Department of Planning and Environment

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Hydrologic analysis of options for the South Coast Regional Water Strategy -regulated Bega-Brogo and unregulated Bega rivers

Regional Water Strategies Program

May 2022

Department of Planning and Environment

dpie.nsw.gov.au

Acknowledgement of Country

The NSW Government acknowledges Aboriginal people as Australia's first people and the Traditional Owners and Custodians of the lands and waters. 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 acknowledge the Yuin people as having an intrinsic connection with the lands and waters of the South Coast Regional Water Strategy area. The landscape and its waters provide the Yuin people 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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Executive Summary

The NSW Government made an election commitment to develop and progress regional water strategies across NSW. The South Coast Regional Water Strategy, which includes the regulated Bega-Brogo and unregulated Bega rivers, is one of 12 strategies being developed across NSW to meet this commitment. The strategies aim to determine how much water a region needs to meet future demand and identify challenges and choices involved in meeting those needs. The strategies set out actions to manage risks to water security, enable economic prosperity, and protect and enhance the environment.

The NSW Department of Planning and Environment has applied a risk-based approach to assessing hydrologic and economic implications and outcomes for a range of potential water supply and demand options. This approach was aimed at defining risks to essential water supplies and the regional economy from climate variability and drought.

Hydrological assessment was undertaken to understand the impact of the option on existing water supply risks to water users in the regulated Bega-Brogo and unregulated Bega rivers, and to inform the detailed economic assessment of this option.

The assessment of water security and changes in the flows regime in regulated Bega-Brogo and unregulated Bega rivers was undertaken for three climatic regimes:

1. Instrumental climate ‐ this data includes the period of available instrumental meteorological recordings for the catchment (1889‐2020)
2. long-term historic climate projections (stochastic data) based on historic data — this approach applied stochastic modelling to our 130-year picture of past climate (step 1) to develop 13,000 years of possible climate sequences. This approach provided more information on climate variability and shows it's possible the region could experience more severe drought and wet sequences.
3. Applying climate-change projections to our new climate dataset: two climate change scenarios were developed based on work carried out through NARCliM, the Electricity Sector Climate Information project and research undertaken by University of Newcastle. The scenarios were applied to the 13,000 year dataset, including:
   a. A NARCliM-informed future climate scenario (based on a dry scenario for 2060 to 2079): this assumes that there is a dry, worst case climate change scenario in the future.
   b. Reduced number of east coast low (ECL): modelled one less east coast low event per year. A potential reduction in east coast lows as well as intensity of rainfall associated with east coast lows are associated with concerns for water security.

Table 1 lists the six options modelled. For some of these options, several different scenarios were assessed. Option numbers in the table correspond to the options listed in the *Draft South Coast Regional Water Strategy – Long list of options* released in October 2020.

Table 1 List of modelled South Coast options

Option number	Option description	Scenarios modelled
1	Pipeline from Brogo Dam to Bega-Tathra town water supply system	1. Additional town water supply entitlement
16	Increase on-farm water storage	16a. Dams with low flow bypass
		16b. Dams without low flow bypass
19	Increase capacity of Brogo Dam	19a. Pipe to Tuross town water supply
		19b. Pipe to Bega town water supply
		19c. Pipe to Tuross and pipe to Bega town water supply
21	Brown Mountain Water Project (pumped hydro scheme)	21a. 5.3 GL extra storage, existing demand
		21b. 5.3 GL extra storage, increased demand
		21c. 20 GL extra storage, proclaimed regulated, existing demand
		21d. 20 GL extra storage, proclaimed regulated, increased demand
34	Active and effective water markets	34. Activating sleeper licences

*More details in DPE (2022), *Hydrologic analysis of options for the South Coast Regional Water Strategy -Tuross River*

The eWater Source River System model was used to develop the regulated Bega-Brogo and unregulated Bega rivers baseline model. This model was then used to undertake hydrologic and water supply assessment modelling to understand the key water security risks in the catchment and the impact the identified infrastructure option could have on this risk profile.

1. Introduction

The NSW Government made an election commitment to develop and progress regional water strategies across NSW. One of the key actions recommended in the State Infrastructure Strategy 2018–38 is to develop regional water strategies for all catchments in NSW. The South Coast Regional Water Strategy, which covers the regulated Bega-Brogo and unregulated Bega rivers, and Tuross River, is one of 12 strategies being developed across NSW to meet this commitment. The strategies aim to determine how much water a region needs to meet future demand and identify challenges and choices involved in meeting those needs. The strategies set out actions to manage risks to water security, enable economic prosperity, and protect and enhance the environment.

The NSW Department of Planning and Environment has applied a risk-based approach to assessing hydrologic, economic and ecological implications and outcomes for a range of potential water supply and demand options. This approach was aimed at defining risks to essential water supplies and the regional economy from climate variability and drought in the South Coast region under existing water supply infrastructure, and potential for mitigating this risk by augmenting infrastructure or making operational changes.

For the regulated Bega-Brogo and unregulated Bega rivers, six infrastructure options from the *Draft South Coast Regional Water Strategy – Long list of options*[1] released in October 2020, met the criteria for hydrological modelling. A separate report presents the hydrological modelling of options for Tuross River[2] The modelling has been done to further understand the impact of the options on supply risks to water users in the regulated Bega-Brogo and unregulated Bega rivers, as well as to feed into the economic assessment of options for augmentation and development and for assessing ecological impacts.

The modelling was completed using the eWater Source River System Model. Hydrological modelling is a key input to the development of the final South Coast Regional Water Strategy. The modelling provides part of the evidence for the infrastructure options within the regulated Bega-Brogo and unregulated Bega rivers being included in the proposed shortlist of actions identified the *Draft South Coast Regional Water Strategy: Shortlisted Actions -Consultation Paper*[3]. Modelling was undertaken for the combined options developed for the regulated Bega-Brogo and unregulated Bega rivers, which combine several modelled options for further assessment.

[1] https://water.dpie.nsw.gov.au/plans-and-programs/regional-water-strategies/what-we-heard/south-coast-regional-water-strategy

[2] https://www.dpie.nsw.gov.au/water/plans-and-programs/regional-water-strategies/public-exhibition/south-coast-regional-water-strategy

[3] https://water.dpie.nsw.gov.au/plans-and-programs/regional-water-strategies/public-exhibition/south-coast-regional-water-strategy

2. Background

Regulated Bega-Brogo and unregulated Bega rivers

The regulated Bega-Brogo and unregulated Bega rivers catchment is situated on the far South Coast of NSW (Figure 1). The 1,940 km^2 catchment is dominated by an escarpment which rises steeply from rounded foothills, a floodplain and an estuary. The Bega River has two major arms that meet 20 km upstream of the mouth of the river: the Bega–Bemboka arm (catchment area of 1,020 km^2) and the Brogo River arm (800 km^2), with a further 120 km^2 below the junction. The Brogo River is regulated by Brogo Dam (9,000 ML in capacity), while the Bega–Bemboka arm is mainly unregulated with flows supplemented by releases from Cochrane Dam (2,700 ML). The Bega–Bemboka arm has several large tributaries along its mid and lower reaches: Sandy Creek (catchment area of 100 km^2), Tantawangalo Creek (360 km^2) and Wolumla Creek (130 km^2), while Double Creek (160 km^2) is the major tributary to the Brogo River. The Bega–Bemboka arm has large areas of uplands (tablelands) in its upper catchment, while Brogo has only a small proportion of uplands.

The Bega River starts at the confluence of the Bemboka River (430 km^2) and the smaller Tantawangalo Creek (360 km^2). The headwaters of the Bemboka River lie on the Kybeyan Range at elevations above 1,200 mAHD. The Bega–Bemboka trunk stream is around 80 km in length, which is roughly equivalent to the length of the Brogo River. Most creeks in both arms of the catchment are short, not extending more than 35 km from source to the trunk stream confluence. The only exception is Tantawangalo Creek in the Bega–Bemboka arm which extends past the escarpment into the uplands to more than 60 km in length.

The Brogo arm is a tributary of the Bega River, which rises in Wadbilliga National Park, at elevations above 1200 mAHD. Brogo Dam is situated about two-thirds of the way up the Brogo River. The dam is operated to regulate flows dam past the confluence of the Bega and Brogo Rivers into the lower Bega River (downstream to the Jellat Jellat Creek confluence). The 120 km^2 of catchment area below the Bega and Brogo Rivers confluence is relatively flat with small streams—Jellat Jellat Creek being the largest stream.

Water resource planning and management

The water sharing plan for the Bega and Brogo Rivers Area Unregulated, Regulated, and Alluvial Water Sources covers 12 water sources (one regulated water source and 11 unregulated water sources as shown in Figure 1) and covers almost all of the water extraction within the Bega Valley. The plan contains two extraction management units: one for the regulated water source (Bega-Brogo regulated river system) and one for all other water sources.

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Figure 1. Bega River catchment

The majority of the rivers and creeks in the water sharing plan area are unregulated, having no major storages to capture and control flows for water supply. Therefore, many water users rely on natural flows or small structures, such as weirs, for their supply. As in most unregulated rivers, flows are mostly affected during relatively dry times, when water is low and demand is high. The management of lands along river and creek banks is an important issue that can affect water flow and quality. For example, cattle grazing can damage sensitive riverbank vegetation resulting in erosion. Development along the coastal fringe can alter natural waterways and increase water pollution.

Entitlement and water use

Water sharing plans set the limits on the amount of water that can be extracted from surface water and groundwater sources in the South Coast region. The annual sharing of water is managed through long-term average annual extraction limits (LTAAELs), while daily sharing is managed through cease-to-take rules,4 which can vary for different categories of licence.

There are significant extractions from rivers and groundwater in the catchment. The majority of the extractions are licensed for town water supply, power generation, pasture and crop irrigation, dairy wash down, and food processing industry (including Bega Cheese). There are also some extractions in the form of basic landholder rights for domestic and stock watering purposes, which do not require a licence or works approval.

Agriculture in the regulated Bega-Brogo and unregulated Bega rivers is primarily dairy farming, an industry which is heavily reliant on water for irrigation of pastures to ensure the supply of feed.

Local water utility requirements

Bega Valley Shire Council is the only local water utility covered by the water sharing plan. The main urban centres serviced by the council include Bega, Merimbula, Eden, Pambula, and Bermagui. There are many smaller towns and villages with a town water service, including Tathra, Pambula Beach, Tura Beach, Cobargo, Candelo, Wolumla and Bemboka. Characteristics of each are provided in subsections below.

Brogo–Bermagui water supply system

The Brogo–Bermagui water supply system supplies water to Bermagui, the villages Quaama and Cobargo, settlements around Wallaga Lake, and individual properties with a connection to the trunk main network. The main source of water for the system is the Brogo Regulated River, below the Brogo Dam. The Brogo River provides 90% of the system's water due to its greater security of supply.

Bega–Tathra water supply system

The Bega–Tathra water supply system supplies water to Bega and Tathra, Kalaru village, small settlements and individual properties with a connection to the trunk main network. The source of water for the system is the Mid Bega River Sands. Water is extracted from six bores aligned parallel to the Bega River.

[4] Water sharing plans for unregulated rivers require licence holders to stop pumping when the river flow falls below a certain volume or salinity levels in tidal pool or estuary water sources increase above certain thresholds. These rules are referred to as cease-to-take rules. Cease-to-take rules apply to surface water licences in all unregulated water sources, excluding licences held by local water utilities, licensed stock and domestic users, and licences used for food safety and essential dairy care.

Tantawangalo–Kiah water supply system

The Tantawangalo–Kiah water supply system supplies water to Merimbula, Tura Beach, Pambula, Pambula Beach and Eden, the villages Candelo, Wolumla and South Pambula, small settlements and individual properties with a connection to the trunk main network.

The northern source of water for the system is Tantawangalo Creek. Water extracted from Tantawangalo Creek fills Yellow Pinch Dam, a 3,000 ML off-stream storage. Tantawangalo Creek also supplies water direct to Candelo and Wolumla and properties with a trunk main connection upstream of Yellow Pinch Dam. Yellow Pinch Dam supplies Merimbula and Tura Beach and also areas south to Bellbird Hill, although these areas are often supplied from the southern source and storage. Extraction from Tantawangalo Creek ranges between

0 and 5 ML/d, depending on creek flow. The southern source of water for the system, the Lower Towamba River, is covered by the Towamba River Water Sharing Plan.

Bemboka water supply system

The Bemboka water supply system supplies water to Bemboka only. Water is extracted directly from the Bemboka River to a small town water service reservoir.

3. Assessment framework

Modelled options

Hydrological assessment was completed for the options from the South Coast Regional Water Strategy long list of options. The modelling has been done to further understand the impact of an option on supply risks to water users in the regulated Bega-Brogo and unregulated Bega rivers and Tuross River, as well as to feed into the economic assessment.

The options from South Coast Regional Water Strategy list of options that were modelled using Bega and Tuross Source models are provided in Table 2. Not all proposed longlist options were modelled, hence the gaps in numbering. In this report, the options modelled using the Bega Source model are discussed. Tuross options are presented in a separate report[5].

Table 2. List of modelled south coast options

Option number	Option description	Scenarios modelled	Source modelled used
1	Pipeline from Brogo Dam to Bega-Tathra town water supply system	1. Additional town water supply entitlement	Bega
12*	Eurobodalla Shoalhaven Southern Storage	12a. Extracting from flows > 20 ML/d and from low flows	Tuross
		12b. Extracting from flows > 20 ML/d only	
16	Increase on-farm water storage	16a. Dams with low flow bypass	Bega
		16b. Dams without low flow bypass	
19	Increase capacity of Brogo Dam	19a. Pipe to Tuross town water supply	Bega
		19b. Pipe to Bega town water supply	
		19c. Pipe to Tuross and pipe to Bega town water supply	
21	Brown Mountain Water Project (pumped hydro scheme)	21a. 5.3 GL extra storage, existing demand	Bega
		21b. 5.3 GL extra storage, increased demand	
		21c. 20 GL extra storage, proclaimed regulated, existing demand	
		21d. 20 GL extra storage, proclaimed regulated, increased demand	
34	Active and effective water markets	34. Activating sleeper licences	Bega

Options that passed the rapid cost-benefit analysis underwent additional hydrologic assessment. The hydrological assessment was completed using three sources of data.

[5] DPE (2022), Hydrologic analysis of options for the South Coast Regional Water Strategy -Tuross River, available for download at: https://water.dpie.nsw.gov.au/plans-and-programs/regional-water-strategies/public-exhibition/south-coast-regional-water-strategy

Climate datasets

Instrumental climate

The instrumental climate refers to the period of available instrumental meteorological recordings (1889–2020) that are used as input into the rainfall–runoff models, required to generate runoff for river system models and as direct climate input to river system model simulations. River system modelling was initially undertaken using an historical dataset, which covered a 130-year period of data representing climatic and hydrological conditions (i.e. rainfall, lake evaporation, potential evapotranspiration and streamflow) over the period 1 July 1889 to 30 June 2020. All inflows are simulated.

For options assessment, fourteen replicates of 40-year periods were sampled from this data to provide a preliminary basis to evaluate options for shortlisting for combined options. Further, it provided a faster way of testing the mechanics of the options.

Long-term climate projections (stochastic data) based on historic data

The 'long-term climate projections (stochastic data) based on historic data' refers to the 13,000 years of stochastically-generated climate data (Kiem et al., 2020) that was used to assess options and combined options, as well as to define the base case. The data was originally supplied as 100 replicates of 130-year periods, which was merged to two continuous timeseries to represent the 13,000 year model run. For options assessment, a thousand 40-year periods were sampled from this data to provide a comprehensive assessment of valley outcomes across many possible climate realisations.

This approach provided more information on climate variability and shows it's possible the region could experience more severe drought and wet sequences.

This climate data set is referred to as 'stochastic' throughout this report.

Dry climate change scenario (NARCliM modelling)

The 'dry climate change scenario (NARCliM modelling)' refers to the stochastic climate data generated by multiplying the stochastic time-series of 13,000 years with average monthly scaling factors derived from NSW and Australian Regional Climate Modelling (NARCliM) climate projections for 2060–2079 compared to the baseline period of 1990–2009 for each climate timeseries for every climate station used in the modelling. The average monthly scaling factors represent the mean of three regional climate models of CSIRO-MK3 GCM used in NARCliM 1.0. This set of stochastic data with climate projections are used in conjunction with the stochastic data to evaluate the final viability of combined options, as well as to define future base cases. For options assessment, 1,000 replicates of 40-year periods were sampled from this data to provide a comprehensive assessment of outcomes across many possible climate realisations.

This is source of data is referred to as 'NARCliM' throughout the report.

Dry climate change scenario (east coast low: ECL-1)

Options were also assessed against an alternative climate pathway to the NARCliM scaling. The stochastic climate was processed to remove one east coast low (ECL) event every year. A potential reduction in East

Coast Lows as well as intensity of rainfall associated with east coast lows are associated with concerns for water security for the South Coast region.

This is source of data is referred to as 'ECL-1' throughout the report and utilises research undertaken through the Electricity Sector Climate Information project and research undertaken by University of Newcastle. This led to the ECL-1 scenario of 13,000 years duration.

Note, there was only a change in the rainfall time series and no change to the evaporation time series.

Outputs for option assessment

The outputs for all model runs that are provided for economic assessment are shown in Table 3. In the table 'ordered' refers to the demand generated for the output type, 'supplied' refers to the ordered water that was successfully supplied, and 'shortfall' refers to the difference between supplied and ordered. These outputs were provided at a daily timestep.

Some model outputs were only available for specific model options. These have been noted as option specific in Table 3.

Table 3

Table 3 Model outputs for Economic Options Assessment

Output name	Option specific?
Town water supply (TWS) Brogo Bermagui - supplied	-
TWS Brogo Bermagui - ordered	-
TWS Brogo Bermagui - shortfall	-
High security - supplied	-
High security - ordered	-
High security -shortfall	-
Stock and domestic - supplied	-
Stock and domestic - ordered	-
Stock and domestic - shortfall	-
General security supplied	-
Supplementary supplied	-
Uncontrolled flow supplied	-
Regulated rainfall volume harvested	-
General security allocation	-
Regulated idealised requirement	-
TWS Bega Tathra - supplied	Option 1/19
TWS Bega Tathra - ordered	Option 1/19
TWS Bega Tathra - shortfall	Option 1/19
General security - supplied (Cochrane Dam)	Option 21
General security - allocation (Cochrane Dam)	Option 21
TWS Bemboka - supplied	-
TWS Bemboka - ordered	-
TWS Bemboka - shortfall	-
TWS Tantawangalo-Kiah - supplied	-
TWS Tantawangalo-Kiah - ordered	-
TWS Tantawangalo-Kiah shortfall	-
Unregulated supplied	-
Unregulated rainfall volume harvested	-
Unregulated idealised requirement	-
Farm Dams_ Extracted Volume	Option 16

4. Regulated Bega-Brogo and unregulated Bega rivers hydrological baseline model

Model description

The hydrological computer models used by the Department of Planning and Environment to underpin water management in NSW are quantitative, simulation models. Simulation models are widely used in water resources management to improve understanding of how a system works and could behave under different conditions. The department, along with other Australian water agencies, uses or is migrating to use the eWater Source software platform, which has been adopted as Australia's National Hydrological Modelling Platform.

In 2020, Department of Planning and Environment—Water built a Bega River System Model in the Source platform by retaining key components of the merged and updated Bega IQQM model but making improvement in model performance through re-calibrations of some of the model components (which were not in the recently updated IQQM model) using recent data and updating model conceptualisation where required to inform decision making. One of the key objectives of new model development is to build a high-quality, robust and fit-for-purpose model to run a range of scenarios to inform decisions related to policy, planning and strategies, including regional water strategies.

A systematic approach **Error! Reference source not found.** was used to develop the model, which included the following key steps:

1. conceptualisation
2. data collation and review for flow modelling
3. flow model calibration
4. collation and review of data for demand modelling and demand model calibration
5. implementing management rules and ordering calibration
6. full model calibration and validation.

Table 4 and Table 5 present the headwater catchments and residual reaches included in the model. The locations of the gauges used for headwater and river reach calibrations are shown in **Error! Reference source not found.**.

Table 4 Bega and Brogo headwater catchments

Gauge number	Gauge name
219001	Rutherford Brown Mountain
219005	Georges and Steeple Flat
219006	Tantawangalo Mountain
219008	Nunnock @ Brown Mountain
219017	Double Creek Near Brogo
219020	Sandy Creek @ Mogilla
219027	Brogo Dam
219034	Bega River @ Kanoona

Gauge number	Gauge name
NA	Wolumla Creek Inflow

Table 5. Bega and Brogo residual catchments

Upstream gauge	Downstream gauge	Downstream gauge name
219001, 219005, 219008	219021	Bemboka River @ Bemboka
219021	219003	Bemboka River @ Morans
219006	219022	Candelo Damsite
219003, 219020, 219022, 219034	219032	Bega River @ Kanoona
219027	219013	Brogo @ North Brogo
219013, 219017	219025	Brogo River @ Angledale
219025, 219032, Wolumla Ck Inflow	219026	Bega River Warraguburra
219026	End of system	Ocean Outlet

Table 6 presents the list of the storages and weirs included in the Bega River system model. The irrigation and urban water demands are represented through demand models distributed in different sections of the model as per their extraction locations.

Table 6. Bega and Brogo river storages and weirs from existing IQQM model

Storage / weir name	Full storage volume [ML]
Brogo Dam	9,200
Cochrane Dam	2,700
Tantawangalo town water supply weir	-

A simplified schematic diagram of the model is presented in Figure 2. The technical details of the Bega model build are documented in a series of technical reports on model development.

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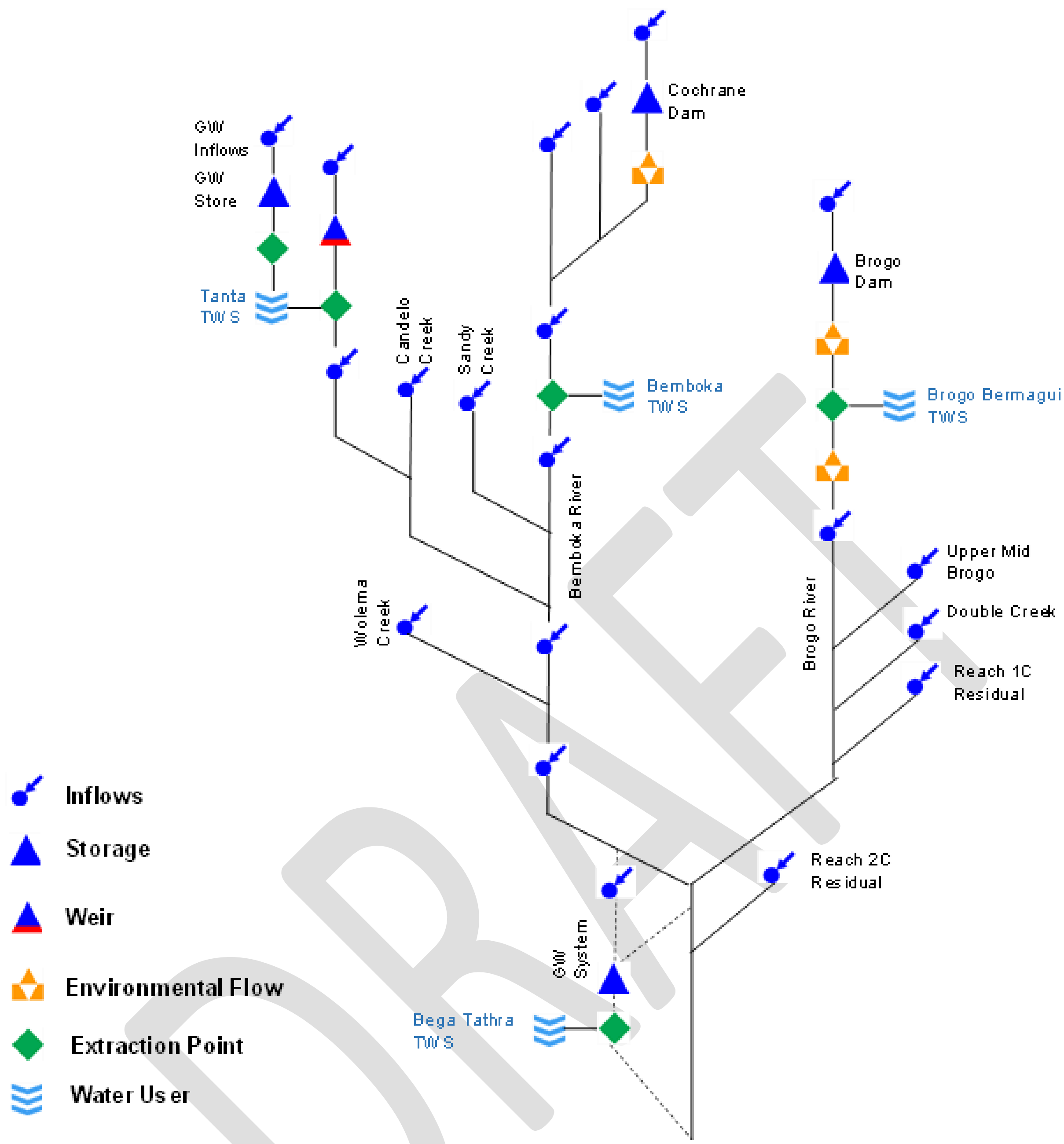

Figure 2 Simplified schematic of regulated Bega-Brogo and unregulated Bega rivers Source model

5. Option 1. Pipeline from Brogo Dam to Bega–Tathra town water supply system

Option description

With forecast rises in sea level, more extreme droughts and increased demands on surface and alluvial water resources, saltwater ingress into the Bega Sands aquifer presents a potential risk to the security of the Bega town water supply. A pipeline from Brogo Dam into the Bega–Tathra town water supply would provide an alternative supply of water should saltwater ingress risks to the current groundwater source become too great.

Option 1 was adding a pipeline from Brogo Dam to the Bega–Tathra town water supply node in the baseline model. The result of this was removing the Bega–Tathra town water supply node from the unregulated system to the regulated system. The Bega–Tathra

town water supply has the largest demands in the regulated Bega-Brogo and unregulated Bega rivers model.

Model configuration and assumptions

Model configuration

Conceptualisation of this option is displayed in Figure 3. The existing Bega-Tathra town water supply demand node was removed from the groundwater system and attached directly to Brogo Dam.

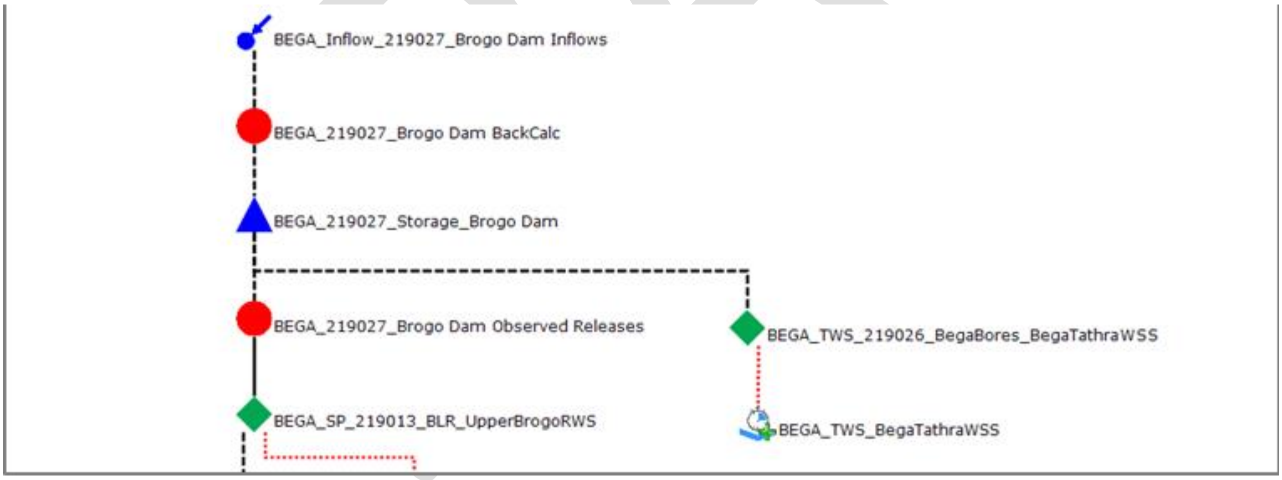

Figure 3 Option 1 modelling conceptualisation–pipeline connecting Bega-Tathra town water supply to Brogo Dam

Error! Reference source not found.Model assumptions

The following assumptions (in the absence of suitable data and information) were made to model Option 1.

- The Bega–Tathra town water supply node in the model will be 100% reliant on the regulated system. The connection was removed from the groundwater system so any supply shortfalls from the regulated system couldn't be met with groundwater.

- It was assumed that there were no transmission losses, travel time requirement or pumping limitations to supply Bega–Tathra town water supply node from Brogo Dam.
- The existing unregulated licence for Bega–Tathra was converted from 2,640 ML of unregulated entitlement to 1,120 ML of town water supply regulated entitlement:
  - as the entitlement was significantly greater than the observed and modelled usage, it was determined that it was an overestimate to convert unregulated entitlement to general security entitlement at 1:1
  - it was assumed that there was no change in usage behaviour
  - the reasoning for this was to prevent over-allocation which would reduce the available water determination for other users. From the stochastic model runs, it was determined that the 95th percentile annual usage of the town water supply node was 948 ML. To add a level of security, this was increased by a factor of 1.2 to 1,120 ML.

Modelling results

Overall, there is significantly increased security for the Bega–Tathra town water supply users, but this reduces the amount of water available for the general security users in the regulated system. The summary results are presented in Table 7.

The following key results identified in the instrumental model run were:

- there was significantly less supply shortfall for the town water supply at a calendar year aggregate (Figure 4). Nearly all the shortfalls experienced during the instrumental period were reduced to zero. This indicates an increase in security for these users.
  - 1942 was the only year where there was an increase in shortfalls (one of the worst years on record). During extreme events there may be more security in the Bega alluvial system than in Brogo Dam.
- Brogo Dam has lower modelled storage volumes (Table 7)
- a reduction in mean end of water year allocations for general security users of 4% (64% to 60%)
  - this likely leads to the modelled reduction in general security usage and the increase in uncontrolled flow usage to make up the reduction
- a significant reduction in the 5th percentile of total annual flows in the regulated system (gauge 219025: 6.5% reduction).

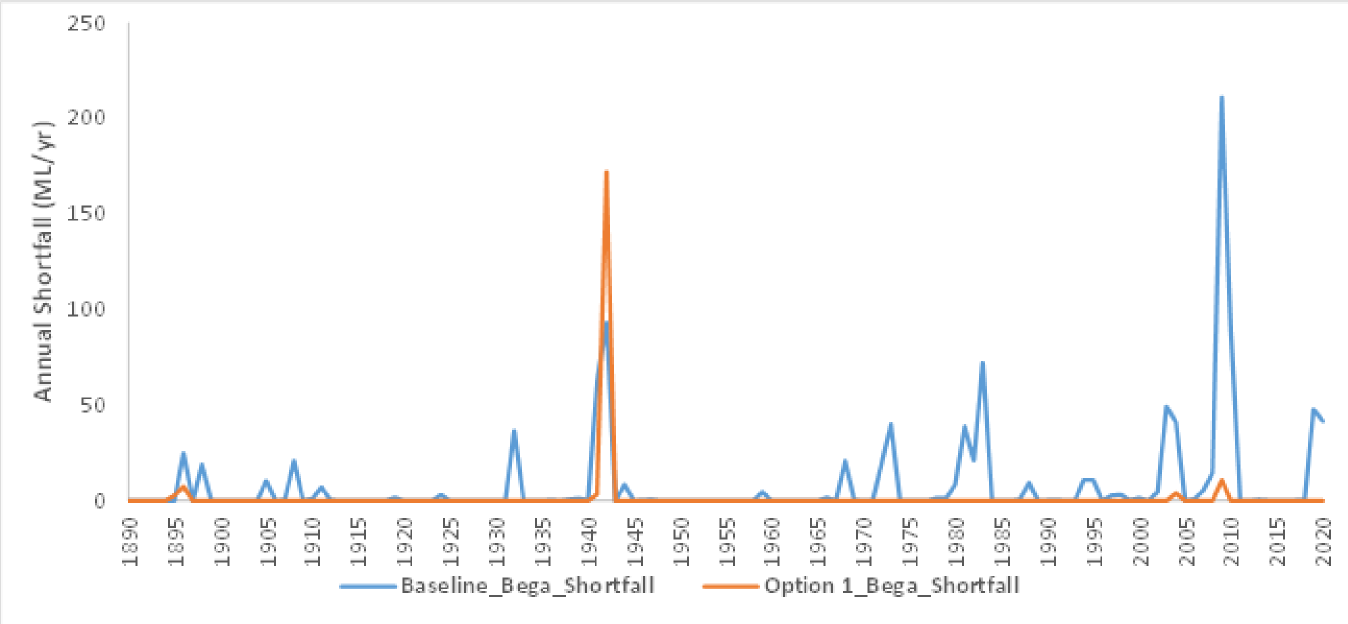

Figure 4 Option 1 results–Bega town water supply shortfall with pipeline connecting Bega-Tathra town water supply to Brogo Dam

Table 7 Option 1 results summary (1895-2020) - pipeline connecting Bega-Tathra town water supply to Brogo Dam

	Base case	Option 1
Mean annual diversion (ML/yr)		
Town water supply - Tantawangalo	1,854	1,863
Town water supply - Bega Tathra	943	945
Town water supply - Brogo Bermagui	329	328
Town water supply - Bemboka	33	33
Stock and domestic	53	53
High Security	410	406
General Security	3,509	3,428
Supplementary	11	15
Uncontrolled flow	307	345
Unregulated	5,483	5,484
Total Usage	12,933	12,900
Mean end of water year allocations (%)		
Stock and domestic	100.0%	100.0%
Town water supply	100.0%	100.0%
High security	100.0%	99.8%
General security	64.1%	59.6%
Mean agricultural production		
(1-Jan) total crop area - regulated(ha)	957	960
(1-Jan) total crop area - unregulated (ha)	1,226	1,226
Unregulated rainfall harvested (ML/yr)	5,741	5,741
Regulated rainfall harvested (ML/yr)	4,361	4,362
Storage behaviour (daily analysis)		
Brogo Dam		
At full storage level (9,000 ML)	56.8	54.4
Below 50% (4,601ML)	5.9	7.6
Below 10% (1,090 ML)	1.0	1.4
Below 5% (651 ML)	0.7	1.1
Cochrane Dam		
At full storage level (2,700 ML)	5.1	5.1
Below 50% (1,400 ML)	80.2	80.2
Streamflow (ML/yr)		
219032: Downstream flow (yearly mean)	148,856	148,856
219025: Downstream flow (yearly mean)	179,502	178,692
219032: Downstream flow (5th percentile)	14,436	14,433
219025: Downstream flow (5th percentile)	16,553	15,484

6. Option 16. Increase on-farm water storage

Option description

Lack of water storage is a major constraint to balancing water supply and demands in South Coast catchments. This is a particular problem in the Bega Valley catchments where higher volumes of entitlement have been issued for industry. On-farm water storage may assist in developing industry responses to emerging markets as they provide greater flexibility in access to water.

Information provided by Bega Cheese included the proposed locations and volumes of the on-farm storage. These on-farm storages were able to harvest from the upstream catchment area.

The modelled sub-options were:

- 16a: Increase on-farm storage with low flow bypass
- 16b: Increase on-farm storage with no low flow bypass

Only the proposed storages in the regulated Bega-Brogo and unregulated Bega rivers area were modelled.

Model configuration and assumptions

Model configuration

An example of the updated node setup for an unregulated irrigator with access to an on-farm storage is presented in Figure 5. For the shared irrigator node, it was set that the water that the irrigator could order from the on-farm storage was the lowest priority water source.

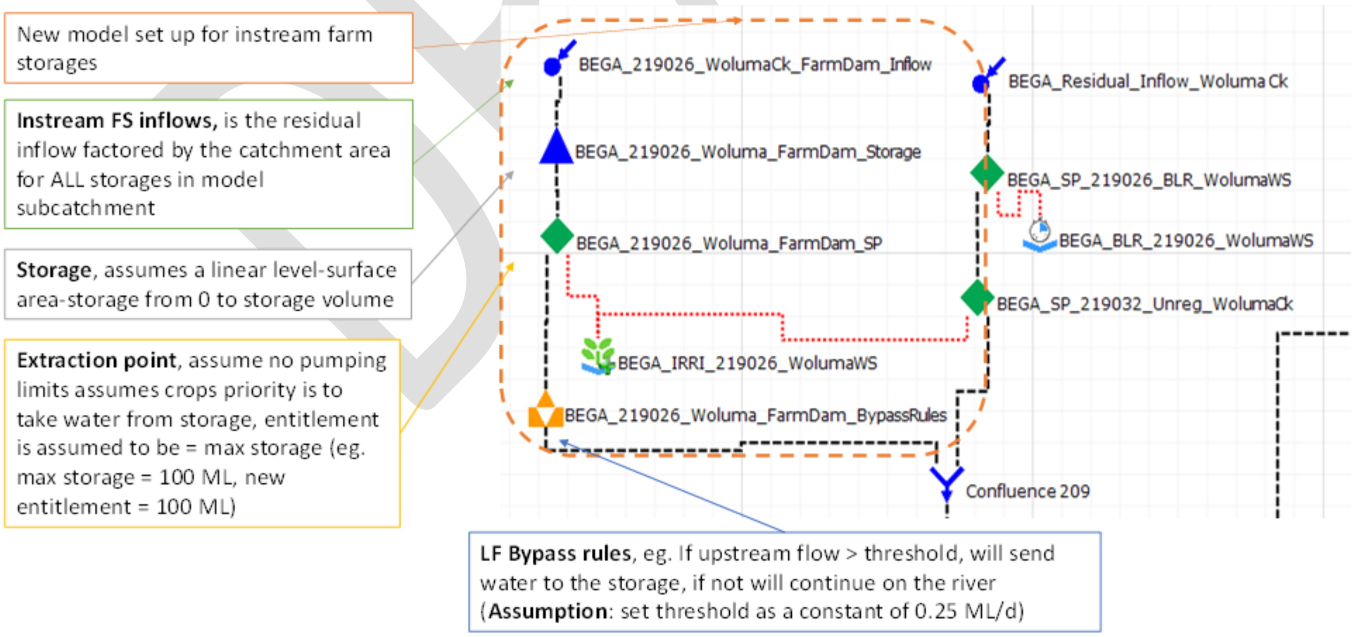

Figure 5 Option 16 conceptualisation of model change (inclusion of in-stream harvesting dams)

The aggregated on-farm storage catchment areas and storage volumes were calculated (Table 8) following GIS processing and catchment delineation. The results in the table were applied using the above conceptualisation and assumptions.

Table 8 Modelled potential on-farm storage area and volumes for Bega valley sub catchments

Model Sub-catchment	Model sub-catchment area (km²)	OFS catchment area (km²)	OFS catchment % of model sub-catchment	Total OFS storage volume for sub-catchment (ML)
219003_BegaBemboka_trib	192.8	5.3	2.8%	1,500
219022_Tantawangalo	118.0	0.3	0.2%	500
219032_BegaBemboka_trib	80.7	5.1	6.3%	900
219032_Candelo	82.5	0.9	1.1%	400
219013_unregulated	57.0	2.5	4.3%	300
219025_unregulated	113.6	1.8	1.6%	600
219026_unregulated	57.5	7.0	12.2%	1,200
219026_Woluma	131.3	6.4	4.8%	900

Model assumptions

The following assumptions were made (in absence of suitable data and information) to model Option 16.

- The upstream catchment of the on-farm storage was determined ensuring that the location of the storage was on a reasonable river order and proximal to existing users.
  - The upstream catchment was delineated from the on-farm storage location as determined above.
  - The on-farm storage volumes and upstream catchment areas were aggregated at a model sub-catchment level, reducing the number of model updates required.
    - The residual inflows in the model sub-catchment were then reduced by the amount captured in the harvesting dams.
- The storage nodes were approximated level-volume-area using a simple trapezoidal storage shape with the max volume being provided and the assumed depth of 5 m.
- No transfer limits or transmission losses associated with the on-farm storage. It was assumed that if the storage level was greater than 0.5 m, the valve capacity was maximum at 100 ML/d, if the storage level was greater than 5 m, the spillway capacity was a constant capacity of 10,000 ML/d.
- It was assumed that an irrigator would use the water available in the on-farm storage as a last resort, meaning it would take from other water sources available as a higher priority.
- It assumed that the irrigator could only extract one on-farm storage volume per water year, so an entitlement associated with ordering from the storage of its volume was created (for example, if the on-farm storage in the model was 300 ML, the irrigator could take 300 ML in one water year).
- Evaporation and rainfall was applied to the water surface of the storage. It was assumed that the station used in the reach routing was appropriate to use for the on-farm storages.

The following assumptions were made specifically to model Option 16a.

- A low flow bypass threshold of 0.25 ML/day was determined to be a general threshold that was suitable for the majority of the aggregated storages. This limit was agreed to be reasonable with the other regional water strategy team members.

Modelling results

Overall, there is significantly increased security for the unregulated irrigators, but this reduces the amount of median environmental water available. The full summary results are presented in Table 9.

The following were the key results identified in the instrumental model run:

- as there was another water source available, the unregulated irrigators were able to extract more water (mean extractions):
  - base case: 5,483 ML
  - Option 16a: 5,695 ML (3.8% increase)
  - Option 16b: 5,725 ML (4.4% increase)
- it can be seen from the 1-Jan unregulated planted areas in Figure 6 that by including an on-farm storage there is a reduction in the severity of dry years (such as 2020), where the crop area is more stable.
- the mean yearly flows are reduced in the unregulated system due to the on-farm storage harvesting
- as expected, there is more security provided by Option 16b, as more water is able to be harvested, but this reduces the downstream streamflows more than option 16a.

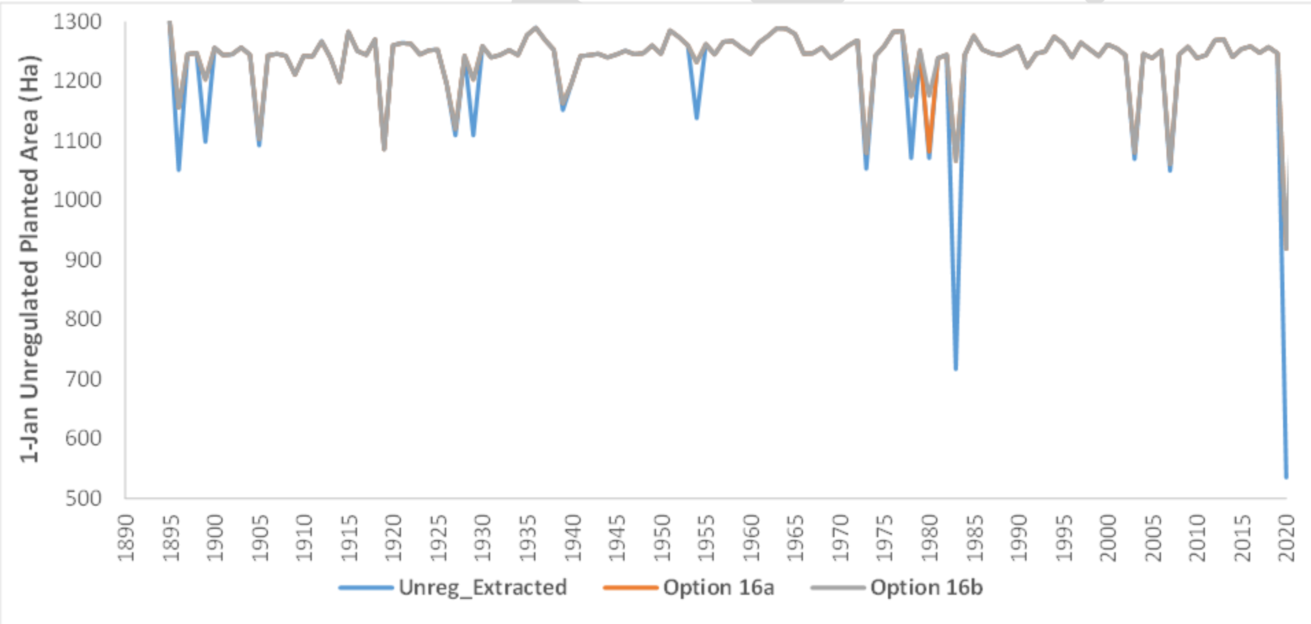

Figure 6 Option 16 results–1-Jan unregulated planted area - increased on-farm water storage

Table 9 Option 16 results summary (1895-2020) - option 16a (Increase on-farm storage with low flow bypass) and option 16b (Increase on-farm storage with no low flow bypass)

	Base case	Option 16a	Option 16b
Mean annual diversion (ML/yr)			
Town water supply (TWS) Tantawangalo	1,854	1,854	1,854
TWS Bega Tathra	943	943	943
TWS Brogo Bermagui	329	329	329
TWS Bemboka	33	33	33
Stock and domestic	53	53	53
High security	410	410	410
General security	3,509	3,547	3,547
Supplementary	11	12	12
Uncontrolled flow	307	243	242
Unregulated	5,483	5,490	5,491
Instream harvesting extracted	-	205	234
Total Usage	**12,933**	**13,120**	**13,150**
Mean end of water year allocations (%)			
Stock and domestic	100.0%	100.0%	100.0%
Town water supply	100.0%	100.0%	100.0%
High security	100.0%	100.0%	100.0%
General security	64.1%	64.4%	64.4%
Mean agricultural production			
(1-Jan) total crop area - regulated(ha)	957	961	961
(1-Jan) total crop area - unregulated (ha)	1,226	1,237	1,238
Unregulated rainfall harvested (ML/yr)	5,741	5,777	5,780
Regulated rainfall harvested (ML/yr)	4,361	4,376	4,376
Storage behaviour (daily analysis)			
Brogo Dam			
At full storage level (9,000 ML)	56.8	57.4	57.4
Below 50% (4,606ML)	5.9	5.7	5.7
Below 10% (1,090 ML)	1.0	0.9	0.9
Below 5% (651 ML)	0.7	0.7	0.7
Cochrane Dam			
At full storage level (2,700 ML)	5.1	5.1	5.1
Below 50% (1,400 ML)	80.2	80.2	80.2
Streamflow (ML/d)			
219032: downstream flow (daily mean)	148,856	148,416	148,361
219025: downstream flow (daily mean)	179,502	179,393	179,382
219032: downstream flow (5^{th} percentile)	14,436	14,416	14,377
219025: downstream flow (5^{th} percentile)	16,553	16,586	16,561

7. Option 19. Increase capacity of Brogo Dam

Option description

In most years, start of season and end of season water allocations from Brogo Dam are relatively low, which restricts the level of investment in regional industry. The low level of allocations is due in part to the high level of regulated entitlements (15,000 ML) relative to the dam capacity (8,920 ML).

Increasing the capacity of Brogo Dam would be one way of addressing the high proportion of entitlement to dam volume.

This option would improve water reliability and start of year allocations for general security water access licence holders, which could give irrigators improved confidence in investing in their farming practices. This could directly impact on production and promote growth and diversification in the region's agricultural sector.

The sub-options included attaching town water supply systems to Brogo Dam to increase their security. The increase in volume is estimated to be 8,640 ML, which is based on raising the Brogo Dam wall 6.5m, from the Brogo Dam Augmentation Preliminary Study (State Water 2004).

The modelled sub-options were:

- 19a. Brogo Dam augmentation with pipeline to supply Tuross town water supply shortfall
- 19b. Brogo Dam augmentation with pipeline to supply Bega–Tathra town water supply
- 19c. Brogo Dam augmentation with pipeline to supply Tuross town water supply shortfall and Bega–Tathra town water supply.

Model configuration and assumptions

Model configuration

Conceptualisation of Option 19 is displayed in Figure 7. For Bega–Tathra town water supply, the existing demand node was disconnected from the groundwater system and attached directly to Brogo Dam. For the Tuross town water supply, the shortfall was imported into the model as a time-series demand.

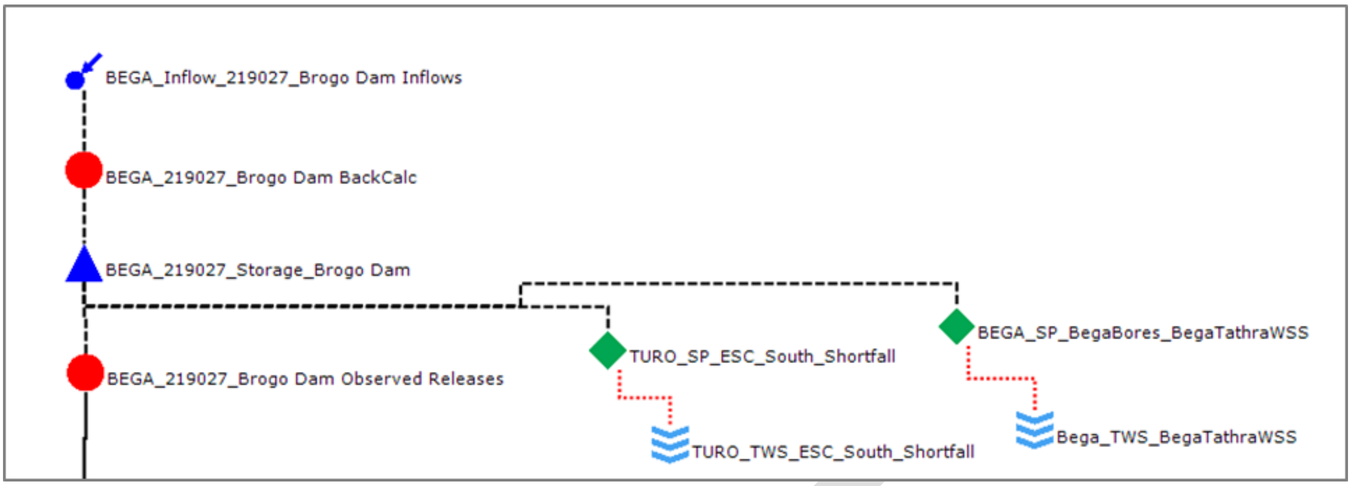

Figure 7 Bega Option 19 conceptualisation (inclusion of town water supply pipelines)

For the augmentation of Brogo Dam:

- the same level-volume-area curve and valve curve was assumed and the spillway rating was updated to reach the new dam wall height (+ 6.5 m)
- the full supply volume of Brogo Dam was updated to 17,640 ML.

The evaporation commitment in the water resource allocation process was updated to account for the increase in likely evaporation losses from 1,100 ML to 1,650 ML—1.5 times larger due to the 1.5 times larger average water surface.

Model assumptions

The following assumptions were made in the absence of suitable data and information, to model Option 19.

- Due to the large upstream catchment of the storage, the storage inflows were assumed to not change even though there was an increase in size of water surface of the catchment.
- It was assumed that the existing level-volume-area curve was valid for the dam wall raising in absence of more accurate planning information.
- It was assumed that the existing spillway curve and valve curve are valid.
- It was assumed that the existing operational rules for Brogo dam will remain the same (transparency releases when flows above the new 50% dam level).
- Evaporation commitments were increased for Brogo Dam water resources assessment

The following assumptions were made specifically to model Option 19a.

- The shortfall for the Tuross town water supply currently within the Tuross Source model was extracted as a time series. This was then set as a time-series demand in the model. It was assumed there was no increase in demand.
- It is assumed that there were no transmission losses from the Bega System to the Tuross System and travel time was less than a day.
- The new town water supply entitlement was set to be the maximum yearly Tuross town water supply shortfall factored to 250 ML.
- Option 19b was modelled with the same assumptions as were made for Option 1 (Section 5).

No additional assumptions were required to model sub-option 19c, as Option 19a and 19b were independent.

Modelling results

Overall, there is significantly increased security for the Tuross town water supply and Bega–Tathra town water supply users. With the increase in Brogo Dam volume, there is an increase in usage in the regulated system with a significant increase in the available water determination. The full summary results are presented in

Table 10.

The following key results identified in the instrumental model run were:

- a complete reduction in the shortfall in the attached town water supply systems (Figure 8)
- a significant increase in the end of water year allocation (Figure 9)
- an increase in mean annual general security usage of approximately 5% (for Option 19c)
- more security for the Bega–Tathra town water supply user than Option 1
- a reduction in the annual flows in the regulated system, likely due to the reduction in spills from Brogo Dam.

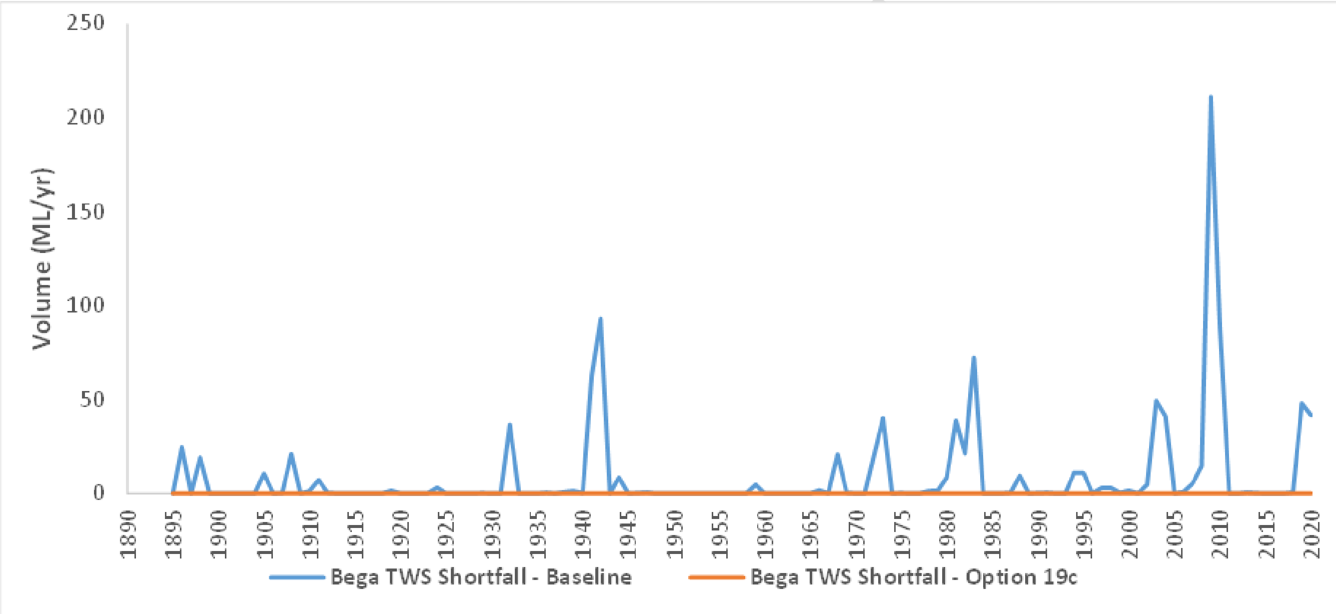

Figure 8 Option 19c results–Bega town water supply shortfall with modelled Brogo Dam augmentation with pipeline to supply Tuross town water supply shortfall and Bega–Tathra town water supply

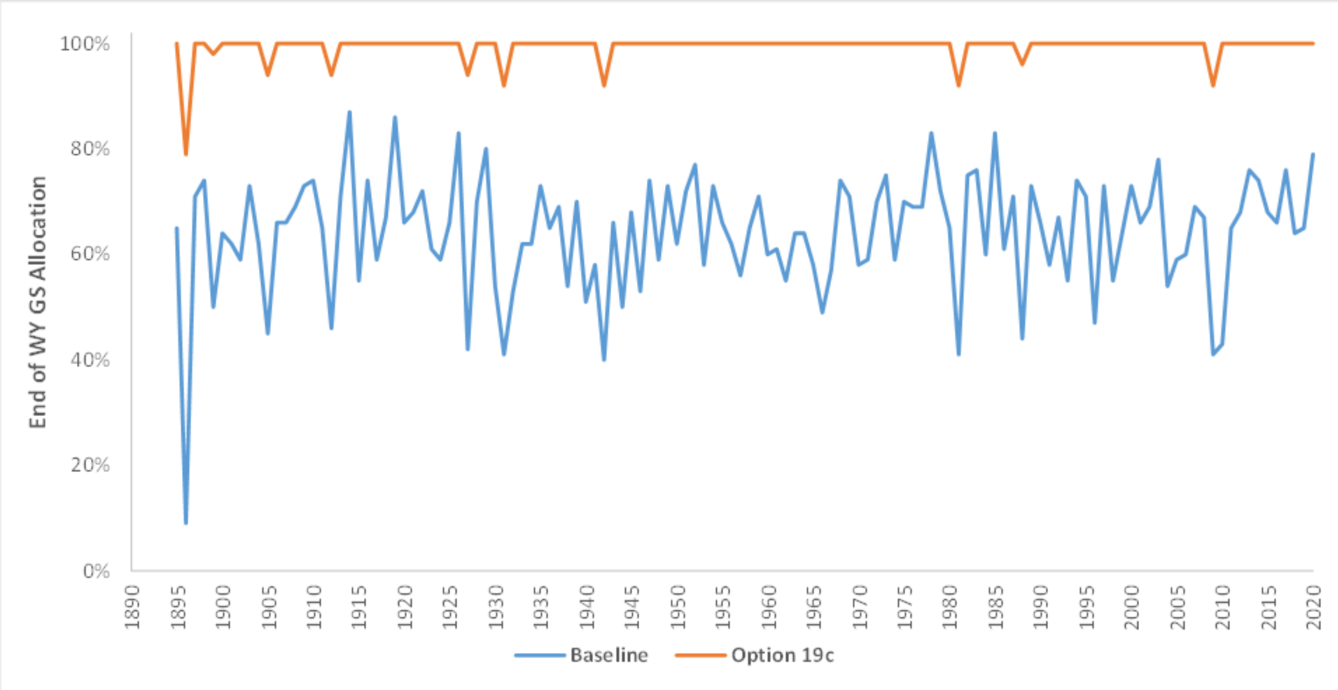

Figure 9 Option 19c results–general security available water determination with modelled Brogo Dam augmentation with pipeline to supply Tuross town water supply shortfall and Bega–Tathra town water supply

Table 10 Option 19 results summary (1895-2020) - Brogo Dam augmentation with pipeline to supply Tuross town water supply shortfall (19a), 19b. Brogo Dam augmentation with pipeline to supply Bega–Tathra town water supply (19b), and combination of option 19a and 19b (19c)

	Base case	Option 19a	Option 19b	Option 19c
Mean Annual Diversion (ML/yr)				
Town water supply (TWS) Tantawangalo	1,854	1,854	1,863	1,863
TWS Bega Tathra	943	943	952	952
TWS Brogo Bermagui	329	330	330	330
TWS Bemboka	33	33	33	33
TWS Tuross demand		11		11
Stock and domestic	53	53	53	53
High security	410	411	411	411
General security	3,509	3,749	3,693	3,688
Supplementary	11	13	11	11
Uncontrolled flow	307	87	169	175
Unregulated	5,483	5,482	5,484	5,484
Total usage	12,933	12,967	13,000	13,013
Mean end of water year allocations (%)				
Stock and domestic	100.0%	100.0%	100.0%	100.0%
Town water supply	100.0%	100.0%	100.0%	100.0%
High security	100.0%	100.0%	100.0%	100.0%
General security	64.1%	99.8%	99.4%	99.2%
Mean agricultural production				
(1-Jan) total crop area - regulated (ha)	957	955	953	953
(1-Jan) total crop area - unregulated (ha)	1,226	1,226	1,226	1,226
Unregulated rainfall harvested (ML/yr)	5,741	5,741	5,741	5,741
Regulated rainfall harvested (ML/yr)	4,361	4,354	4,341	4,340
Storage behaviour (daily analysis)				
Brogo Dam				
At full storage level	56.8	60.6	57.6	57.6
Below 50%	5.9	0.4	0.8	0.9
Below 10%	1.0	#N/A	#N/A	#N/A
Below 5%	0.7	#N/A	#N/A	#N/A
Cochrane Dam				
At full storage level (2,700 ML)	5.1	5.1	5.1	5.1
Below 50% (1,400 ML)	80.2	80.2	80.2	80.2
Streamflow (ML/yr)				
219032: downstream flow (yearly mean)	148,856	148,856	148,856	148,856
219025: downstream flow (yearly mean)	179,502	179,576	178,756	178,746
219032: downstream flow (5^{th} percentile)	14,436	14,433	14,433	14,433
219025: downstream flow (5^{th} percentile)	16,553	16,787	15,934	15,934

7. Option 21. Brown Mountain Water Project—pumped hydro scheme

Option description

Option 21 was attempting to implement the Brown Mountain Water Project - pumped hydro scheme. This would increase the available storage of Cochrane Dam and/or add a separate upstream dam. The modelling of this option did not explore the operation of a pumped hydro scheme as implementing the rules was too complicated. Instead, it was simplified to increasing the size of the existing storage, essentially modelling what the impact is of having more storage available to make releases.

The modelled sub-options were:

- 21a. Cochrane Dam 5.3 GL extra storage
- 21b. Cochrane Dam 5.3 GL extra storage with increased demand
- 21c. Cochrane Dam 20 GL extra storage (regulated releases for downstream users)
- 21d. Cochrane Dam 20 GL extra storage with increased demand (regulated releases for downstream users).

Model configuration and assumptions

Model configuration

Using the information provided from consultants (GHD) for potential storage options (email correspondence), the level-volume-area curve was updated to the following for the modelled options.

As the size of the upstream catchment to Cochrane Dam is small compared to the dam, the runoff of the catchment will change depending on the surface area of the dam. The reductions in runoff area are:

- Option 21a and b: 2.2% reduction in storage inflows
- Option 21c and d: 5.2% reduction in storage inflows.

Increase in Cochrane Dam volume to:

- Option 21a and b: 8,000 ML
- Option 21a and b: 22,700 ML.

To include an environmental target for the new system, the following minimum flow node was included with the following environmental rules (this rule was confirmed with the regional water strategy team):

- 20 ML/d at gauge 219003 from June – November (the main irrigation season)
- 5 ML/d at gauge 219003 for the rest of the year.

For option 21b and 21d, the updated irrigator nodes are presented in Table 11.

Table 11 Increased irrigation areas for 5.3 GL extra storage with increased demand (21b), and 20 GL extra storage with increased demand (21d)

Node name	Base case maximum area (ha)	Option 21b and 21d fixed area (ha)
Bega irrigation (219021) upper Bemboka	37.4	41.1
Bega irrigation (219003) upper Bemboka	360.4	396.3
Bega irrigation (219032) upper Bega Bemboka	338.4	372.2
Bega irrigation (219026) upper Bega Bemboka	19.0	20.9

A new node had to be created for option 21 c and d (Figure 10). In this case, the unregulated supply point node was deactivated. a new annual accounting system was created to account for the orders on the Cochrane Dam.

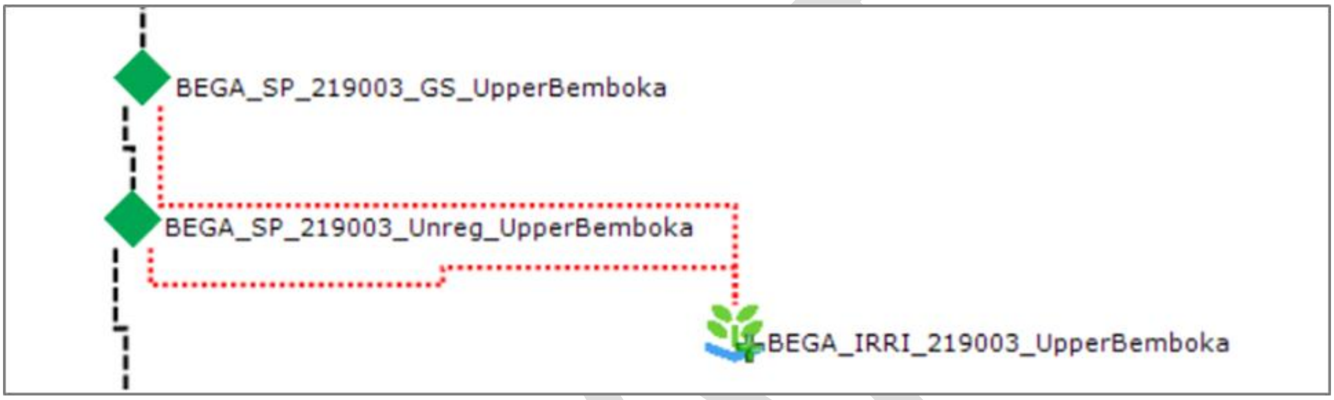

Figure 10 Bega Option 21 c (20 GL extra storage) and 21 d (20 GL extra storage with increased demand) conceptualisation–example of the new regulated supply nodes

Model assumptions

The following assumptions were made in the absence of suitable data and information specifically to model Option 21a:

- conceptualised the pumped hydro system as increasing the storage volume of Cochrane dam. This assumes that the system is operated perfectly, there are no losses and that the downstream conditions will be prioritised. Modelling the hydropower operation was outside the scope of this study.
- an environmental release rule will need to be used to overwrite the current power generation rules in the model
- there were no changes to the spillway and valve curves.

To model Option 21b, the assumptions made for Option 21a were used and specifically:

- increased the maximum planted area of irrigators in the unregulated system downstream of Cochrane Dam by 10% and removed the planted area function to fix the planted area. This was to better represent the increase in usage, where the current unregulated entitlement limits on the planting area functions are unlikely to represent this change in behaviour.

To model Option 21c, the assumptions made for Option 21a were used and specifically:

- the irrigators in the unregulated system downstream of Cochrane Dam will be able to place orders to Cochrane Dam. This will require setting up a regulated system.

- the irrigators will only be able to order from the dam, converting all of their unregulated licenses into general security licenses.

To model Option 21d, the assumptions made for Option 21a and 21c were used and specifically:

- increased the maximum planted area of irrigators in the unregulated system downstream of Cochrane Dam by 10% and removed the planted area function to fix the planted area.

Modelling results

Overall, there is significantly increased security for the Bega unregulated irrigators. The full summary results are presented in Table 12.

The following key results identified in the instrumental model run were:

- increased usage in the unregulated system (Table 12). The increase in crop areas leads to an increase in unregulated usage of approximately 10% for option 21d.
- For Option 21a and Option 21b, the new release rules lead to the storage maintaining more volume. By making releases for the irrigators in Option 21c and 21d this shows that the storage volume is less than 50% full, more often.

Table 12 Option 21 results summary (1895-2020) - 5.3 GL extra storage (21a), plus 5.3 GL extra storage with increased demand (21b),
20 GL extra storage with regulated releases for downstream users (21c), plus increased demand (21d).

	Base case	Option 21a	Option 21b	Option 21c	Option 21d
Mean annual diversion (ML/yr)					
TWS Tantawangalo	1,854	1,854	1,854	1,854	1,854
TWS Bega Tathra	943	944	944	945	945
TWS Brogo Bermagui	329	329	329	329	329
TWS Bemboka	33	33	33	33	33
Stock and domestic	53	53	53	53	53
High security	410	410	410	410	410
General security – Brogo Dam	3,509	3,512	3,512	3,501	3,501
Supplementary	11	11	11	11	11
Uncontrolled flow	307	303	301	332	331
Unregulated	5,483	5,517	5,858	2,422	2,422
General security- Cochrane Dam	-	-	-	3,207	3,598
Total Usage	**12,933**	**12,966**	**13,306**	**13,097**	**13,487**
Mean end of water year allocations (%)					
Stock and domestic	100.0%	100%	100.0%	100.0%	100.0%
Town water supply	100.0%	100%	100.0%	100.0%	100.0%
High security	100.0%	100%	100.0%	100.0%	100.0%
General security – Brogo Dam	64.1%	64.1%	64.1%	64.0%	64.0%
General security - Cochrane Dam	-	-	-	90.9%	89.0%
Agricultural production					
(1-Jan) total crop area – regulated (ha)	957	957	958	956	956
(1-Jan) total crop area - unregulated (ha)	1,226	1,232	1314	1,228	1,318
Unregulated rainfall harvested (ML/yr)	5,741	5,757	6,149	5,745	6,172
Regulated rainfall harvested (ML/yr)	4,361	4,362	4,363	4,353	4,353
Storage behaviour (daily analysis)					
Brogo Dam					
At full storage level (9,000 ML)	56.8	56.8	56.8	56.8	56.8
Below 50% (4,601ML)	5.9	5.9	5.9	1.1	1.1
Below 10% (1,090 ML)	1.0	1.0	1.0	0.5	0.5
Below 5% (651 ML)	0.7	0.7	0.8	0.5	0.5
Cochrane Dam					
At full storage level	5.1	50.4	50.4	27.9	26.4
Below 50%	80.2	7.9	7.9	20.2	25.4
Streamflow (ML/yr)					
219032: downstream flow (yearly mean)	148,856	148,248	147,986	147,052	146,731
219025: downstream flow (yearly mean)	179,502	179,501	179,502	179,501	179,501
219032: downstream flow (5th percentile)	14,436	14,433	15,448	17,779	16,345
219025: downstream flow (5th percentile)	16,553	16,787	16,554	16,550	16,549

8. Option 34. Active and effective water markets

Option description

In Bega, there are a significant number of licenses in the system which are not used (sleeper licenses). Even though these sleeper licenses are not used, there are impacts to other users in the valley. The water for those sleeper licenses is accounted for in the general security available water determination.

Option 34 aims to increase the license utilisation within Bega by activating the sleeper licenses. This required creating new irrigator nodes and areas in the model so that the demand was generated for these activated licenses.

Model configuration and assumptions

Model configuration

Conceptualisation of an example of this option for one sleeper license being utilised is displayed in Figure 11. The existing demand node was copied and attached directly below the existing irrigator for each model reach.

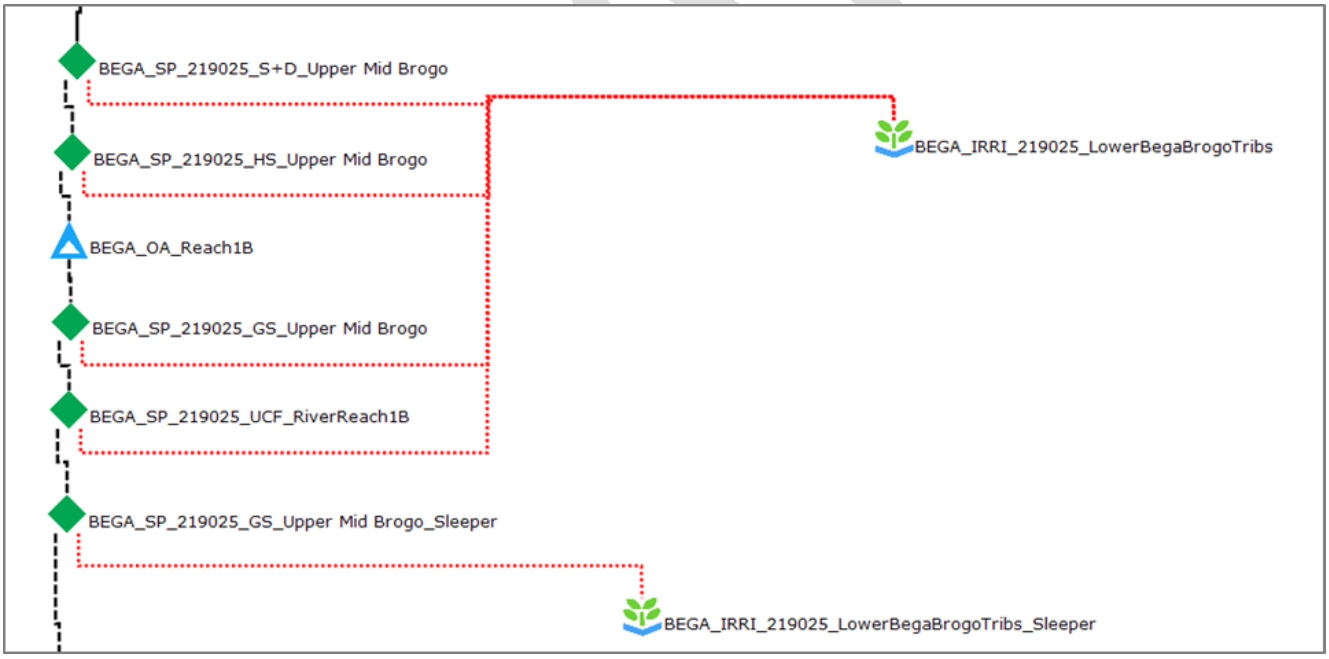

Figure 11 Bega Option 34 conceptualisation–example of including sleeper licences

The updates to the model for the sleeper licenses are presented in Table 13. In the original model, the user had access to all licences—whether now determined to be active or not, and a planting decision function factor was used to get the model closer to what it was originally when the sleeper license was removed from the active user.

Table 13 Option 34 model setup to utilise sleeper licences

Model sub-catchment	Entitlement active (ML)	Entitlement–utilised sleeper (ML)	Planting decision factor	Sleeper max planting area (ha)[1]
219013 - Reach 1A (Brogo Dam to North Brogo Gauge)	670	81	0.92	7.8
219025 - Reach 1B (North Brogo Gauge to Angledale Gauge)	1,600	833	1.00	53.7
219026 - Reach 1C (Angledale Gauge to Bega River Junction)	5,064	656	0.90	92.7
219026 - Reach 2 (Brogo River Junction to Jellat Jellat Gully)	2,832	186	0.95	32.1
Tidal Reach 2	1,741	115	0.95	13.2

[1]The maximum planted areas were taken as a function of the non-sleeper users in the modelled reach. The same planting decision function structure was used for the sleeper licenses—refer to past reports about this planting decision function for more information.

Model assumptions

The following assumptions were made in the absence of suitable data and information to model Option 34:

- the planting decisions and area per entitlement for the activated users was the same as the existing crop models per model sub-catchment
- the activation rate is assumed to be the results presented in Table 14
  - It is noted in Table 14 that the entitlements are not equal to what was in the water resource allocation spreadsheet for current entitlement in the catchment. It notes what licenses have recorded usages (including if it is 0 ML usage). Only general security licenses were investigated. The license was assumed to be a sleeper license if there were no orders and usages in the 10-year water sharing plan record.
- no new losses or change in catchment runoff would occur
- the new sleeper license users would be located after the currently active license holders in the system
- there would be no limits on pumping capacity for the new users.

Table 14 Option 34 sleeper license results–general security

Regulated river reach	Active	Sleeper	% Utilisation
1A—Brogo Dam to North Brogo gauge	585	71	12
1B—North Brogo Gauge to Angledale gauge	1,582	824	52
1C—Angledale gauge to Bega River junction	4,612	597	13
2—Brogo River junction to Jellat Jellat Gully	4,418	291	7

Modelling results

Overall, there is increased usage in general security users overall. There is more usage from Brogo Dam. The full summary results are presented in

Table 15.

The following key results identified in the instrumental model run were:

- increased mean annual general security usage of 9%
  - It is noted in one of the driest years on record (1942), there is a decrease in usage. This is likely due to the dam failing earlier due to increased demand on the system—for that year approximately 20% less general security water is used.
- increased mean 1-Jan regulated planting area of 9.6%
- more stress on Brogo Dam and a reduction in flows in the regulated system (219025: 5th percentile)

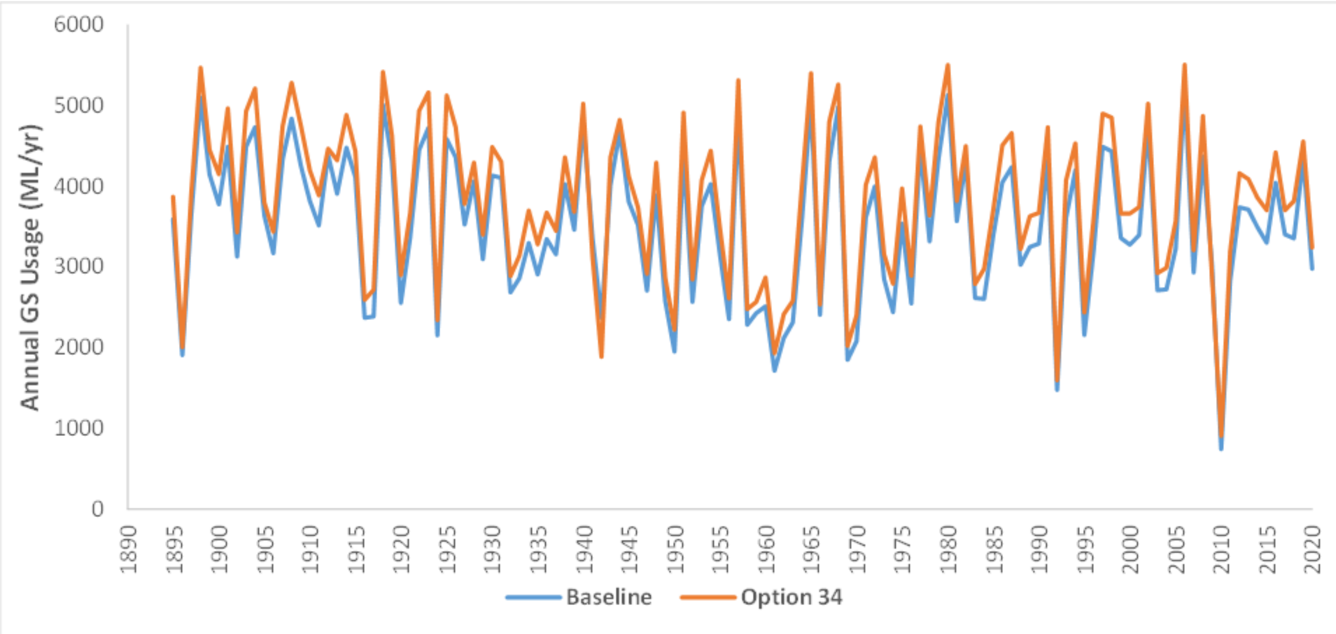

Figure 12 Option 34 results–general security usage

Table 15 Option 34 results summary (1895-2020)

	Base case	Option 34
Mean annual diversion (ML/yr)		
Town water supply (TWS) Tantawangalo	1,854	1,854
TWS Bega Tathra	943	943
TWS Brogo Bermagui	329	329
TWS Bemboka	33	33
Stock and domestic	53	53
High security	410	410
General security	3,509	3,820
Supplementary	11	14
Uncontrolled flow	307	326
Unregulated	5,483	5,482
Total usage	12,933	13,265
Mean end of water year allocations (%)		
Stock and domestic	100.0%	100.0%
Town water supply	100.0%	100.0%
High security	100.0%	100.0%
General security	64.1%	65.9%
Mean agricultural production		
(1-Jan) total crop area – regulated (ha)	957	1,049
(1-Jan) total crop area - unregulated (ha)	1,226	1,226
Unregulated rainfall harvested (ML/yr)	5,741	5,741
Regulated rainfall harvested (ML/yr)	4,361	4,778
Storage behaviour (daily analysis)		
Brogo Dam		
At full storage level (9,000 ML)	56.8	56.2
Below 50% (4,601ML)	5.9	6.1
Below 10% (1,090 ML)	1.0	1.1
Below 5% (651 ML)	0.7	0.8
Cochrane Dam		
At full storage level (2,700 ML)	5.1	5.1
Below 50% (1,400 ML)	80.2	80.2
Streamflow (ML/yr)		
219032: downstream flow (yearly mean)	148,856	148,856
219025: downstream flow (yearly mean)	179,502	179,317
219032: downstream flow (5th percentile)	14,436	14,433
219025: downstream flow (5th percentile)	16,553	16,301

9. Combined option assessment with instrumental, stochastic, NARCliM and east coast low climate data

Combined option descriptions

The combined options considered preferred for stochastic and climate change modelling assessment are presented in Table 16, all of which are located in the Bega Valley. In total five combined options have been evaluated. Of those five combined options, only the three most likely were assessed using the stochastic climate data sets, which included the climate change model runs.

Based on work completed by the economics team, the population projections for the region were expected to decrease in the future. No change was made to the model to allow for population growth.

Table 16 South Coast Regional Water Strategy combined options

Combined option	Options that were combined	Model Run Types
1	• Option 16a. Increase on-farm water storage: with low flow bypass • Option 34. Active and effective water markets	Instrumental and Stochastic, Climate Change and ECL-1
2	• Option 16a. Increase on-farm water storage: with low flow bypass • Option 21 a. Brown Mountain Water Project (pumped hydro scheme): 5.3 GL extra storage, existing demand • Option 34. Active and effective water markets	Instrumental and Stochastic, Climate Change and ECL-1
3	• Option 16a. Increase on-farm water storage: with low flow bypass • Option 21d. Brown Mountain Water Project (pumped hydro scheme): 20 GL extra storage, proclaimed regulated, increased demand • Option 34. Active and effective water markets	Instrumental and Stochastic, Climate Change and ECL-1
4	• Option 16a. Increase on-farm water storage: with low flow bypass • Option 21a. Brown Mountain Water Project (pumped hydro scheme): 5.3 GL extra storage, existing demand	Instrumental[1]
5	• Option 16a. Increase on-farm water storage: with low flow bypass • Option 21d. Brown Mountain Water Project (pumped hydro scheme): 20 GL extra storage, proclaimed regulated, increased demand	Instrumental[1]

[1] Availability of resources constrained the ability to model the climate change and ECL-1 scenarios for combined actions 4 and 5. However option 16a and option 21a were modelled with these scenarios in combined action 2, similarly with option 16a and option 21d were modelled with these scenarios in combined action 3.

Modelling results - combined option

The baseline model and the combined option models were simulated using four sets of multiple replicates of climate data of 40-year duration for economic analysis:

- 14 replicates for instrumental climate
- 1,000 replicates for stochastic climate
- 1,000 replicates for stochastic climate with NARCliM climate projection

- 1,000 replicates for stochastic climate with east coast low climate projection.

A summary of the key combined option results for the instrumental period is presented in Table 17. A summary of the results for the stochastic, and the NARCliM and east coast low climate change scenarios are presented in

Table 18. The values represent the average ML/year. These results focused present the key results for the usage in the unregulated and the regulated system. Overall, all combined options lead to an increase in water availability to users with combined option 3 causes the largest increase in usage in the Bega valley, increasing the average usage by approximately 8%. Typically, the combined options increased the average water availability to irrigators.

Table 17 Regional water strategy combined option results–instrumental, mean total yearly usage (1895-2020)

Mean annual water usage (ML) – water year						
Modelled output	Base case	Combined option 1	Combined option 2	Combined option 3	Combined option 4	Combined option 5
Town water supply (TWS) -Tantawangalo	1,854	1,854	1,854	1,854	1,854	1,854
TWS Bega Tathra	943	943	944	945	944	945
TWS_Brogo Bermagui	329	329	329	329	329	329
TWS Bemboka	33	33	33	33	33	33
Stock and domestic	53	53	53	53	53	53
High security	410	410	410	410	410	410
General security (Brogo Dam)	3,509	3,868	3,868	3,887	3,506	3,513
Supplementary	11	16	16	16	9	9
Uncontrolled flow	307	234	234	242	248	257
Unregulated	5,483	5,491	5,518	2,422	5,518	2,422
General security (Cochrane Dam)	-	-	-	3,370	-	3,370
Instream harvesting	-	204	205	372	205	373
Unregulated rainfall harvested	5,741	5,777	4,792	4,777	4,348	4,338
Regulated rainfall harvested	4,361	4,792	5,783	6,187	5,783	6,187
Total supplied	23,034	24,005	24,039	24,897	23,242	24,094

Table 18 Regional water strategy combined option results - mean total yearly usage (13,000 years), Stochastic, NARCliM and east coast low

Mean annual water usage (ML) – water year			
Modelled output	Combined option 1	Combined option 2	Combined option 3
Stochastic data sets			

Mean annual water usage (ML) – water year			
Modelled output	Combined option 1	Combined option 2	Combined option 3
Town water supply (TWS) Tantawangalo	1,847	1,847	1,848
TWS Bega Tathra	939	940	941
TWS Brogo Bermagui	327	327	327
TWS Bemboka	33	33	33
Stock and domestic	53	53	53
High security	407	407	407
General security (Brogo Dam)	3,775	3,777	3,789
Supplementary	17	17	17
Uncontrolled flow	250	250	257
Unregulated	5,447	5,463	2,405
General security (Cochrane Dam)			3,297
Instream harvesting	182	181	356
Unregulated rainfall harvested	5,868	5,868	6,281
Regulated rainfall harvested	4,887	4,887	4,877
Total supplied	**24,032**	**24,052**	**24,889**
NARCliM data set			
TWS Tantawangalo	1,855	1,856	1,858
TWS Bega Tathra	944	945	948
TWS Brogo Bermagui	326	326	326
TWS Bemboka	33	33	33
Stock and domestic	52	52	52
High security	397	397	397
General security (Brogo Dam)	3,843	3,840	3,855
Supplementary	21	21	20
Uncontrolled flow	298	295	303
Unregulated	5,731	5,750	2,477
General security (Cochrane Dam)			3,503
Instream harvesting	203	204	368
Unregulated rainfall harvested	5,755	5,756	6,164
Regulated rainfall harvested	4,779	4,783	4,769
Total supplied	**24,237**	**24,258**	**25,074**
East coast low data set			
TWS Tantawangalo	1,830	1,831	1,832
TWS Bega Tathra	930	931	933

Mean annual water usage (ML) – water year			
Modelled output	Combined option 1	Combined option 2	Combined option 3
TWS Brogo Bermagui	322	322	322
TWS Bemboka	33	33	33
Stock and domestic	53	53	53
High security	396	396	396
General security (Brogo Dam)	3,615	3,616	3,630
Supplementary	18	18	18
Uncontrolled flow	257	257	265
Unregulated	5,312	5,333	2,288
General security (Cochrane Dam)			3,226
Instream harvesting	171	170	316
Unregulated rainfall harvested	5,726	5,727	6,129
Regulated rainfall harvested	4,808	4,808	4,796
Total supplied	**23,471**	**23,494**	**24,236**

Outputs for economic analysis for preferred combined options

The outputs for economic assessment of combined options are supplied as 1,000 replicates of 40-year daily replicates with the same initial storage conditions. These are:

- Cochrane Dam: 779 ML
- Brogo Dam: 9,052 ML.

These values are based on storage volumes on 01/01/2020. The outputs are shown in

Table 18. The climate scenarios supplied are the stochastic, NARCliM-scaled stochastic and ECL-1 scenarios.

Outputs for ecological analysis of preferred combined options

The baseline model and the combined options models were simulated using three sets of two sequences of climate data for ecological analysis:

- 13,000-year stochastic climate
- 13,000-year stochastic climate with NARCliM climate projection
- 13,000-year stochastic climate with one less east coast low event per year (ECL-1).

The ecological outputs for combined options are supplied as two daily time series combined equalling 13,000-year outputting modelled flow at the following gauges:

- 219001; 219003; 219005; 219006; 219008; 219013; 219017; 219020; 219021; 219022; 219025; 219026; 219027; 219032; 219034.

The climate scenarios supplied are the stochastic, NARCliM-scaled stochastic and east coast low scenarios.

10. References

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