from combined option 1.

The major findings for the environmental analysis are:

- No significant (3% or greater) effect was found for mean annual discharge, the frequency of freshes or the size of larger flows (2.5- and 5-year annual recurrence interval).
- Minor to moderate environmental impacts are predicted for the frequency of low flow periods and the size of base and very low flows.
- Minor improvements (reductions) in duration of no-flow periods: At Goolmangar Creek a 3.4% improvement was observed in both climate scenarios. This could be due to reduced drawdown at the Goolmangar Creek – Terania Creek junction. The more continuous low flows modelled downstream of the Rocky Creek – Dunoon dam system boost the water levels in Goolmangar Creek. No-flow duration at Rocky Creek reduced by only 2.4% in the stochastic climate scenario.
- The strongest impact on the Richmond system was a minor increase in the number of days where flow occurred below the low flow threshold. This overall result was almost entirely driven by Terania Creek at Keerong (below Rocky Creek Dam) where under the NARCliM climate scenario the number of these lower flow days increased from 4 to 16 days.

Table 46. Richmond catchment effects under combined option 1

Flow range	Long-term stochastic model (10,000 years)	Long-term dry climate change model (10,000 years)
Mean annual discharge (ML/y)	no effect (no effect - no effect)	no effect (no effect - no effect)
No flows (duration in days)	no effect (minor improv - no effect)	no effect (minor improv - no effect)
No flows (frequency over 130 years)	no effect (no effect - minor impact)	no effect (minor improv - minor impact)
Number of days below low flow (median, days)	minor impact (no effect - extreme impact)	moderate impact (no effect - extreme impact)
Very low flows (size of 95th percentile, ML/day)	no effect (moderate impact - no effect)	no effect (moderate impact - no effect)
Base flows (size of 80th percentile, ML/day)	no effect (moderate impact - no effect)	no effect (moderate impact - no effect)
Freshes (20th percentile, frequency)	no effect (no effect - no effect)	no effect (no effect - no effect)
Size (ML/day, of flow with an average 2.5-year recurrence interval)	no effect (no effect - no effect)	no effect (no effect - no effect)
Size (ML/day, of flow with an average 5-year recurrence interval)	no effect (no effect - no effect)	no effect (no effect - no effect)

There is limited catchment health information available on the Richmond River catchment. However, the 2015 Richmond River ecohealth assessment found degrading geomorphology and a general decline in water quality, riparian vegetation condition and macroinvertebrate communities in the transition from upland reaches to the estuary.[12] The report also found that the major stressors leading to poor condition were:

- land use, clearing and associated nutrient and sediment run-off
- grazing and weeds in riparian zones
- habitat degradation through sediment smothering and nutrient enrichment.

The report did not identify flow modification as a major threat. However, it did identify water quality risks associated with both dissolved oxygen (low flows) and pH (floods). It also noted that most nutrient and sediment transport occurs during freshes and floods, which would affect in-stream and estuarine communities.

[12] Ryder, D., *et al.* 2015, *Richmond Ecohealth Project 2014: Assessment of River and Estuarine Condition - Final Technical Report*, www.une.edu.au/about-une/faculty-of-science-agriculture-business-and-law/school-of-environmental-and-rural-science/research/life-earth-and-environment/aquatic-ecology-and-restoration-research-group/recent-publications, accessed 24 November 2022.

The reductions in size and quality of habitats shown in previous studies, together with the low-flow impacts identified in the Richmond River ecohealth assessment, suggest that the Rocky Creek–Terania Creek system is at risk. This is especially so during low-flow periods and under this combined option which has the greatest flow impacts. Downstream of Rocky Creek Dam, Rocky Creek runs through cleared farmland with associated poor riparian vegetation condition. It is possible that the dam provides protection from sediment smothering, which may explain high scores in the macroinvertebrate sampling. However, longer low-flow events are likely to have a detrimental effect on the macroinvertebrate community within the creek.

The endangered Eastern Cod has been recorded in the Terania Creek catchment, including at Rocky Creek. The increased frequency of low-flow periods anticipated in the Terania Creek catchment from this combined option would increase risks to these fish in the short term due to reduced habitat and poor water quality, particularly in areas with poor riparian vegetation. In the longer term, changes to the macroinvertebrate community caused by cease-to-flow events may reduce the amount or quality of food available to support large predatory fish. The low-flow implications for Terania Creek are not fully represented with these data, as the results presented are based on site averages over time. This risk would need further exploring if this combined option was pursued.

Mapping by Department of Planning and Environment — Fisheries suggests that Southern Purple-spotted Gudgeon inhabits smaller creeks in the tributaries of the Richmond River. The importance of Rocky or Terania Creek to sustaining populations within the catchment is not known.

Tweed River catchment effects under combined option 2 — maximise use of the proposed Clarrie Hall Dam augmentation

This analysis found that no obviously ecologically significant effects were likely as a result of this combined option. A summary of the ecological assessment results for the effects on the Tweed River catchment from combined option 2 are shown in Table 47.

The major findings for the environmental analysis are:

- No significant (at 3% or greater) effect was found for mean annual discharge and the size of very low flows
- Slight improvement in frequency of no-flow (cease-to-flow) events. This was particularly noticeable in downstream sections, with a 24% decrease at Bray Park weir and in the Tweed River at Braeside (10% decrease), especially under the long-term dry climate change scenario. However, these changes relative to very small base case numbers, with 0.64 to 0.58 modelled events over a 130-year period for Tweed River at Braeside, and 0.28 to 0.21 at Bray Park Weir. These are unlikely to have an ecological effect.
- Minor to moderate environmental impacts are predicted for base flows, which are likely to have little impact on ecological communities.
- Minor improvements in no-flow (cease to flow) duration. This was the most evident under the stochastic scenario for Bray Park weir where the duration of the no-flow period changed from 1.06 to 1.00 day. This change is unlikely to have a meaningful ecological effect for any single event. However, since these are averaged values, they could be masking large, infrequent events that affect species survival ecosystem composition.

- Minor improvements for larger (2.5 or 5 year recurrence) flows, which could be bankful or overbank flows, were recorded. For example, five year return flows increased from 7,981 ML/day to 8,644 ML/day over the modelling period for Doon Doon Creek at downstream Clarrie Hall. This could have a meaningful ecological effect if it better enables fish, invertebrate, carbon and nutrient movement by allowing flows to connect over barriers.
- The strongest effect (negative impact) was on the number of days where flow occurred below the low flow threshold. This overall result was almost entirely driven by the impact at Doon Doon Creek downstream of Clarrie Hall Dam where under the NARCliM climate scenario the number of these low flow days increased from 115 to 149 days.

Table 47. Tweed catchment effects under a raise Clarrie Hall & connected Rous & Tweed supplies scenario

Flow range	Long-term stochastic model (10,000 years)	Long-term dry climate change model (10,000 years)
Mean annual discharge (ML/y)	no effect (no effect - no effect)	no effect (no effect - no effect)
No flow (duration in days)	no effect (minor improvement with a decrease - no effect)	no effect (no effect - no effect)
No flow (frequency over 130 years)	no effect (moderate improvement with a decrease - no effect)	no effect (major improvement - no effect)
Number of days below low flow (median, days)	no effect (no effect - extreme impact with an increase)	no effect (no effect - extreme impact)
Very low flows (size of 95th percentile, ML/day)	no effect (no effect - no effect)	no effect (no effect - no effect)
Base flows (size of 80th percentile, ML/day)	no effect (minor impact with a decrease - no effect)	no effect (no effect - no effect)
Freshes (20th percentile, frequency)	no effect (no effect - no effect)	no effect (no effect - no effect)
Size (ML/day, of flow with an average 2.5-year recurrence interval)	no effect (no effect - minor improvement (increase))	no effect (no effect - minor improvement)
Size (ML/day, of flow with an average 5-year recurrence interval)	no effect (no effect - minor improvement)	no effect (no effect - minor improvement)

Doon Doon Creek is mapped as key fish habitat by NSW Fisheries. The ecological impact statement for raising Clarrie Hall Dam by Eco Logical Australia[13] concluded that impacts on the aquatic ecology of the dam and downstream waterways will result in some loss of habitat, but may create additional key fish habitat in the long-term. The hydrological modelling conducted for the regional water strategy similarly suggests that habitat in Doon Doon Creek could deteriorate, with impacts on fish and water quality. Improvements in freshes and flooding can lead to improvements for vegetation, particularly if the increased flows occur in autumn. This is because flows are naturally high in autumn and weed seeds do not benefit as much as natives.[14] However, there is also a significant increase in low-flow periods, with about a 30% and 50% increase in flows below the 80 and 75 percentiles respectively. Given that extended low-flow periods tend to lead to channel contraction, the overall effect in Doon Doon Creek would be habitat loss across the stream's width.

These low-flow impacts are not reflected downstream. However, contrary to the ecological impact statement, our results suggest that downstream improvements are too small to create habitat for fish or other aquatic biota. Our modelling results suggest that the river at Brae Park weir (end of system) and Braeside (main stem, not far below Clarrie Hall dam and about 8 km downstream in a direct line) will have minor reductions in the number of no-flow events, and very small reductions in the length of low-flow periods. Brae Park weir is critical for sustaining freshwater supplies in the area. The modelled changes are unlikely to have any significant ecological effects, whereas both the weir and the water supply have been identified as vulnerable to climate change (from changes in flows and rising sea levels). The weir also represents a barrier to fish movements between freshwater, estuarine and marine habitats.

Richmond River catchment effects under combined option 2 — maximise use of the proposed Clarrie Hall Dam augmentation

A summary of the ecological assessment results for the effects on the Richmond River catchment from combined option 2 are shown in Table 48.

The major findings for the environmental analysis are:

- No significant (at 3% or greater) effect was found for most metrics.
- Minor improvements (reductions) in duration of no-flow periods with small decreases in the average total annual low-flow duration. Minor improvements (reductions) were also observed in the frequency of no-flow periods. The strongest local effect in this no-flow trend was for the Richmond River at Kyogle, which had a 3% decrease in the number of no-flow events under both the stochastic and dry climate change scenarios (from about 38 to 37, and 48 to 46 events respectively). Goolmangar Creek at Coffee Camp also had a decrease of about 3% in no-flow duration under both these climate scenarios. As this model only assumed changes to connected infrastructure and river operations across the Tweed River catchment, these small effects under both the stochastic and dry climate change models in the Richmond

[13] Several documents make up the ecological impact statement. The key documents relevant to the discussion are Eco Logical Australia 2019. *Environmental Flow Assessment Raising Clarrie Hall Dam*. Prepared for Tweed Shire Council; and Eco Logical Australia 2021. *Proposed Raising of Clarrie Hall Dam*.

[14] Howell, J. and Benson, D. 2000, Predicting potential impacts of environmental flows on weedy riparian vegetation of the Hawkesbury–Nepean River, south-eastern Australia. *Austral Ecology*, 25(5), 463-475.

catchment are assumed to be modelling artefacts. In any case, they are such small effects it is hard to argue they would be ecologically significant.

Table 48. Richmond River catchment effects under a Raise Clarrie Hall & connected supplies scenario

Flow range	Long-term stochastic model (10,000 years)	Long-term dry climate change model (10,000 years)
Mean annual discharge (ML/y)	no effect (no effect - no effect)	no effect (no effect - no effect)
No flow period duration (days)	no effect (minor improvement with a decrease - no effect)	no effect (minor improvement - no effect)
No flow (frequency over 130 years)	no effect (no effect - no effect)	no effect (minor improvement - no effect)
Number of days below low flow (median, days)	no effect (no effect - no effect)	no effect (no effect - no effect)
Very low flows (size of 95th percentile, ML/day)	no effect (no effect - no effect)	no effect (no effect - no effect)
Base flows (size of 80th percentile, ML/day)	no effect (no effect - no effect)	no effect (no effect - no effect)
Freshes (20th percentile, frequency)	no effect (no effect - no effect)	no effect (no effect - no effect)
Size (ML/day, of flow with an average 2.5-year recurrence interval)	no effect (no effect - no effect)	no effect (no effect - no effect)
Size (ML/day, of flow with an average 5-year recurrence interval)	no effect (no effect - no effect)	no effect (no effect - no effect)

Richmond River catchment effects under combined option 3 — maximise use of Toonumbar Dam

A summary of the flow impacts for this combined option is shown in Table 49. The major findings for the environmental analysis are:

- The model suggested this combined option may lead to a reduction in the number of no-flow events at Iron Pot creek and downstream at Eden Creek, both of which are below Toonumbar Dam. This tended to be more pronounced under the stochastic climate scenario, but still observed under the NARCliM climate scenario. For example, a 75% improvement under the stochastic climate scenario compared to 67% improvement under the NARCliM climate scenario for Iron Pot Creek at Toonumbar. However, these values are coming off a very low baseline, with typically a chance of about 1 in 10 for an event over the modelling period for the base case, with the average duration of no-flow reducing from 25 to 13 days. These are very modest changes, but the direction of these changes could be expected to occur under an increase in water orders down to Casino.

- The largest impact of this combined option is seen in the number of days below low-flow levels (80th percentile flow). This is about a 2% average increase across all sites under both scenarios. For the Iron Pot Creek at Toonumbar gauge, which increases by just over 50% under both climate scenarios this represents an increase from 31 days per year to 47 days per year.
- There are some moderate improvements in the frequency of large flows, particularly in the size of flows with a 5-year average recurrence interval. This represented an increase from 5,527 ML/day to 6,109 ML/day at Iron Pot creek for the stochastic climate scenario.

Table 49. Richmond River catchment effects under a raise Toonumbar Dam scenario

Flow range	Long-term stochastic model (10,000 years)	Long-term dry climate change model (10,000 years)
Mean annual discharge (ML/y)	no effect (no effect - no effect)	no effect (no effect - no effect)
No Flow (duration (days))	no effect (extreme improvement - moderate impact)	no effect (major improvement - moderate impact)
No flows (frequency over 130 years)	minor improvement (extreme improvement - no effect)	minor improvement (extreme improvement - no effect)
Number of days below low flow (median, days)	no effect (minor improvement - extreme impact)	no effect (minor improvement - extreme impact)
Very Low Flows (size of 95th percentile, ML/day)	no effect (no effect - minor improvement)	no effect (no effect - minor improvement)
Base Flows (size of 80th percentile, ML/day)	no effect (moderate impact - minor improvement)	no effect (moderate impact - minor improvement)
Freshes (20th percentile, frequency)	no effect (no effect - no effect)	no effect (no effect - no effect)
Size (ML/day, of flow with an average 2.5-year Recurrence Interval)	no effect (no effect - minor improvement)	no effect (no effect - minor improvement)
Size (ML/day, of flow with an average 5-year Recurrence Interval)	no effect (no effect - moderate improvement)	no effect (no effect - moderate improvement)

The only ecological impact on this scenario appears to be in the nearby streams downstream of Toonumbar Dam, especially in Iron Pot Creek. This is unsurprising since Iron Pot Creek is regulated by Toonumbar Dam. Iron Pot creek has some level of resilience to the increase in low-flow areas because forests in national parks, state forests, conservation areas or unprotected residual patches account for approximately 69% of its sub-catchment area.[15] In other stream sections, any low-flow effects are likely to be exacerbated by the loss of moisture-trapping riparian vegetation, impacts of grazing animals, poor water quality and associated agricultural impacts. Iron Pot creek has some of the better riparian and macroinvertebrate communities in the Far North Coast region, and is home to threatened species including Orange-bellied Crayfish and Richmond Range Mountain Frog.[16] These ecological effects will need to be mitigated if this option progresses.

Conclusions

The hydrological analyses suggest that the most at-risk stream communities are in the smaller upstream reaches closest to the effects of dams. Although this hydrological analysis is more detailed than the rapid ecological assessment, it is still very high level with results averaged over time at the site level, and metrics not applied to specific species or ecosystem requirements.

In combined option 1 (Expand Rous County Council's bulk water system through Dunoon Dam), the greatest effect was an increase in low-flow days on Terania Creek below Rocky Creek dam. The effects of degraded habitat and low flows would likely combine, which could affect the viability of endangered water-dependent species.

Under combined option 2 (Maximise use of the proposed Clarrie Hall Dam augmentation), it was Doon Doon Creek downstream of Clarrie Hall dam that suffered an extreme impact on the number of low flows days, which could also lead to long-term habitat loss.

For combined option 3 (Maximise use of Toonumbar Dam), it was Iron Pot Creek that showed a large increase in flows below the 80th and 75th percentiles which — like Terania Creek — is likely to lead to a contraction in stream habitat. Additionally, similar to Doon Doon and Rocky Creeks, the flow effects on Iron Pot Creek are likely to interact with local agricultural impacts to threaten local significant species.

The models were generally not able to detect significant impacts further downstream, which the expert assessments indicated could arise. However, these two assessments should be considered complementary — one is based on models of hydrologic effects at specific locations, and the other is drawn from collective, long-term expert observations from similar scenarios and past experience. If these options are progressed, then more detailed analyses should be applied to attempt to reconcile the differences in these assessments.

[15] Ryder, D., *et al.* 2015, *Richmond Ecohealth Project 2014: Assessment of River and Estuarine Condition - Final Technical Report*, www.une.edu.au/about-une/faculty-of-science-agriculture-business-and-law/school-of-environmental-and-rural-science/research/life-earth-and-environment/aquatic-ecology-and-restoration-research-group/recent-publications, accessed 24 November 2022.

[16] Coughran, J. 2011, Aspects of the biology and ecology of the Orange-Bellied Crayfish, *Euastacus mirangudjin* Coughran 2002, from northeastern New South Wales. *Australian Zoologist*, 35(3), 750-756; and Willacy, R. J., Mahony, M., & Newell, D. A. 2015, If a frog calls in the forest: Bioacoustic monitoring reveals the breeding phenology of the endangered Richmond Range mountain frog (Philoria richmondensis). *Austral Ecology*, 40(6), 625-633.

Table 50. Summary of the ecological assessment of the combined options in the Far North Coast region

Combined option	Main modelled effects from the detailed ecological assessment	Most relevant predictions from the rapid expert assessment
Richmond catchment effects under combined option 1 — expand Rous County Council's bulk water system through Dunoon Dam	Minor to moderate increases in low flow days for Terania Creek at Keerong below Rocky Creek dam	*Major / Extreme impact* (Range: Moderate to Extreme) for New Dunoon Dam on Rocky Creek (Option 14). Concerns there could be a significant impact on the flow regime below the dam, with ecohydrological impacts on native fish and habitats including decreased recruitment, decreased growth, reduced migration potential, barriers to fish movement, disruption to spawning and migration cues, changes to opening and closing regimes of estuary entrances, cold water pollution, altered ecological communities, loss of flowing habitat, increased recruitment of pest fish species, poor water quality and potential impacts from headwater streams through to lowland systems.
Tweed catchment effects under combined option 2 — maximise use of the proposed Clarrie Hall Dam augmentation	Generally weak effects, with the most significant effect an 'extreme' increase in low-flow days at Doon Doon Creek downstream of Clarrie Hall Dam, but it was a change from 115 to 149 days over the 130-year model period.	*Major / Extreme impact* (Range: Moderate to Extreme) for Raise Clarrie Hall Dam level (Option 12). Same range of potential adverse outcomes as listed for Dunoon Dam above.
Richmond River catchment effects under combined option 2 — maximise use of the proposed Clarrie Hall Dam augmentation	Some small effects with improvements in no-flow duration and frequency that will need further exploration if this option progresses.	
Richmond River catchment effects under combined option 3 — maximise use of Toonumbar Dam	Slightly over 50% increase in the number of days below the low-flow threshold under both climatic scenarios for Iron Pot Creek at Toonumbar, from 47 to 31 days over the 130 year model period. Some moderate improvement in 5-year average recurrence interval flows at the same site, from 5,527 ML/day to 6,109 ML/day.	*Major / Extreme impact* (Range: Moderate to Extreme) for Raise Toonumbar Dam level (Option 19). Could impact the flow regime of the stream and degrade the ecosystem depending on the size of the dam and how releases are managed. Same range of potential adverse outcomes as listed for Dunoon Dam above.