Department of Planning and Environment

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Regional Water Strategies Program

Hydrologic analysis of options for the Far North Coast Regional Water Strategy – Tweed Valley

January 2023

Acknowledgement of Country

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

Today, they practice the oldest living culture on earth.

The NSW Government acknowledges the **First Nations people/Traditional Owners** from the Far North Coast Region 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 **First Nations people** with essential links to their history and help them to maintain and practice their **Traditional** culture and lifestyle.

We recognise the **Traditional Owners** were the first managers of Country and by incorporating their culture and knowledge into management of water in the region is a significant step for closing the gap.

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

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

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

We acknowledge that further work is required under this regional water strategy to inform how we care for Country and ensure **Traditional Owners/First Nations people** hold a strong voice in shaping the future for **Indigenous/Aboriginal** and non-Aboriginal communities.

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Title: Hydrologic analysis of options for the Far North Coast Regional Water Strategy – Tweed River valley

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1. Introduction

What are regional water strategies?

Across NSW, valuable and essential water resources are under pressure. A more variable climate, as well as changing industries and populations, mean we face difficult decisions and choices about how to balance the different demands for this vital resource and manage water efficiently and sustainably into the future.

The Far North Coast Regional Water Strategy is one of a suite of catchment-based strategies across the state. The strategies identify critical challenges that we need to tackle over the coming decades and outline the priorities and actions that we will undertake to respond to those challenges. The best and latest climate evidence, along with a wide range of tools and solutions, has been used to chart a progressive implementation of actions for the region's water needs over the next 20 years and beyond.

Purpose of this options modelling report

The Far North Coast regional water strategy aims to have a comprehensive, balanced package of options that delivers on five key objectives:

- deliver and manage water for local communities
- enable economic prosperity
- recognise and protect Aboriginal water rights, interests and access to water
- protect and enhance the environment
- affordability

The strategy actions aim to deliver benefits and complementary actions across all stakeholder groups. To support the regional water strategies, we have developed hydrologic models for each major catchment in a region. We have used these models to:

- improve our understanding of the water systems in the region
- understand the effects that different water management options could have on the environment and on the supply, demand and allocation of water.

This report outlines how the different management options were conceptualised and built in the model. It also discusses the assumptions we needed to make and presents a summary of the hydrologic results. More detailed discussion on the implications of the results for the economic and environmental assessments is presented in the detailed economic and ecological analysis for the Far North Coast.[1]

Methodology

The assessment approach aims to define risks to essential water supplies and the regional economy from climate variability and drought in the Tweed Valley. This considered existing infrastructure and the potential for mitigating risks by augmenting water supply infrastructure or making operational changes. The hydrological assessment was a key tool for understanding the effects that options may have on existing water supply risks, on water users and on the environment in the Tweed River catchment.

All hydrologic and water supply assessment modelling was completed using the eWater Source modelling platform. The model was developed as a tool for planning and evaluating water resource management policies at the river basin scale. In addition to assessing water quantity, this model can be applied to regulated and unregulated streams to understand water quality and environmental issues.

Not all options presented in the long-list of options[2] have been modelled. 5 combined options for the Tweed catchment have been modelled. These have been selected primarily on their capacity to influence the supply, demand or allocation of water.

The options modelling was carried out in two stages. In the first stage, modelling was undertaken for each preferred option and the results were assessed for water security and fed into initial economic assessment of the modelled options. Based on the initial assessment, a series of portfolios was developed for further assessment. These portfolios combined a number of different options.

In stage 2, modelling was undertaken for the selected portfolios to better understand the impacts of the portfolios on water supply risks to water users in the Tweed River catchment. This modelling also informed the economic assessment of options and for assessing ecological impacts.

We used 3 climatic datasets to test the resilience of the system and proposed options. The hydrologic modelling in the Far North Coast region is based on:

- historical data from the instrumental record (130 years): this provided initial insight into current water supply performance and risks, potential improvements under augmentation options and relative benefits between defined options
- 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

[1] Department of Planning and Environment 2022, *Far North Coast Regional Water Strategy: Detailed economic and ecological analysis*, www.dpie.nsw.gov.au/water/plans-and-programs/regional-water-strategies, accessed 9 December 2022.

[2] Department of Planning, Industry and Environment 2020, *Draft Regional Water Strategy — Far North Coast: Long list of options*, www.dpie.nsw.gov.au/water/plans-and-programs/regional-water-strategies, accessed 9 December 2022.

- a dry climate change scenario (NARCliM 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

We also performed stochastic hydro-economic assessment by splitting the 10,000-year datasets into 1,000 40-year segments. This allowed us to assess the impact to each major water user 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.

The configuration, assumptions and results summaries of the options modelling are presented in detail in the sections below. Discussions on the implications of these results for water supply, economics and the environment are presented in the detailed economic and ecological analysis for the Far North Coast.[3]

[3] Department of Planning and Environment 2022, *Far North Coast Regional Water Strategy: Detailed economic and ecological analysis*, www.dpie.nsw.gov.au/water/plans-and-programs/regional-water-strategies, accessed 9 December 2022.

2. Background

2.1 Tweed River catchment

The Tweed River Area Water Sharing Plan contains 31 water sources across the Tweed River catchment as well as Cudgen, Cudgera and Mooball creek catchments as shown in Figure 1. The water sharing plan covers the area directly south of the Queensland–NSW border on the NSW Far North Coast. The areas under the water sharing plan are within the Tweed Shire Council, which covers an approximate area of 1,325 km^2 and contains the major towns of Tweed Heads and Murwillumbah, as well as the coastal villages of Kingscliff, Hastings Point and Pottsville

Figure 1. Tweed unregulated water sharing plan area map[4]

The catchment contains three main rivers — Tweed River, Rous River and Oxley River — and a number of creeks. The Oxley River flows into the Tweed River above the influence of tidal forces, whereas the Rous River flows into the Tweed River below the tidal limit. A number of creeks, including Cobaki and Bilambil creeks, flow into the Tweed River system in the estuarine environment close to the coast. Tidal influences and salt inundation are limited in the Tweed River, with an unregulated weir at the town of Murwillumbah called Bray Park Weir. This weir creates a tidal pool of fresh water that

[4] NSW Office of Water 2010, *Water Sharing Plan for the Tweed River Area Unregulated and Alluvial Water Sources - Background document*

the Tweed Shire Council water utility can draw from. Cudgen, Cudgera and Mooball creek catchments all independently drain to the ocean without sharing an estuary.[5]

The Tweed catchment is bounded in the east by the Pacific Ocean and in the north and western edges with significant geographic features of escarpments and mountain ranges exceeding 900 m in elevation. These unique geographic features are the remains of extinct caldera. Almost all areas of elevation within the catchment are contained in the national parks of Border Ranges, Mount Warning, and Nightcap

Tweed River Valley is within the Bundjalung Nation, which is bounded to the north and south by Logan River and Clarence River respectively, and in the east and west by the Pacific Ocean and the Great Dividing Range at Tenterfield and Warwick.

The Tweed River was first discovered by Europeans in 1823. The first commercial industry in the Tweed Valley was the logging industry, primarily focused on cedar. With the logging industry came other industries such as boat building, timber dealing, mills, and hotels and workers such as farmers lawyers. The waterways in the Tweed River Valley were essential to the initial growth of the valley's population and economy.

The economy of the Tweed Valley has diversified, with concentrations of health and community services, construction, accommodation, education and training. The agriculture industry in the Tweed Shire is mainly comprised of sugarcane, bananas, beef, vegetables and dairy. Sugarcane comprises the largest part of Tweed's agriculture industry at 28% of total value, followed by bananas at 17%, beef at 12%, vegetables at 7% and Dairy at 6%.[6]

Water resource planning and management

The *Water Sharing Plan for the Tweed River Area Unregulated and Alluvial Water Sources*[7] covers 31 water sources that are grouped into three extraction management units:

- environmental water rules — the share of the water reserved for the environment
- access rules — when extraction is allowed (for example, above a set river flow rate)
- dealing rules — control the trade of water, both the transfer of share components of an access licence and assignment of water allocation between access licences, as well as changing the location for water extraction.

2.2 Water supply

The majority of the Tweed Valley uses unregulated water, with the only dam in the system being run by Tweed Shire Council for town water utilities. There are two weirs in the system: Tyalgum Weir

[5] NSW Office of Water 2010, *Water Sharing Plan for the Tweed River Area Unregulated and Alluvial Water Sources - Background document*

[6] Tweed Shire Council 2011, *Tweed Sustainable Agriculture Strategy: Discussion Paper*, tweed.nsw.gov.au/files/assets/public/documents/environment/agriculture-and-farming/sustainable-agriculture-strategy, accessed 19 December 2022.

[7] NSW Government 2010, *Water Sharing Plan for the Tweed River Area Unregulated and Alluvial Water Sources 2010*, legislation.nsw.gov.au, accessed 9 December 2022.

above gauge 201006 on the Oxley River, and Bray Park Weir downstream of the 201001 and 201003 gauges on the Tweed River.

Within the area covered by the water sharing plan, the total annual volume of surface water licensed for extraction (as at February 2009) is 35,207 ML per year, compared to an annual average flow of approximately 365,000 ML for the Tweed River at Brays Park Weir.[8]

In addition, there is 780 ML per year of authorised groundwater extraction from the 'upriver' alluvial aquifers and the 'coastal floodplain' alluvial aquifers within the plan area. This volume was included in the plan due to the degree of connectivity of these aquifers with their parent streams. The licensed extraction is separated into three extraction management units.

For the Tweed River Catchment extraction management units, the total volume of surface water licensed for extraction is 33,197 ML, including up to 27,567 ML (about 83%) for town water supply from the mid-Tweed water source for Tweed Heads and Murwillumbah (current annual usage is approximately 11,000 ML) ML), while the total volume of groundwater licensed for extraction is 295 ML. For the Burringbar River Catchment extraction management units, the total annual volume of surface water licensed for extraction from the extraction management units is 1,278 ML, of which approximately 771 ML (or 60%) is extracted for irrigation purposes within the Burringbar River water source, while the total volume of groundwater licensed for extraction is 245 ML.

For the Clothiers Creek Catchment extraction management units the total volume of surface water licensed for extraction is approximately 732 ML, with 597 ML (or 82%) extracted from the Cudgen Lake water source mainly for irrigation on the agricultural areas on the Cudgen plateau, while the total volume of groundwater licensed for extraction is 240 ML.

2.3 Tweed River Valley Baseline Source model

In 2020, DPIE Water built a new river system model for the Tweed River unregulated system using the eWater Source River System model. The key objective of the new model was to create a high-quality, robust and fit-for-purpose model, suitable for running a range of scenarios to inform decisions related to policy, planning and strategies including regional water strategies.

A schematic diagram of the model for the Tweed River is shown in Figure 2. The key stages of the model development were:

- conceptualisation
- data collation and review for flow modelling
- flow model calibration
- collation and review of data for demand modelling and demand model calibration
- implementing management rules and ordering calibration
- full model calibration and validation.

[8]Tweed Shire Council 2011, *SMEC Report of 2007: Reading the report in the context of Clarrie Hall Dam*, www.yoursaytweed.com.au/widgets/documents, accessed 19 December 2022.

Table 1 and Table 2 show the headwater catchments and residual reaches included in the model.

Table 1. Tweed headwater catchments

Gauge ID	Gauge name
201004	Tweed River at Kunghur
201006	Oxley River at Tyalgum
201007	Hopping Dick Creek at Limpinwood
201008	Rous River at Chillingham
201009	Rolands Creek at Uki
201010	Byrrill Creek at Glen Warning
201011	Doon Doon Creek at Lower Doon Doon
201012	Cobaki Creek at Cobaki
202002	Burringbar Creek at Burringbar

Table 2. Tweed residual catchments

Upstream gauge	Downstream gauge	Downstream gauge name
201006	201001	Oxley River at Eungella
201008	201005	Rous River at Boat Harbour No. 3
201005	201002	Rous River at Boat Harbour No.1
201004	201015	Tweed River downstream of Palmers Road Crossing
201015	201900	Tweed at Uki
201900	201003	Tweed River at Braeside
201003	End of system (no gauge)	

Clarrie Hall Dam and Bray Park Weir are also in the model. At this stage, Tyalgum Weir is not modelled because it has no upstream gauges and does not contain a significant storage capacity.

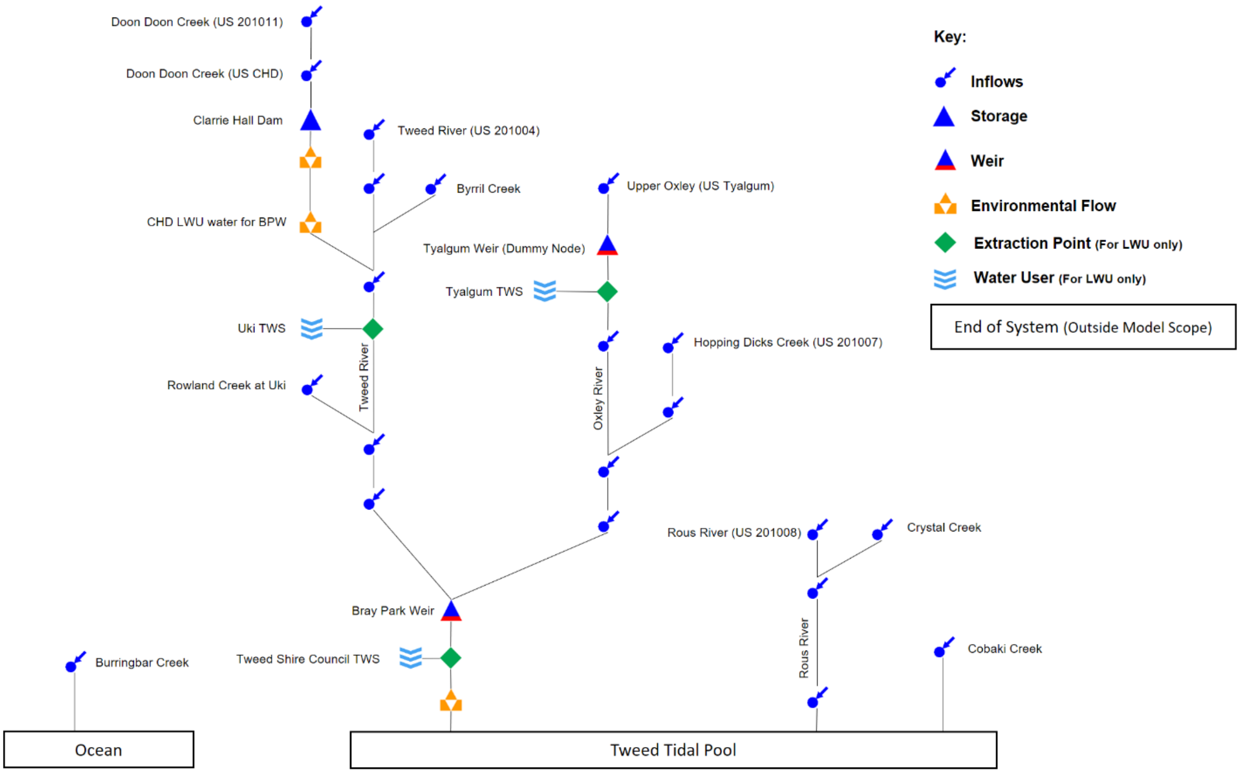

Figure 2. Schematic diagram of Tweed River model

3. Assessment framework

3.1 Modelled options

Table 3 lists the scenarios modelled from the Far North Coast Regional Water Strategy.

Table 3. Options assessed using hydrologic modelling from the Far North Coast Regional Water Strategy

Scenario	Short description
Baseline	Current conditions and management arrangements
Option 2	Interconnection of Rous County Council and Tweed Shire Council bulk water supplies
Option 11	Regional desalination
Option 12	Raising Clarrie Hall Dam level
Option 16	Provide purified recycled wastewater for industry and rural users
Portfolio 4	Combining options 2 and 12

3.2 Instrumental climate

The 'instrumental climate' refers to the period of available instrumental meteorological recordings (1889–2019) 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. 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 portfolios. Further, it provided a faster way of testing the mechanics of the options. 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 2019. All inflows are simulated.

3.3 Stochastic (long-term) with instrumental subset

The 'stochastic climate' refers to the 10,000 years of stochastic-generated climate[9] that are used to evaluate the final viability of portfolios as well as define the base case.

[9] Leonard, M., *et al.* 2020, *Methodology Report for Multisite Rainfall and Evaporation Data Generation of the Northern Basins — Far North Coast Region Stochastic Evaluation*, University of Adelaide

On completion of historical climate modelling, the performance of options under a longer stochastic climatic sequence was evaluated. This data set represents climatic and hydrological conditions developed using paleo climatic information by University of Adelaide.

3.4 Stochastic (long-term) with climate change projections

Stochastic (long-term) with climate change projections refers to the stochastic climate data generated by multiplying the stochastic timeseries of 10,000 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 portfolios, as well as to define future base cases. Upon completion of stochastic climate modelling, the performance of options under a stochastic dataset with projected climate change was evaluated. This data set projected changes in rainfall and evapotranspiration.

3.5 Performance metrics

Table 4 shows the metrics used to interpret the performance of each option.

Table 4. Performance metrics

Category	Component
Mean annual diversions	Town water supply — Bray Park Weir From weir From desalination From wastewater Town water supply — Uki Town water supply — Tyalgum Unregulated
Storage behaviour	**Clarrie Hall Dam** Clarrie Hall Dam daily average storage volume (ML) Percentage of time below full supply level (FSL) (16,192.4 ML) Percentage of time below 50% capacity (8096.2 ML)

Category	Component
	Percentage of time below 10% capacity (1619.2 ML) Percentage of time below dead storage level (271.2 ML) **Bray Park Weir** Bray Park Weir daily average storage volume (ML) Percentage of time below full supply level (FSL) (838.5 ML) Percentage of time below 50% capacity (419.3 ML) Percentage of time below 10% capacity (83.9 ML) Percentage of time below 5% capacity (41.9 ML)
Mean annual streamflows	201001 Oxley River at Eungella 201003 Tweed River at Braeside 201005 Rous River at Boat Harbour No.3 201010 Byrrill Creek at Glen Warning 201011 Doon Doon Creek at Lower Doon Doon 201013 Doon Creek downstream of Clarrie Hall Dam 201015 Tweed River downstream of Palmers Road Crossing Clarrie Hall Dam

4. Option 2: Interconnection of Rous County Council and Tweed Shire Council bulk water supplies (instrumental assessment)

4.1 Option description

Option 2 connects the two major regional water supply systems, with the aim of improving system resilience by increasing and diversifying the water supplies available in both the Tweed and Rous regions. This option can also improve the feasibility of a regional desalination scheme by making the desalinated water available to both systems.

4.2 Model configuration and assumptions

- A supply point and water-user nodes have been added downstream of Bray Park Weir.
- The supply point has a set maximum extraction limit of 11.25 ML/day.
- The Tweed River Valley Baseline Source model was run to supply Richmond only when Richmond has a shortfall.
- Clarrie Hall Dam operational management rules were updated to include the water extracted for Richmond, because the water level in the Bray Park Weir is maintained by releases from Clarrie Hall Dam.

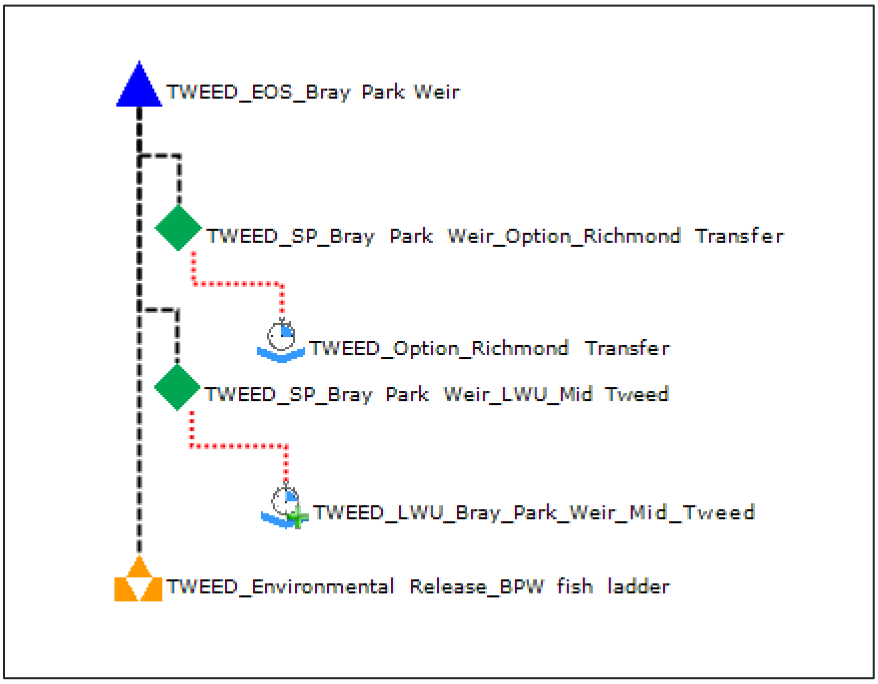

Figure 3. Option 2: Interconnection of Rous County Council and Tweed Shire Council bulk water supplies model schematic

4.3 Modelling results

Changes in water diversions

Table 5 shows the average annual water diversions under the base case and Option 2. Diversions are identical due to Richmond demand shortfalls being close to zero during the entire instrumental simulation.

Table 5. Average annual water diversions for the base case and Option 2

Water diversions	Base case (ML/yr)	Option 2 (ML/yr)
Town water supply Bray Park Weir (mid-Tweed local water utility and Richmond transfer)	11,354	11,354
Town water supply Uki	55.3	55.3
Town water supply Tyalgum	11.6	11.6
Unregulated water supply	1,275	1,275

Changes in storage behaviour

Alterations in Clarrie Hall Dam and Bray Park Weir storage behaviour are shown in Table 6. Behaviour is unchanged from the base case due to negligible Richmond transfers.

Table 6. Storage behaviour for the base case and Option 2

	Base case*	Option 2
Storage behaviour		
Clarrie Hall Dam daily average storage volume (ML)	15,925.2	15,652.2
Percentage of time below full supply level (FSL) (16,192.4 ML)	30.5	33.1
Percentage of time below 50% capacity (8096.2 ML)	0.0	0.6
Percentage of time below 10% capacity (1619.2 ML)	0.0	0.0
Percentage of time below dead storage (271.2 ML)	0.0	0.0
Bray Park Weir		
Bray Park Weir daily average storage volume (ML)	874.0	872.4
Percentage of time below FSL (838.5 ML)	15.0	18.7
Percentage of time below 50% capacity (419.3 ML)	0.0	0.0
Percentage of time below 10% capacity (83.9 ML)	0.0	0.0
Percentage of time below 5% capacity (41.9 ML)	0.0	0.0

Changes in river flows

Resulting changes in the flow regime are shown for selected stream gauges in Table 7. There is no change in flow behaviour from the base case.

Table 7. Comparison of the mean daily flow for the base case and Scenario 2

Gauging sites	Base case (ML/d)	Option 2 (ML/d)
201001 Oxley River at Eungella	440	440
201003 Tweed River at Braeside	544	544
201005 Rous River at Boat Harbour No.3	292	292
201010 Byrrill Creek at Glen Warning	121	121

Gauging sites	Base case (ML/d)	Option 2 (ML/d)
201011 Doon Doon Creek at Lower Doon Doon	143	143
201013 Doon Creek downstream of Clarrie Hall Dam	151	151
201015 Tweed River downstream of Palmers Road Crossing	226	226
Clarrie Hall Dam	150	150

5. Option 11: Regional desalination (instrumental assessment)

5.1 Option description

Option 11 introduces a climate-independent source of water through construction of a desalination plant south of Pottsville. A regional desalination facility would be able to supplement supply for the entire region and could service both the Rous and Tweed systems. An instrumental assessment of a regional desalination plant was modelled for 10, 20 and 30 ML/day.

5.2 Model configuration and assumptions

- A supply point was added between the new inflow and the local water utility user node. The conceptualisation did not easily allow for the control of which water source the node was extracting from, which made it harder to record the results.
- The proposed regional desalinisation plant is for both the Richmond and Tweed catchments. As the models for these two areas are not connected, the behaviour of both systems when sharing capacity could not be modelled. Therefore, it was decided to model three scenarios consisting of 10 ML/day, 20 ML/day and 30 ML/day, with desalinisation water being made available for the Tweed. It is assumed that this water is used before water from the weir is used.

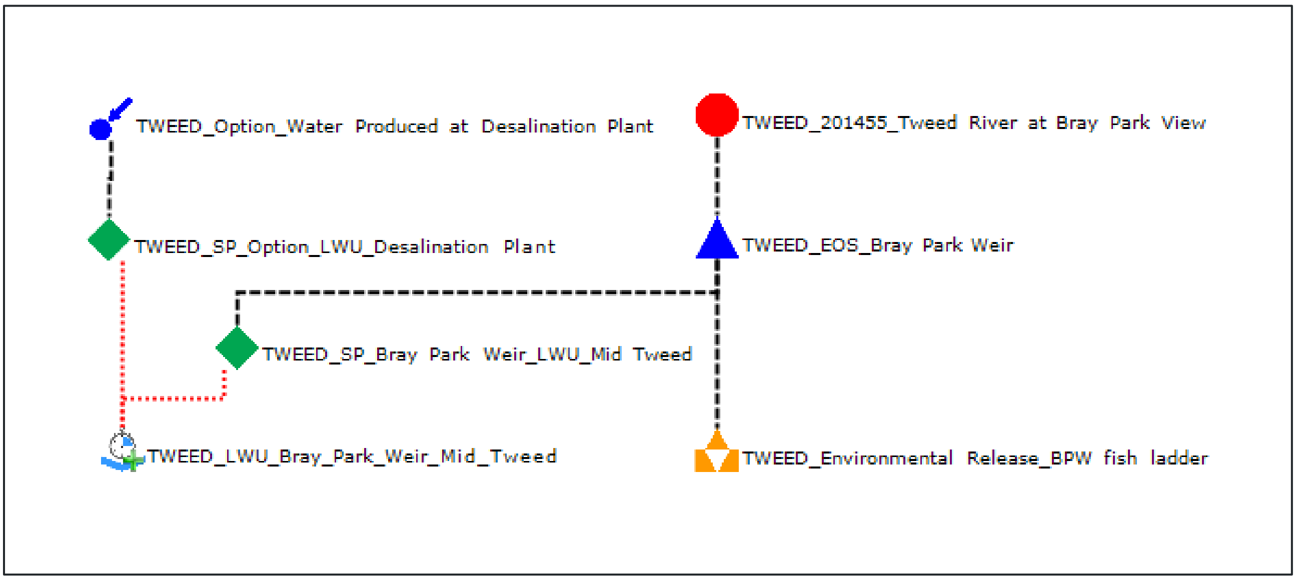

Figure 4. Option 11: Regional desalination model schematic

5.3 Modelling results

Changes in water diversions

Table 8 shows the average annual water diversions under the base case and under Option 11. Desalination use increases with increasing supply volumes. At 30 ML/d, some of the desalinisation water produced remains unused by the town. Option 11 also results in the smallest use from Bray Park Weir.

Table 8. Mean annual water diversions for the base case and Option 11

Water diversions	Base case (ML/yr)	Option 11 10 ML/day (ML/yr)	Option 11 20 ML/day (ML/yr)	Option 11 30 ML/day (ML/yr)
Town water supply Bray Park Weir (mid-Tweed local water utility)	11,354.0	7,702.0	4,051.0	996.0
Town water supply (mid-Tweed local water utility) — desalinisation plant volume produced		3,652.0	7,303.0	10,427.0
Town water supply (mid-Tweed local water utility) — desalinisation plant volume used		3,652.0	7,303.0	10,358.0
Total mid-Tweed local water utility diversion	11,354.0	11,354.0	11,354.0	11,354.0
Town water supply — Uki	55.3	55.3	55.3	55.3
Town water supply — Tyalgum	11.6	11.6	11.6	11.6
Unregulated water supply	1,275.0	1,275.0	1,275.0	1,275.0

Changes in storage behaviour

Alterations in storage behaviour for Clarrie Hall Dam and Bray Park Weir are shown in Table 9. Average storage volumes for both the dam and weir increase with increasing supply from the desalination plant.

Table 9. Storage behaviour for the base case and Option 11

	Base case	Option 11 10 ML/day (ML/yr)	Option 11 20 ML/day (ML/yr)	Option 11 30 ML/day (ML/yr)
Storage behaviour				
Clarrie Hall Dam daily average storage volume (ML)	15,925.2	16,078.3	16,173.0	16,215.8
Percentage of time below full supply level (FSL) (16,192.4 ML)	30.5	28.6	27.2	26.4
Percentage of time below 50% capacity (8,096.2 ML)	0.0	0.0	0.0	0.0
Percentage of time below 10% capacity (1,619.2 ML)	0.0	0.0	0.0	0.0
Percentage of time below dead storage (271.2 ML)	0.0	0.0	0.0	0.0
Bray Park Weir				
Bray Park Weir daily average storage volume (ML)	874.0	879.0	883.8	887.8
Percentage of time below full supply level FSL (838.5 ML)	15.0	11.4	7.5	4.0
Percentage of time below 50% capacity (419.3 ML)	0.0	0.0	0.0	0.0
Percentage of time below 10% capacity (83.9 ML)	0.0	0.0	0.0	0.0
Percentage of time below 5% capacity (41.9 ML)	0.0	0.0	0.0	0.0

Changes in river flows

Changes in the flow regime are shown for selected stream gauges in Table 10. While averages remain the same, there are day-to-day variations in flow as shown in Table 10 and Figure 5 for Gauge 201013 immediately below the Clarrie Hall Dam.

Table 10. Comparison of the mean daily flow for the base case and Option 11

Gauging sites	Base case (ML/d)	Option 11 10 ML/day (ML/d)	Option 11 20 ML/day (ML/d)	Option 11 30 ML/day (ML/d)
201001 Oxley River at Eungella	440	440	440	440
201003 Tweed River at Braeside	544	544	544	544
201005 Rous River at Boat Harbour No.3	292	292	292	292
201010 Byrrill Creek at Glen Warning	121	121	121	121
201011 Doon Doon Creek at Lower Doon Doon	143	143	143	143
201013 Doon Creek downstream of Clarrie Hall Dam	151	151	151	151
201015 Tweed River downstream of Palmers Road Crossing	226	226	226	226
Clarrie Hall Dam	150	150	150	150

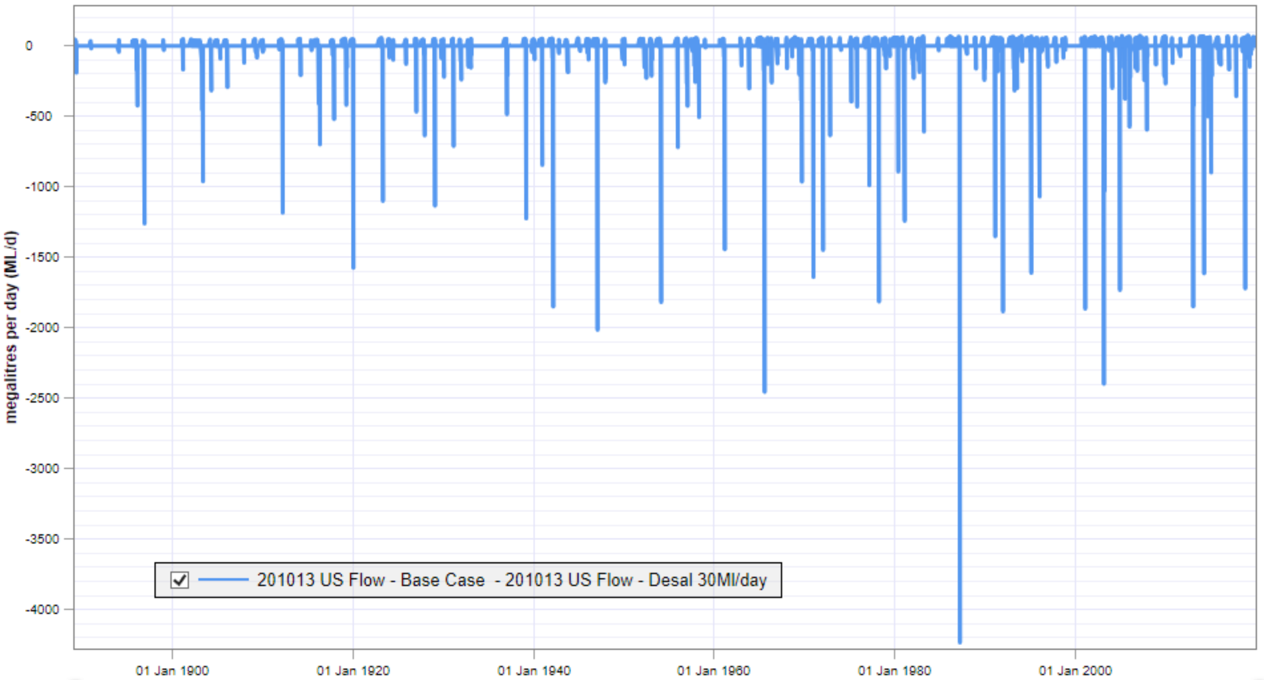

Figure 5. Gauge 201013 – upstream flow – base case vs Option 11 30 ML/day at a daily time step

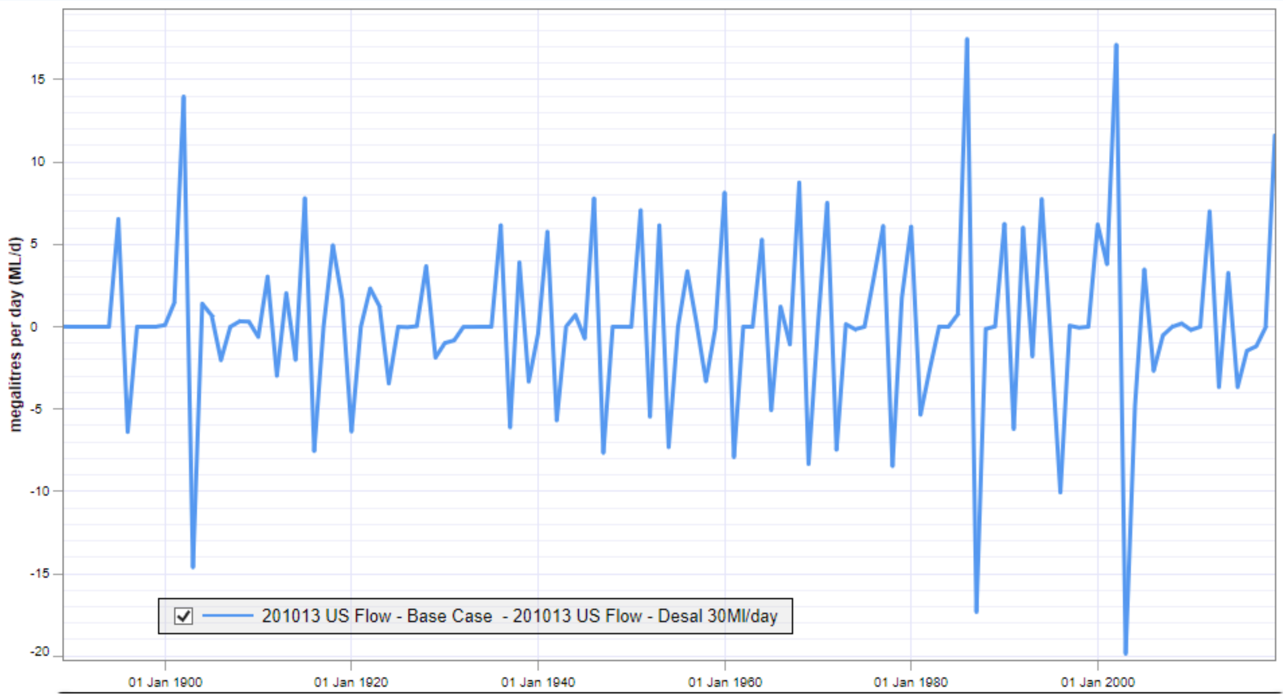

Figure 6. Gauge 201013 – upstream flow – base case vs Option 11 30 ML/day aggregated to yearly mean

6. Option 12: Raising Clarrie Hall Dam level – instrumental assessment

6.1 Option description

This option raises Clarrie Hall Dam by 8.5 m to increase dam storage capacity from 16 GL to 42.3 GL. Tweed Shire Council identified that raising Clarrie Hall Dam is the best option for improving water supply security for town water in the Tweed Shire.

6.2 Model configuration and assumptions

- Operation rules, including environmental water release rules, are kept the same as for the existing dam.
- The level–volume–area relationship for the current dam has been extend for the raised dam.
- The planned spillway rating from the 2018 Public Works report has been assumed.

Storage characteristics

Storage volume versus elevation and assumed spillways ratings are shown in Figure 7 and Figure 8.

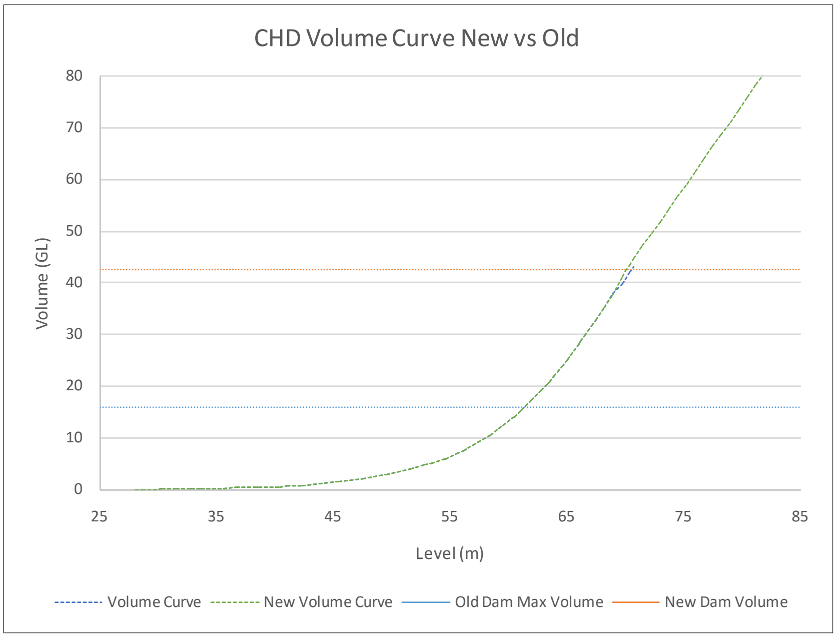

Figure 7. Option 12: Raising Clarrie Hall Dam – storage volume vs level

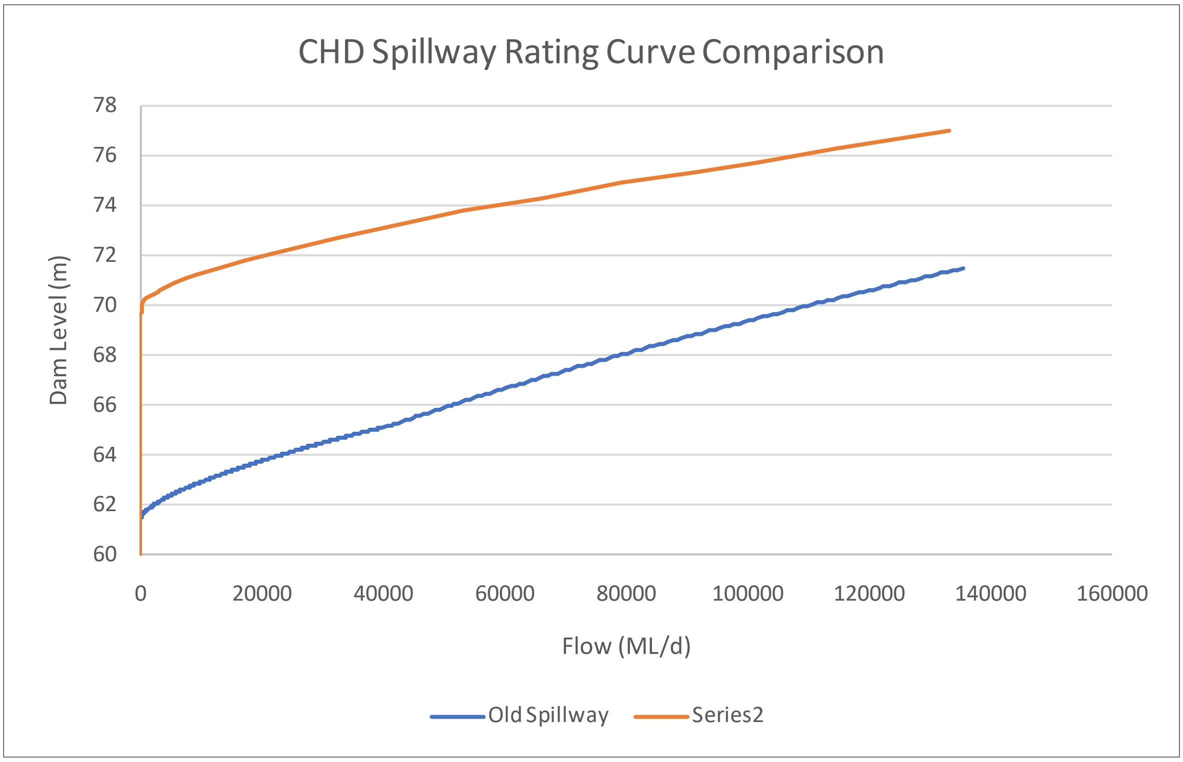

Figure 8. Option 12: Raising Clarrie Hall Dam – existing and raised dam spillway rating

6.3 Modelling results

Changes in water diversions

Table 11 shows the average annual water diversions under the base case and Option 12.

Diversions remain unchanged under an instrumental climate.

Table 11. Mean annual water diversions for the base case and Option 12

Water diversions	Base case (ML/yr)	Option 12 (ML/yr)
Town water supply — Bray Park Weir (mid-Tweed local water utility and Richmond transfer)	11,354.0	11,354.0
Town water supply — Uki	55.3	55.3
Town water supply — Tyalgum	11.6	11.6
Unregulated water supply	1,275.0	1,275.0

Changes in storage behaviour

Alterations in storage behaviour are presented in Table 12. As can be seen from the results, raising the dam wall results in more than double the average volume held in Clarrie Hall Dam compared to the base case.

Table 12. Storage behaviour for the base case and Option 12

	Base case	Option 12
Storage behaviour		
Clarrie Hall Dam daily average storage volume (ML)	15,925.2	39,631.4
Percentage of time below full supply level (FSL) (16,192.4 ML)	30.5	0.0
Percentage of time below 50% capacity (8096.2 ML)	0.0	0.0
Percentage of time below 10% capacity (1619.2 ML)	0.0	0.0
Percentage of time below dead storage (271.2 ML)	0.0	0.0
Bray Park Weir		
Bray Park Weir daily average storage volume (ML)	874.0	873.8
Percentage of time below full supply level (FSL) (838.5 ML)	15.0	15.1
Percentage of time below 50% capacity (419.3 ML)	0.0	0.0
Percentage of time below 10% capacity (83.9 ML)	0.0	0.0
Percentage of time below 5% capacity (41.9 ML)	0.0	0.0

Changes in river flows

Resulting changes in the flow regime are shown for selected stream gauges in Table 13. Alterations in daily flows are greatest immediately downstream of the dam as shown in Figure 9.

Table 13. Comparison of the mean daily flow for the base case and Option 12

Gauging sites	Base case (ML/d)	Option 12 (ML/d)
201001 Oxley River at Eungella	440	440
201003 Tweed River at Braeside	544	541
201005 Rous River at Boat Harbour No.3	292	292
201010 Byrrill Creek at Glen Warning	121	121

Gauging sites	Base case (ML/d)	Option 12 (ML/d)
201011 Doon Doon Creek at Lower Doon Doon	143	140
201013 Doon Creek downstream of Clarrie Hall Dam	151	148
201015 Tweed River downstream of Palmers Road Crossing	226	226
Clarrie Hall Dam	150	147

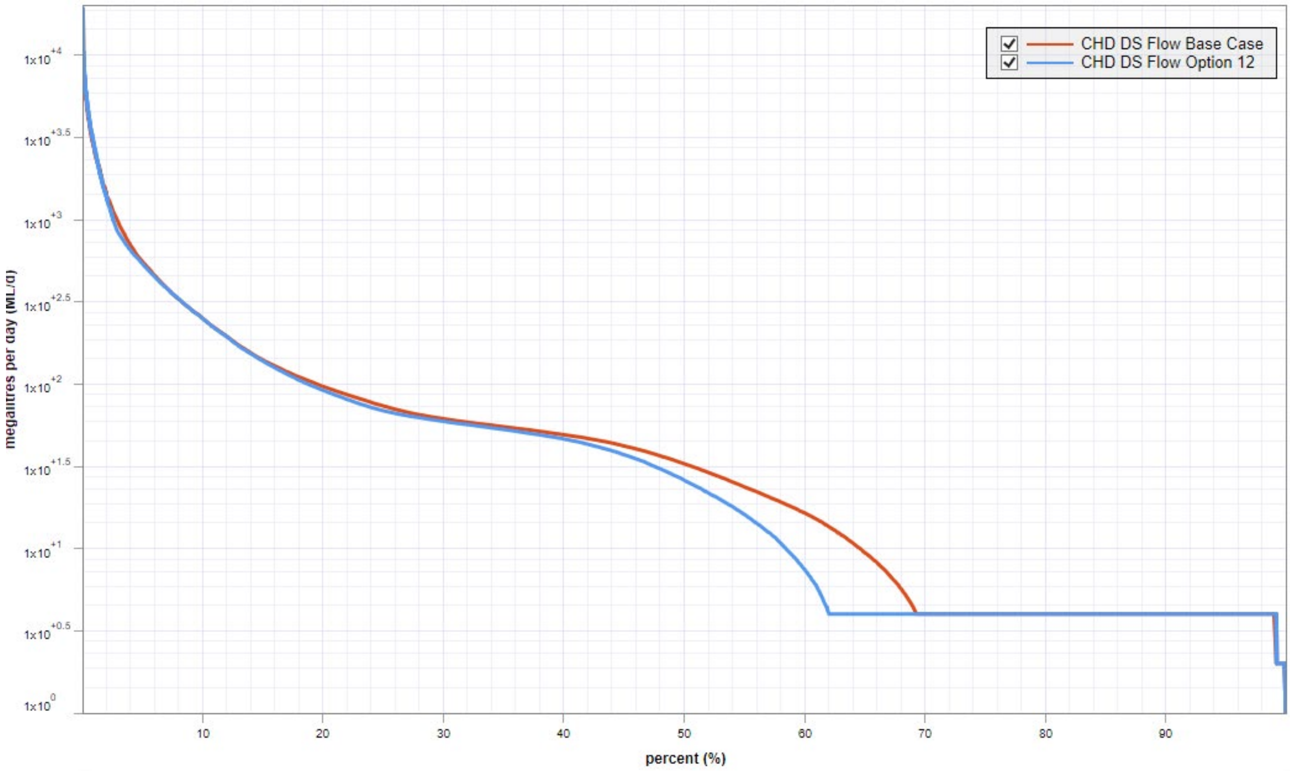

Figure 9. Option 12: Raising Clarrie Hall Dam – flow duration curve downstream of Clarrie Hall Dam (201013)

7. Option 16: Provide purified recycled wastewater for industry and rural users instrumental assessment

7.1 Option description

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 users presents an opportunity to both support industry growth and reduce pressure on town water supplies and other water sources.

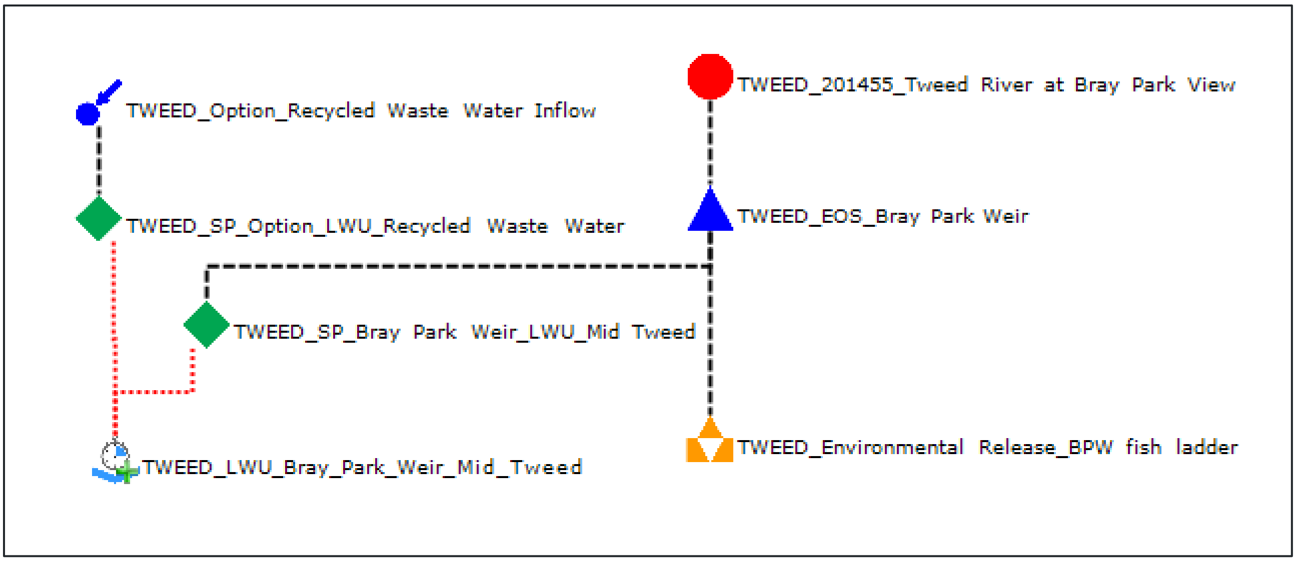

Figure 10. Option 16: Provide purified recycled wastewater for industry and rural users – model schematic

7.2 Model configuration and assumptions

Recycled water is used before water from the weir.

7.3 Modelling results

Changes in water diversions

Table 14 shows the average annual water diversions under the base case and Option 16. The majority of local water utility supply can be met from recycled water. Only a small amount is drawn from the

Bray Park Weir. In a number of instances, water generated from recycling is not used — this amounts to almost an extra 1000 ML, on average, that is unused.

Table 14. Mean annual water diversions for the base case and Option 16

Water diversions	Base case (ML/yr)	Option 16 (ML/yr)
Town water supply — Bray Park Weir (mid-Tweed local water utility)	11,354	501
Recycled wastewater volume produced (mid-Tweed local water utility)		11,851
Recycled wastewater volume used (mid-Tweed local water utility)		10,853
Total mid (mid-Tweed local water utility)	11,354	11,354
Town water supply — Uki	55.3	55.3
Town water supply — Tyalgum	11.6	11.6
Unregulated water supply	1,275	1,275

Changes in storage behaviour

Alterations in storage behaviour are presented in Table 15. Use of recycled water results in average volumes in both Clarrie Hall Dam and Bray Park Weir being greater than under the base case.

Table 15. Storage behaviour for the base case and Option 16

	Base case	Option 16
Storage behaviour		
Clarrie Hall Dam daily average storage volume (ML)	15,925.2	16,220.6
Percentage of time below full supply level (FSL) (16,192.4 ML)	30.5	26.4
Percentage of time below 50% capacity (8,096.2 ML)	0.0	0.0
Percentage of time below 10% capacity (1619.2 ML)	0.0	0.0

	Base case	Option 16
Percentage of time below dead storage (271.2 ML)	0.0	0.0
Bray Park Weir		
Bray Park Weir daily average storage volume (ML)	874.0	888.5
Percentage of time below FSL (838.5 ML)	15.0	3.3
Percentage of time below 50% capacity (419.3 ML)	0.0	0.0
Percentage of time below 10% capacity (83.9 ML)	0.0	0.0
Percentage of time below 5% capacity (41.9 ML)	0.0	0

Changes in river flows

Table 16 shows the changes in flow regime for selected stream gauges. While averages remain the same, there are day-to-day variations in flow. This behaviour is similar to Option 11.

Table 16. Comparison of the mean daily flow for the base case and Option 16

Gauging sites	Base case (ML/d)	Option 16 (ML/d)
201001 Oxley River at Eungella	440	440
201003 Tweed River at Braeside	544	544
201005 Rous River at Boat Harbour No.3	292	292
201010 Byrrill Creek at Glen Warning	121	121
201011 Doon Doon Creek at Lower Doon Doon	143	143
201013 Doon Creek downstream of Clarrie Hall Dam	151	151
201015 Tweed River downstream of Palmers Road Crossing	226	226
Clarrie Hall Dam	150	150

8. Portfolio 4: Combination of Options 2 and 12 – instrumental assessment

8.1 Option description

This option combines the interconnection of Rous County Council and Tweed Shire Council bulk water supplies with raising Clarrie Hall Dam by 8.5 m to increase dam storage capacity from 16 GL to 42.3 GL.

8.2 Model configuration and assumptions

Configuration is the same as for options 2 and 12.

8.3 Modelling results

Changes in water diversions

Table 17 shows the average annual water diversions under the base case and Portfolio 4. Negligible transfer volumes and demands for town water supply already being met under the base case means there is no change in diversions under this portfolio option.

Table 17. Mean annual water diversions for the base case and Portfolio 4

Water diversions	Base case (ML/yr)	Portfolio 4 (ML/yr)
Town water supply — Bray Park Weir (mid-Tweed local water utility)	11,354	11,354
Total mid (mid-Tweed local water utility)	11,354	11,354
Town water supply — Uki	55.3	55.3
Town water supply — Tyalgum	11.6	11.6
Unregulated water supply	1,275	1,275

Changes in storage behaviour

Alterations in storage behaviour are shown in Table 18. As with Option 2, raising the dam means that average storage volumes increase above the base case.

Table 18. Storage behaviour for the base case and Portfolio 4

	Base case	Portfolio 4
Storage behaviour		
Clarrie Hall Dam daily average storage volume (ML)	15,925.2	39,326.1
Percentage of time below full supply level (FSL) (16,192.4 ML)	30.5	0.0
Percentage of time below 50% capacity (8096.2 ML)	0.0	0.0
Percentage of time below 10% capacity (1619.2 ML)	0.0	0.0
Percentage of time below dead storage (271.2 ML)	0.0	0.0
Bray Park Weir		
Bray Park Weir daily average storage volume (ML)	874.0	872.1
Percentage of time below full supply level (FSL) (838.5 ML)	15.0	18.8
Percentage of time below 50% capacity (419.3 ML)	0.0	0.0
Percentage of time below 10% capacity (83.9 ML)	0.0	0.0
Percentage of time below 5% capacity (41.9 ML)	0.0	0.0

Changes in river flows

Changes in the flow regime are shown for selected stream gauges in Table 19. While averages remain the same, there are day-to-day variations in flow. This behaviour is similar to Option 11.

Table 19. Comparison of the mean daily flow for the base case and Portfolio 4

Gauging sites	Base case (ML/d)	Portfolio 4 (ML/d)
201001 Oxley River at Eungella	440	440
201003 Tweed River at Braeside	544	544
201005 Rous River at Boat Harbour No.3	292	292
201010 Byrrill Creek at Glen Warning	121	121
201011 Doon Doon Creek at Lower Doon Doon	143	143
201013 Doon Creek downstream of Clarrie Hall Dam	151	151
201015 Tweed River downstream of Palmers Road Crossing	226	226
Clarrie Hall Dam	150	150

9. Preferred portfolios – stochastic and NARCLiM assessments

9.1 Option description

The preferred portfolio options for the stochastic and NARCliM modelling assessments are shown in Table 20. Four portfolios were evaluated, with the results of the analysis in Table 21.

Table 20. Preferred portfolio options from the Far North Coast Regional Water Strategy

Portfolio	Portfolio description
Base case	The base case represents the current level of development and demand for town water at Bray Park Weir based on the population forecasts from the NSW Common Planning Assumptions.[10]
Base case local government area demand	This portfolio is the same as the base case, but demand for town water at Bray Park Weir is based on the population forecasts by the local government area.
Portfolio 4	Combines interconnection of Rous County Council and Tweed Shire Council bulk water supplies with raising Clarrie Hall Dam by 8.5 m to increase dam storage capacity from 16 GL to 42.3 GL.
Portfolio 5	This portfolio is the same as Portfolio 4 with the local government area demand added in for Tweed Shire and added in the Richmond Model.

The results presented in Table 21 are for two climatic datasets (stochastic and stochastic with NARCliM projections) undertaken for economic analyses of the portfolios with multiple replicates of 40-year durations:

- stochastic: 10,000 years (1,000 replicates of 40-year durations)
- NARCliM: 10,000 years (1,000 replicates of 40-year durations).

[10] Treasury NSW, www.treasury.nsw.gov.au/information-public-entities/nsw-common-planning-assumptions, accessed 19 December 2022.

The results presented on the previous tables are based on the instrumental climate data (1889-2019).

Diversions

Comparison of diversions (shown in Table 21) for these two periods indicate:

- There is a 38% increase in base case diversions when current demand is replaced by the demand associated with the local government authority population forecast under the stochastic sequence. The increase is similar under the NARCliM sequence.
- Diversions for Portfolio 5 are marginally greater than the base case with the local government authority demand scenario under the stochastic sequence. This indicates that raising Clarrie Hall Dam leads to a slight increase in local water utility yields under the local government authority population forecast. This increase does not occur for the base case to Portfolio 4 comparison. The same behaviour is also observed under the NARCliM sequence.
- Diversions are greater under the NARCliM sequence for all base case and portfolio cases when compared to the corresponding stochastic sequence case.

Streamflows

- Under the stochastic sequence, reductions in streamflows for Portfolio 4 and Portfolio 5, relative to the two base cases downstream of Clarrie Hall Dam are almost identical. The same behaviour is also observed under the NARCliM sequence.
- Streamflows are lower under the NARCliM sequence for all bade cases and portfolio cases when compared to the corresponding stochastic sequence case.

Storage behaviour

- The introduction of local government authority demands into the base case results in increased drawdown frequency for Clarrie Hall Dam or volumes below full supply levels and above 50% under a stochastic climate. This is also apparent under a NARCliM sequence.
- For Portfolio 4 and Portfolio 5, Clarrie Hall Dam remains above the old full supply level under a stochastic climate. However, under a NARCliM sequence, Clarrie Hall Dam is below the old full supply level for approximately 30% of the time.

Table 21. Portfolio results for stochastic and NARCLiM climatic sequences

Water year average 1,000 x 40-yr replicates (0100–9131)	Stochastic				NARCliM			
	Base case	Base case — LGA demand	Portfolio 4	Portfolio 5	Base case	Base case — LGA demand	Portfolio 4	Portfolio 5
Diversion mean (ML/yr)								
Town water supply — Bray Park Weir	11,379.0	15,745.7	11,379.0	15,749.7	11,578.5	16,106.0	11,578.7	16,114.0
- from weir	11,379.2	15,750.7	11,379.2	15,750.7	11,578.9	16,115.9	11,578.9	16,115.9
Total	11,379.2	15,750.7	11,379.2	15,750.7	11,578.9	16,115.9	11,578.9	16,115.9
Town water supply — Uki	55.5	55.4	55.5	55.4	56.8	56.8	56.8	56.8
Town water supply — Tyalgum (weir is not included in modelling)	12.0	12.0	12.0	12.0	11.4	11.4	11.4	11.4
Unregulated water supply	1,216.3	1,216.3	1,216.3	1,216.3	1,311.4	1,311.3	1,311.4	1,311.4
Minimum flow node								
Clarrie Hall Dam minimum flow for town water supply minus actual flow	-3.0	-5.6	-3.0	-5.8	-3.7	-6.8	-3.7	-7.0
Agricultural production								
Idealised requirement (ML/yr)	8829.8	8829.8	8829.8	8829.8	9310.1	9310.1	9310.1	9310.1
Unregulated — rainfall-harvested (ML/yr)	6,954.7	6954.7	6954.7	6954.7	7114.1	7114.1	7114.1	7114.1
Storage behaviour								
Clarrie Hall Dam daily average storage volume (ML)	15935.4	15633.1	39642.4	39259.4	15806.0	15419.3	39446.7	38932.9
Percentage of time below new FSL (42.3 GL)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Percentage of time below old full supply level FSL (16,192.4 ML)	27.8%	31.2%	0.0%	0.1%	31.4%	35.1%	0.0%	0.3%
Percentage of time below old 50% full (8,096.2 ML)	0.2%	1.1%	0.0%	0.0%	0.4%	1.8%	0.0%	0.1%
Percentage of time below old 10% full (1619.2 ML)	0.0%	0.1%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%
Percentage of time below dead storage (271.2 ML)	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
Bray Park Weir								
Bray Park Weir daily average storage volume (ML)	875.3	868.1	875.2	868.6	869.4	860.8	869.4	861.7
Percentage of time below Full Supply Level FSL (838.5 ML)	13.7%	17.8%	13.7%	17.9%	15.9%	20.4%	16.0%	20.5%
Percentage of time below 50% full (419.3 ML)	0.1%	0.3%	0.0%	0.2%	0.1%	0.5%	0.1%	0.3%
Percentage of time below 10% full (83.9 ML)	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
Percentage of time below 5% full (41.9 ML)	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
Streamflow (ML/day)								
Upstream of the dam								
201010 (different stream)	118.4	118.4	118.4	118.4	113.1	113.1	113.1	113.1
201001 (different stream)	433.3	433.3	433.3	433.3	402.1	402.1	402.1	402.1
201005 (different stream)	286.3	286.3	286.3	286.3	256.5	256.5	256.5	256.5
201015	219.8	219.8	219.8	219.8	209.6	209.6	209.6	209.6
201011 (contribution adjusted for bigger surface area of the dam for portfolios)	140.6	140.6	137.8	137.8	130.4	130.4	127.8	127.8
Clarrie Hall Dam inflow (contribution adjusted for bigger surface area of the dam for portfolios)	147.4	147.4	144.6	144.6	136.7	136.7	134.1	134.1
Below the dam								
201013	147.7	147.7	144.8	144.8	136.5	136.5	133.3	133.4
201003	533.3	533.2	530.8	530.7	503.3	503.3	500.6	500.5

9.2 Economic analysis of preferred portfolios

The economic outputs of the preferred portfolios are supplied as 1,000 replicates of 40-year daily replicates, with the same initial storage condition as for Bray Park Weir. These values are based on the storage volume as at 1 January 2021. The climate scenarios are both stochastic and NARCliM-scaled stochastic.

9.3 Ecological analysis of preferred portfolios

The baseline model and the portfolio models were simulated for ecological analysis using two sets of climate data:

- 10,000-year stochastic climate
- 10,000-year stochastic climate with NARCliM climate projections.

Annual trends of the population growth was not included for the single-sequence 10,000-year simulations of the model.

The ecological outputs for portfolios are daily time series for the 10,000-year output modelled flow at the following gauges:

- 201001; 201003; 201004; 201005; 201006; 201007; 201008; 201009; 201010; 201011; 201012; 201013; 201015; 201422; 201455; 201900; 202002.