Braidwood Water Supply – Water Security Assessment and Drought Contingency Plan

Queanbeyan Palerang Regional Council

Report Number: PWA ISR20230

March 2021

Prepared for:

QPRC

QUEANBEYAN-PALERANG REGIONAL COUNCIL

Trim Project No. DIR20/1702

Report Number: PWA ISR20230

Document control

Version	Author(s)	Reviewer	Approved for issue	
			Name	Date
Prelim Draft	Ga Jung Lee	Gareth Clemens	Glenn Fernandes	17/11/20
Draft - incorporating comments from Council (G. Cunningham)	Gareth Clemens	Glenn Fernandes	Glenn Fernandes	22/12/20
Draft v2 - incorporating comments from Council (G. Cunningham)	Gareth Clemens	Glenn Fernandes	Glenn Fernandes	28/01/21
Draft v3 – includes long term water security	Gareth Clemens	Glenn Fernandes	Glenn Fernandes	26/02/21
Final	Gareth Clemens	Glenn Fernandes	Glenn Fernandes	18/03/21

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Executive Summary

The Braidwood Water Supply Scheme sources raw water from an off-stream storage built in the mid-1980s. The storage is filled from the Shoalhaven River which lies within the Southern Rivers Catchment Management Area. Over the past summer (2019/20), up to Stage 4 water restrictions were implemented in Braidwood as a result of the cessation of flows within the Shoalhaven River, related to the ongoing drought.

The water security for Braidwood was not identified as an issue in Council's IWCM Strategy completed in 2019. At the time, the secure yield for the Braidwood off-river storage was estimated to be 394 ML/year. The 2019/20 drought was the worst on record, and the secure yield estimate was updated to 334 ML/year, or 320 ML/year with 1 degree climate warming. The unrestricted future extraction for Braidwood is estimated to exceed the climate change secure yield of 320 ML/year around 2042/43.

Council has engaged Public Works Advisory (PWA) to assess short-term and long-term options to address the water security issue at Braidwood. The short-term solution is to develop a restriction implementation plan to ensure that the town does not run out of water in the event of a repeat of the recent drought.

Short Term Drought Security

A proposed restriction regime (which gives restriction triggers based on dam level and associated target reduction in demand) was developed to determine trigger levels for restrictions. The nominated storage level relating to different restriction levels, is shown in Table S1.

Table S1: Proposed restriction policy

Restrictions	Normal demand	Stage 1	Stage 2	Stage 3	Stage 4
Trigger dam level (% full)		85%	75%	65%	50%
Target reduction in demand	0%	10%	25%	35%	40%
Annual unrestricted extraction (ML/a)	270	243	203	176	162

Figure S1 provides the modelled Braidwood off-stream storage behaviour diagram applying the proposed restriction policy for an extraction of 270 ML/a for the existing Braidwood headworks system for a repeat of the historic climate (2019/2020). The historical climate was used in the simulation as this is being assessed as a short-term solution.

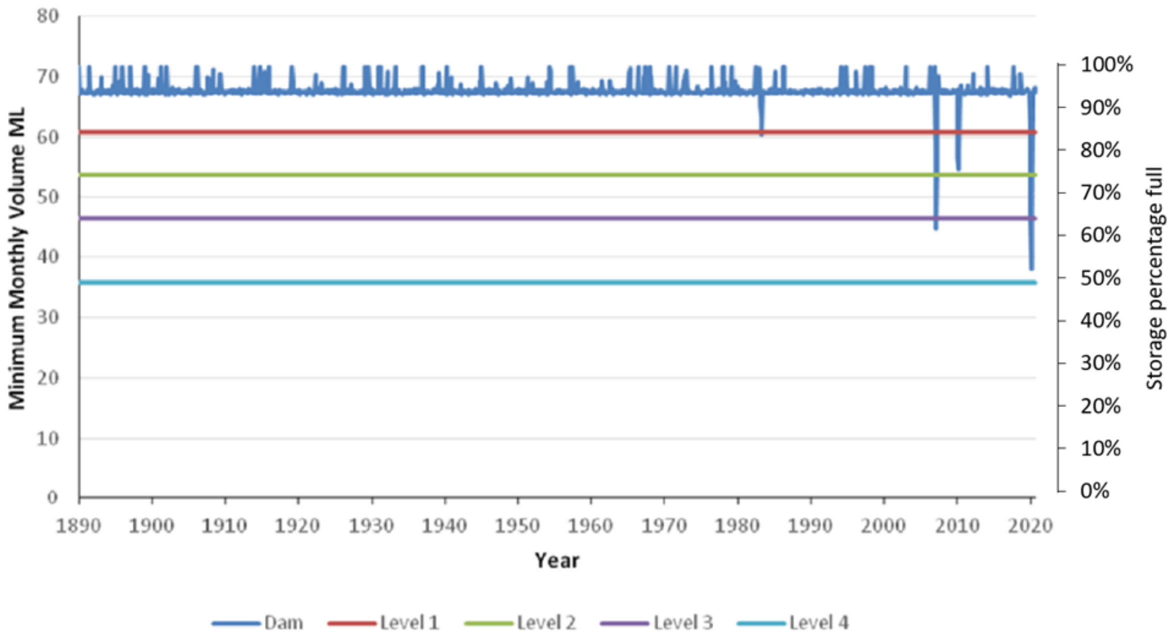

Figure S1: Modelled storage level in Braidwood Dam – extraction of 270 ML/year with proposed restriction policy

Table S2 summarises the application of restrictions from modelling the proposed regime for an annual extraction of 270 ML/a for a repeat of the historic climate (1890-2020) and compares them with those for the 5/10/10 rule

Table S2: Restrictions Comparison – Proposed Policy with Historic Climate

Case	Duration of restrictions % of time	% of years with restrictions applied	Restrictions on demand %
5/10/10 rule	5	10	10
Proposed policy for 270 ML/a for historic climate	0.38	3.1	18.5

The proposed restriction policy meets the first two criteria of the 5/10/10 design planning rules but does not meet the last criteria. It is noted however that the third criteria is not fully comparable as the third criteria allows for a much worse drought then has occurred in the past (1890-2020) and uses a constant demand reduction.

With this restriction regime, the storage would draw down to 52% storage volume for the 2019/2020 (critical) drought. This compares to a storage drawdown to about 25% storage volume for the 2019/2020 drought based on the 5/10/10 operating rules.

Long Term Water Security

It was identified, and confirmed with Council, that non-revenue water in Braidwood is around 36% of the annual WTP production. Typical NRW for water supply schemes is around 10 to 15% of annual production .

Council has indicated that they aim to reduce NRW to 20% in the short term. If this occurs, the 30-year forecast extraction (for the 1°C climate change scenario) would be less than the climate change secure yield of the headworks. This means that the existing headworks would be sufficient to provide water security to Braidwood for the 30-year planning horizon. This is shown in Figure S2.

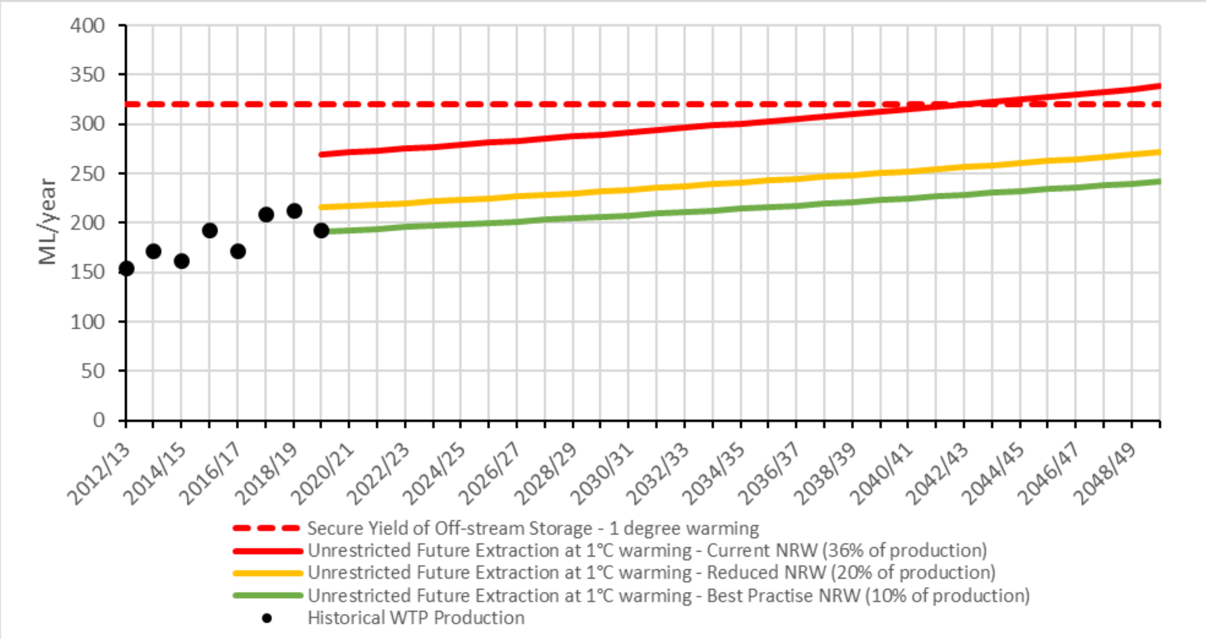

Figure S2: Braidwood water supply - projected dry year extraction compared to Secure Yield for current and reduced non-revenue water volumes

Long-term drought restriction policy

The proposed restriction policy was modelled for the forecast extraction (with reduced NRW) and the secure yield for the 1°C climate warming scenario, to determine the frequency and duration of restrictions. Figure S3 provides the modelled Braidwood off-stream storage behaviour diagram applying the proposed restriction.

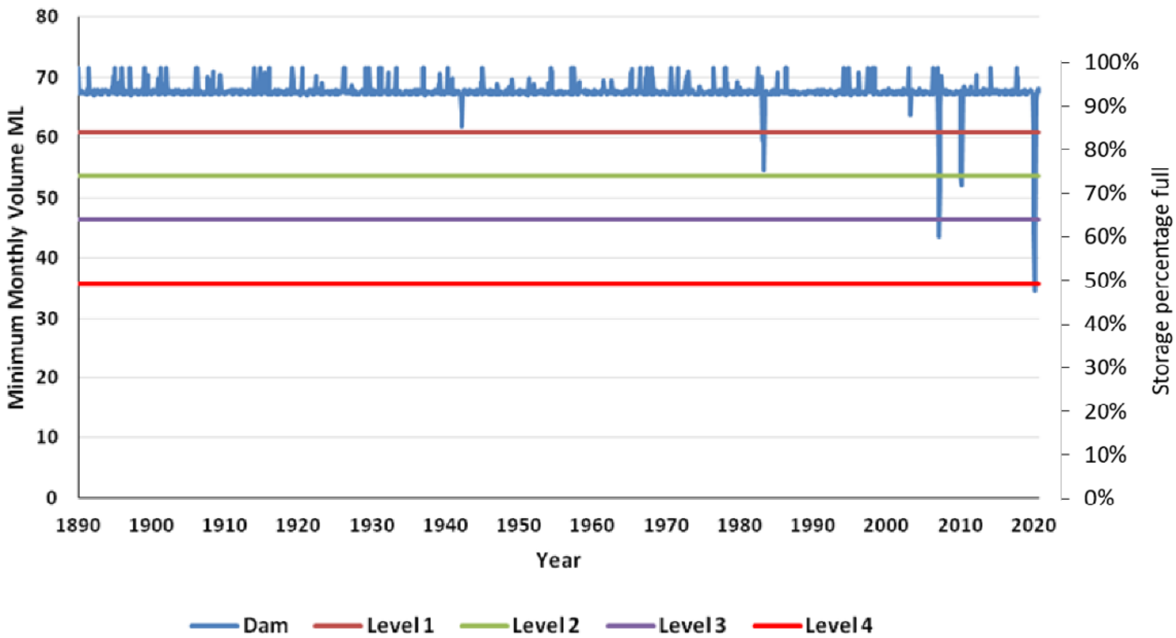

Figure S3: Modelled storage level in Braidwood Dam – extraction of 270 ML/year with proposed restriction policy and 1°C climate warming.

With this restriction regime, the storage would draw down to 48% storage volume for the 2019/2020 (critical) drought. This compares to a storage drawdown to about 25% storage volume for the 2019/2020 drought based on the 5/10/10 operating rules.

Table S3 summarises the application of restrictions from modelling the proposed regime for an annual demand of 272 ML/a for a 1°C warmer climate and compares them with those for the 5/10/10 rule.

Table S3: Restrictions Comparison – Proposed Policy for unrestricted future extraction and 1°C climate warming

Case	Duration of restrictions % of time	% of years with restrictions applied	Restrictions on demand %
5/10/10 rule	5	10	10
Proposed policy for 272 ML/a for historic climate *(flows reduced by 20%, assumed to reflect 1°C climate warming)*	0.52	3.1	18.8

The 1°C climate warming does not appear to have a large effect on duration of restrictions. The most notable change compared to the restriction policy using the historical climate is that the stage 4 restriction level is triggered for a very short period.

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1. Introduction

Braidwood is a town in the Southern Tablelands of NSW, in Queanbeyan–Palerang Regional Council. It is located approximately 200 km south west of Sydney, and about halfway between Canberra and the coastal town of Batemans bay. The town has a population of around 1,200 and is a service town for the surrounding district which is based on sheep and cattle grazing, and forestry operations.

The Braidwood Water Supply Scheme sources raw water from an off-stream storage which is filled from the Shoalhaven River. Over the past summer (2019/20), severe water restrictions were implemented in Braidwood as a result of the cessation of flows within the Shoalhaven River, related to the ongoing drought. In the period between early November and mid-February, water restrictions for Braidwood were progressively increased up to Stage 4 (the highest level).

Council engaged Public Works Advisory (PWA) to assess short-term and long-term options to address the water security issue at Braidwood. The short-term solution is to develop a restriction implementation plan to ensure that the town does not run out of water in the event of a repeat of the recent drought. The long-term solution would be to assess options to increase the secure yield of the Braidwood water supply.

This report presents the recommendations for the short-term solution (Stage 1).

2. Braidwood Water Supply Scheme

Braidwood is a major town within the Palerang Community LGA with an urban centre population of approximately 1,273. In May 2016 Palerang Council amalgamated with Queanbeyan City Council to form Queanbeyan-Palerang Regional Council (QPRC).

Braidwood is serviced by the Braidwood Water Supply Scheme.

2.1 Water source

The Braidwood Water Supply Scheme sources raw water from a 72 ML off-stream storage built in the mid-1980s. The storage is filled from the Shoalhaven River which lies within the upper region of the Southern Rivers Catchment area and forms the upper regions of the Sydney Drinking Water Catchment. This is shown in Figure 2.1.

Figure 2.1: Braidwood water supply

Shoalhaven Catchment

The Shoalhaven catchment has an area of 7,300 square kilometres. The region is well known for its fresh produce sourced from local farms and dairies, and for its beef cattle, wool and other agriculture essential to the NSW economy.

Cattle and sheep grazing is the largest single land use. The catchment also supports horse studs, piggeries, dairies and poultry production as well as vineyards, olive groves, and canola and cereal crops. Cleared grazing land covers 36 per cent of the catchment, along with large areas of national parks (31 per cent) and forests (27 per cent). Rainfall generally increases from the south-west near Cooma to the north-east near Robertson.

The upper Shoalhaven catchment had been modified substantially which resulted in degradation in both aquatic and terrestrial systems. Agriculture and mining have contributed to this process particularly through the removal of timber to drive steam engines and for construction. Agriculture and gold mining have contributed to this process particularly through the removal of timber to drive steam engines and for construction. Although fifty years have passed since significant gold mining ceased, the catchment remains in a highly modified state.

Shoalhaven Catchment is shown in Figure 2.2

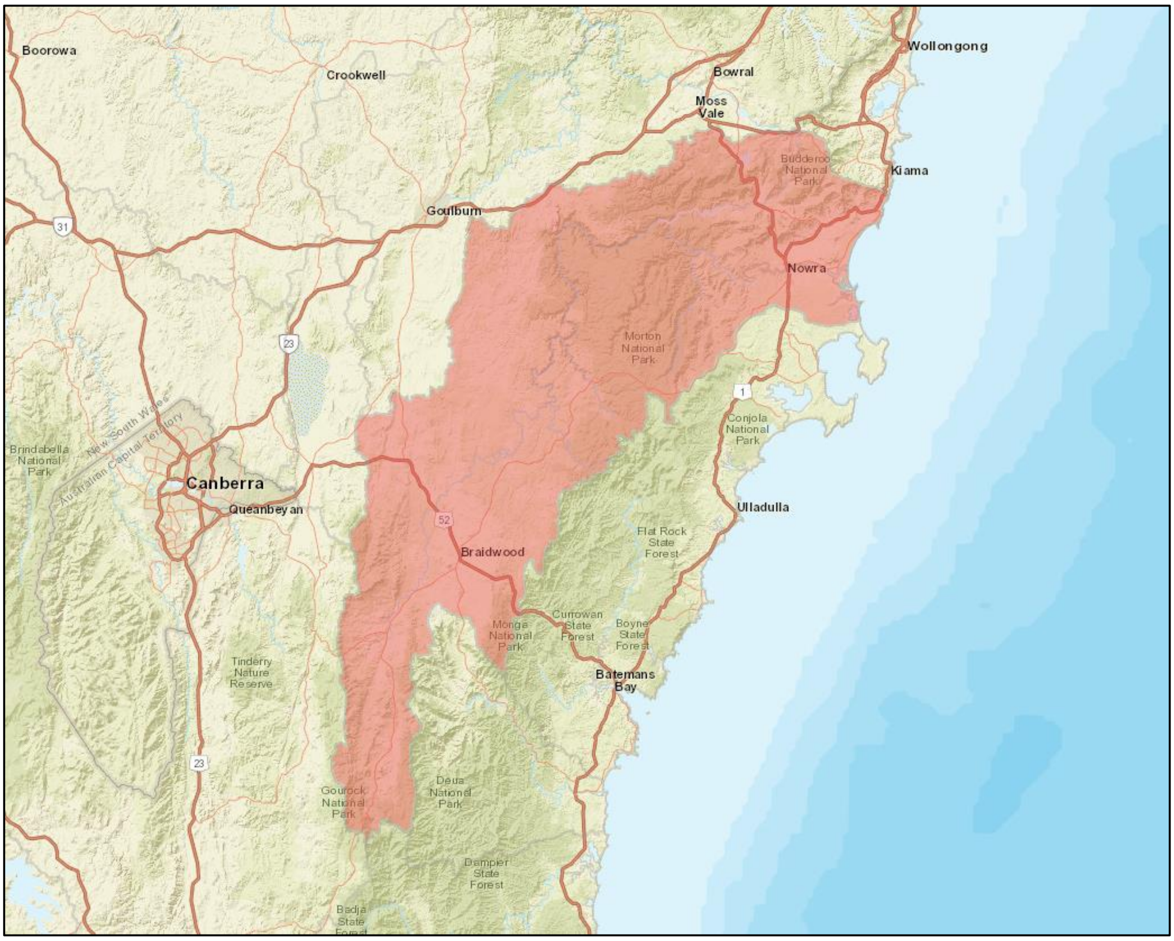


Figure 2.2:Shoalhaven Catchment

2.2 Water Supply

2.2.1 Water Treatment

The Braidwood WTP was commissioned in March 2013. Raw water is pumped from a submerged pipe in the off-stream storage to the Braidwood WTP. The river intake pumps are operated manually as required. When in operation they run 24 hours per day at around 1.17 ML/day.

The WTP has a 2 ML/day capacity and consists of the following processes:

- Powder activated carbon (PAC) (used periodically)
- Coagulation and flocculation with aluminium chlorohydrate
- Dissolved air flotation and filtration via a dual media gravity filter
- Disinfection using chlorine gas
- pH correction with caustic soda (when required)
- Fluoridation with sodium fluoride

The backwash wastewater and sludge are treated on-site, with supernatant recycled to the 72 ML off-stream storage dam. The clear water from the WTP is stored in three reservoirs with a combined capacity of 2.6 ML (2 x 0.55 ML and 1 x 1.5 ML reservoir) at the WTP site. All are roofed with locked access ladders and hatches.

A schematic of the Braidwood Water Treatment Plant is shown in Figure 2.3.

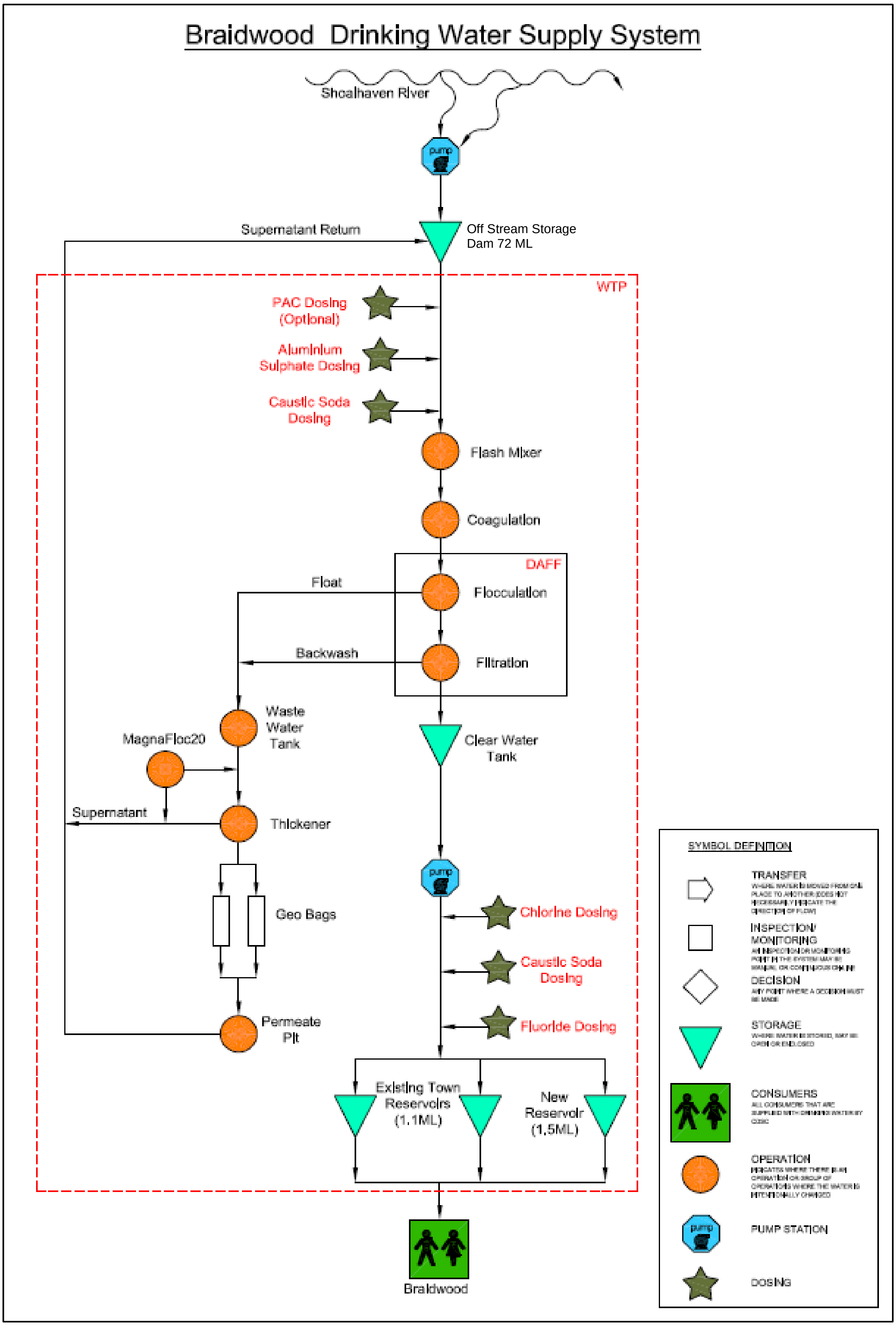


Figure 2.3: Braidwood Water Treatment Plant Schematic

2.2.2 WTP Production

Daily WTP production data from Braidwood WTP was available from 1 July 2004 to 25 July 2020. These flow values were read daily off mag-meters located after the WTP.

Water restrictions were implemented starting 22 November 2019 and continued until 6 March 2020 when they were relaxed. During this period, the restriction level was changed several times, reaching the highest level (Stage 4) over Jan/Feb 2020. The restriction stages are summarised in Table 2.1.

Table 2.1: Water Restriction stages and dates

Water Restrictions Stage	Start Date	End Date	Total Duration (days)
Stage 2	22/11/2019	13/12/2019	21
Stage 3	13/12/2019	10/01/2020	28
Stage 4	10/01/2020	14/02/2020	35
Stage 3	14/02/2020	5/03/2020	21

The historical average daily production is presented in Figure 2.4.

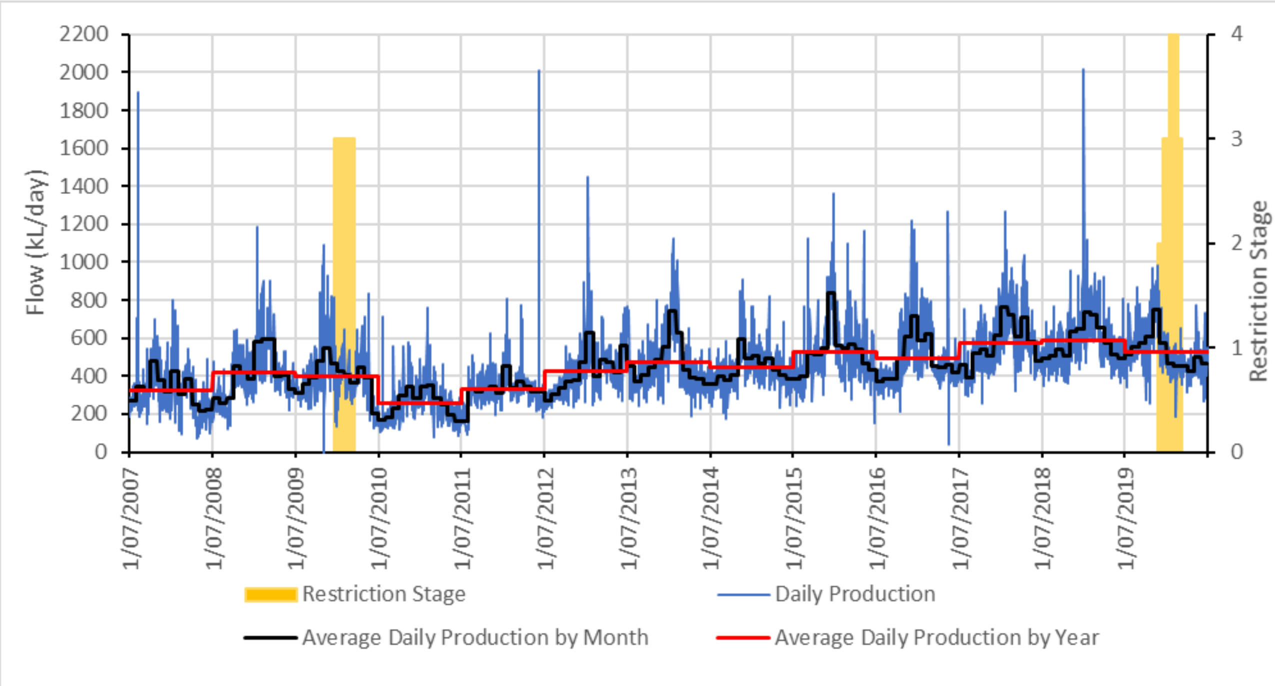


Figure 2.4: Historical daily production data – Braidwood WTP

The historical annual production values are given Table 2.2.

Table 2.2: Historical annual production – Braidwood WTP (ML/year)

Financial Year	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20
Production	120	155	172	162	193	172	210	214	194

2.3 Distribution

Water is pumped from the clear water tank to three reservoirs with a combined storage of 2.6 ML at the WTP site. Treated water stored at the reservoirs supplies Braidwood by gravity via a 2.3 km 300mm diameter DICL trunk main. The potable water trunk main connects with the reticulation at Saleyards Lane.

2.3.1 Metered Customer Demand

Water meter billing data was provided by Council from 2007/08 to 2019/20 financial years. Water meters were read quarterly around the end of the months of January, April, July and October, with the read for each meter and water consumption recorded by Council.

The historical number of assessments (approximately equal to the number of connections) for Braidwood WSS is given in Table 2.3.

Table 2.3: Historical number of assessments

Financial Year	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20
Residential	523	514	531	510	508	527	529	521	537	546	573	558	567
Non-residential	82	82	85	86	87	90	88	88	87	87	90	88	88
Total	605	596	616	596	595	617	617	609	624	633	663	646	655

The historical metered customer demand for Braidwood WSS is given in Table 2.4. Standpipe consumption data was not included in the billing data but in a separate data set and was available only from 2016 onwards.

Table 2.4: Historical customer demand (ML/year)

Financial Year	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20
Residential	52	71	72	59	59	72	73	68	79	73	87	77	81
Industrial	2	1	3	2	2	2	2	2	2	3	4	4	4
Parks and Gardens	3	11	10	6	10	11	13	11	14	10	16	13	9
STP and SPS	2	4	11	7	4	2	1	1	1	2	2	2	1
Commercial	7	11	12	12	11	10	12	11	12	10	12	23 [1]	10
Institutional	13	11	5	5	5	6	6	5	8	6	7	6	5
Education	3	5	3	1	2	2	3	3	4	4	5	2	3
Accommodation	3	4	5	3	4	4	4	4	4	4	4	5	4
Standpipe	-	-	-	-	-	-	-	-	1	1	3	2	4
Total	**84**	**118**	**119**	**94**	**97**	**109**	**114**	**104**	**124**	**113**	**138**	**134**	**122**

1 - Commercial values in 2019 are higher due to the high consumption from the major user Mona Farms.

Historical customer usage split has been around 70% residential to 30% non-residential. The historical usage for all available billing periods for Braidwood WSS is given in Figure 2.5.

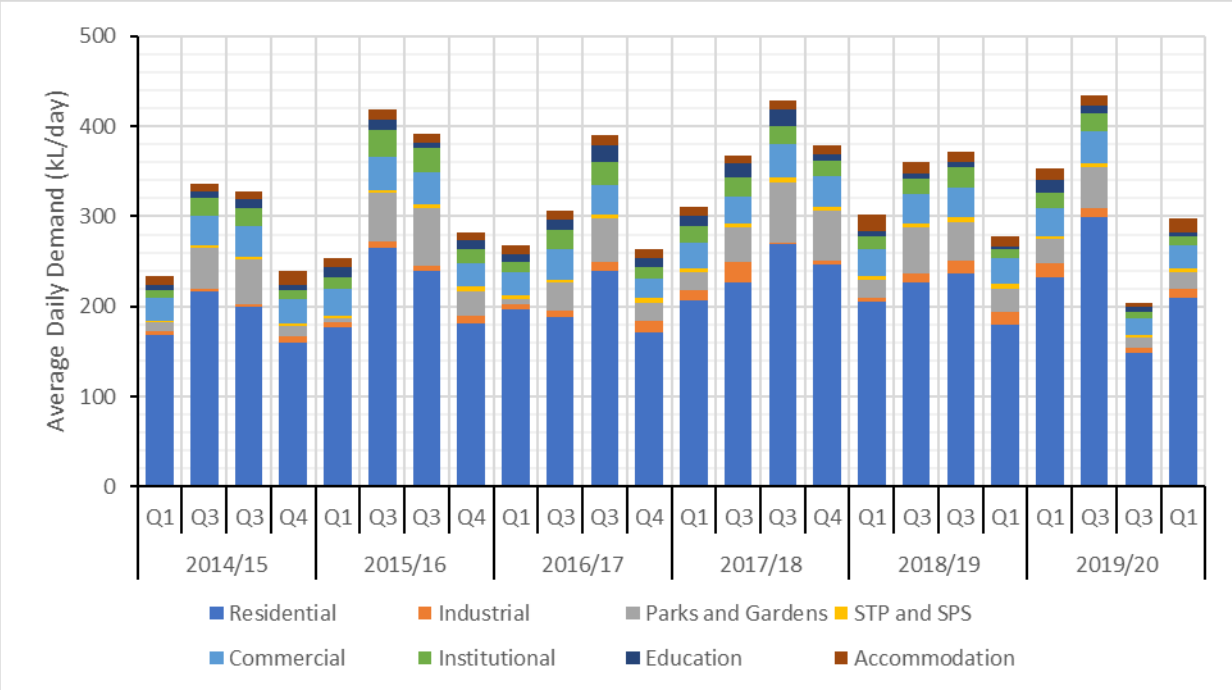


Figure 2.5: Historical quarterly customer demand by user category

2.3.2 Non-revenue water

The NRW represents the difference between the volume of water delivered into a network and the billed consumption. NRW is made up of many components, tabulated below. The apparent and real water losses need to be targeted in order to reduce NRW.

System Input Volume **(WTP Production)**	**Authorised consumption**	**Billed Authorised Consumption (metered/ unmetered)**		Revenue Water
		Unbilled Authorised Consumption e.g. flushing, firefighting, public open spaces		**Non-Revenue Water**
	Water Losses	Apparent Losses	▪ Unauthorised Consumption ▪ Metering inaccuracies	
		Real Losses	▪ Leakage on trunk and/or distribution mains ▪ Overflows at storage tanks ▪ Leakage on service connections	

NRW is estimated by undertaking a water balance between the water production and the metered consumption in each billing period.

The NRW for Braidwood is given in Table 2.5.

Table 2.5: Historical non-revenue water - Braidwood WSS

Financial Year	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20
NRW (ML/year)	24	47	58	58	69	59	71	79	71
NRW (% of annual production)	20%	30%	34%	36%	36%	34%	34%	37%	37%
Unit NRW (L/assessment/day)	109	206	257	261	303	254	295	387	298

NRW is significantly higher than the 2014-15 state-wide median of 92 L/connection/day for Local Water Utilities [1]. The NRW for Braidwood is also seen to be increasing from 2011 to 2020.

2.3.3 Major non-residential users

The criteria used to identify major non-residential users was any customers that used more than 3% of the total customer usage for Braidwood WSS in any financial year.

Seven users met the criteria for a major non-residential user. There usage is given in Table 2.6.

Table 2.6: Major users

Major User	Average Yearly Usage (ML/year)	Max Yearly Usage by FY (ML/year)
Braidwood Multi-Purpose Service Hospital	2.6	9.4
Braidwood Sewage Treatment Plant	2.9	10.8
Braidwood Recreation Ground	3.2	5.8
Braidwood Serviceman's Club	1.9	4.4
Braidwood Central School	2.0	4.3
Ryrie Park	2.4	4.3
Mona Farm (large property and event space)	0.4 [1]	11.0

Mona Farm had an average usage of 0.4 ML/year, excluding two quarters of very high usage. In the June and September 2019 quarters, the quarterly usage was 2.1 ML and 10.1 ML respectively. Council speculated this extreme consumption was caused by a leak or high use related to drought. It is not expected this high usage will continue into the future.

2.4 Water Licensing

Council holds a Water Access License (WAL), issued under the Water Management Act 2000, for the extraction of water for Braidwood Water Supply Scheme, the details are listed in Table 2.7.

Table 2.7: Braidwood water entitlements

WAL Number	Category	Water Source	Water Sharing Plan (WSP)	Nominated Works	Entitlement (ML/annum)
WAL 25376	Domestic and Stock [Town Water Supply]	Shoalhaven River Water Source	Greater Metropolitan Region Unregulated River Water Sources	10CA102425 2 x 100 mm Centrifugal Pump 1 x Overshot Dam	360

3. Growth Strategy and development

3.1 Historical population

The Australian Bureau of Statistics (ABS) creates community profiles for many different statistical areas, which provides a comprehensive statistical picture of the demographics of the area. Quickstats is an ABS service which uses census data to present a community profile for most areas in Australia, based on the place of usual residence.

The historical population for Braidwood Urban Centre/Locality (UCL) obtained from Quickstats 2001 to 2016 is given in Table 3.1.

Table 3.1: Historical Population of Braidwood UCL

Calendar Year	2001	2006	2011	2016
Historical Population	996	1,108	1,158	1,273
Average Annual growth	-	2.2%	0.9%	2.0%

Braidwood UCL has experienced continuous growth since 2001. From 2016 SA1 data, the total population is 1,276 with 1,116 in occupied private dwellings and the remainder in other dwellings.

The number of private dwellings and private dwelling population from the 2016 Census General Community Profile data for Braidwood UCL is given in Table 3.2. The private dwelling population is lower than the 2016 UCL population in Table 3.1 as it does not include population in non-private dwellings.

Table 3.2: Private dwellings and population from 2016 Census General Community Profile data for Braidwood UCL

	Dwellings	Persons
Occupied Separate house	452	1,044
Occupied Semi-detached row or terrace house townhouse etc	23	50
Occupied Flat or apartment	7	7
Occupied Other dwelling	0	3
Occupied Dwelling structure not stated	13	13
Total occupied private dwelling	495	1,121
Unoccupied private dwellings	78	0
Total private dwellings	**564**	**1,121**

Based on the above information, the 2016 household size is about 2.3 people per occupied private dwelling, and around 88% of private dwellings are occupied. Council has advised that they expect higher occupancy rates now because of the advent of the Dargues Reef Gold Mine at Majors Creek which has seen an increase in demand and occupancy rate for rental/purchases in Braidwood.

3.2 Service area population

The serviced area private population numbers were estimated by multiplying the number of “active” residential assessments in the billing data by the estimated household size for Braidwood from ABS (2.3 people per occupied private dwelling). The method for estimating “active” residential assessments is described in Section 4.4.

The estimated population and occupied dwellings serviced by reticulated water is given in Table 3.3.

Table 3.3: Estimated occupied dwellings and serviced population - water supply schemes

Financial Year	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20
Active residential assessments	461	485	465	467	474	478	509	495	511
Inactive residential assessments	47	42	64	54	63	68	64	63	56
Total residential assessments	508	527	529	521	537	546	573	558	567
Estimated serviced population	1,060	1,116	1,070	1,074	1,090	1,099	1,171	1,139	1,175

This estimated serviced population for 2016 (1,090 people) compares well with the Braidwood UCL private dwelling population from the 2016 census data, in Table 3.2 (1,121 people). The reason it is slightly lower is expected to be because some dwelling types, such as semi-detached row or terrace houses, townhouse, flats or apartment, may not show up as individual residential assessments in the billing data.

3.3 Growth Strategy

The growth strategy nominated for the 30-year planning is detailed below. The information has been obtained from Council planners.

Council has nominated a population growth rate of **1.2% per annum**. The projected number of occupied dwellings in Braidwood serviced by water, based on this growth rate are given in Table 3.4. The number of active residential assessments in the billing data was nominated to be the same as the number of occupied dwellings for the starting point for the projections.

Table 3.4: Projected number of occupied dwellings

Financial Year	19/20 (present)	24/25	29/30	34/35	39/40	44/45	49/50
Occupied dwellings	511	542	576	611	649	689	731

There is expected to be no non-residential growth.

4. Water Demand Analysis

A water demand analysis was undertaken to calculate the unit demands, estimate the non-revenue water and forecast the following demands:

- Average (rainfall) annual demands – for revenue planning
- Unrestricted annual demands – to assess drought security

The 30-year forecasts based on the nominated growth are used to identify the issues in meeting the adopted water supply security objectives of the urban water supply system.

The analysis uses the water production data (that is the water delivered into the system), and the customer billing data (metered consumption by users in the system).

4.1 Water production and customer usage modelling

Modelling of water production data, and the customer billing data was undertaken to understand the impact of various factors/trends (demographic, climatic, economic etc.) on the variability of town water demand. The aim was to develop a model which, when input with historical factors/trends, will output a demand that correlates well with the actual historic production or customer usage.

The factors that were considered were:

- Historical water requirement for grass irrigation (lawns and public open spaces) obtained from **PWA's simulated water use model**. The model uses location-specific historical rainfall and evaporation data, soil type and grass type
- Change in number of assessments (reflecting population growth)
- Water restrictions
- Tourism and change in water usage price (determined to not be significant)

The model was then hind-cast over a 50-year period of available climatic data of temperature and rainfall to estimate the annual demands if the current conditions of lot size, household size, number of assessments, pricing and usage patterns were to prevail. The average year and unrestricted annual demand over the 50-year period were then determined and these demands were used as the starting point for the forecasts.

Details on modelling results for each scheme are available in Appendix A.2.

4.1.1 Modelling of production data

Analysis and modelling were undertaken on the production data. Council provided approximately sixteen years of daily production data, from 1 July 2004 to 25 July 2020.

Council has indicated that low production was recorded during 2011 due to the meter used in the WTP being replaced as a new WTP began operation from the beginning of the 2012 financial year (01/07/2012). Thus, the water production model was developed using WTP production records from 2011/12 to 2018/19. The model was trained over the period from 2011/12 to 2017/18 and tested against the WTP production records from 2018/19. Periods of water restrictions were excluded to estimate the unrestricted production. It was determined that the increase in assessments in Braidwood over this period significantly impacted the water usage.

The modelling showed that the outdoor lawn irrigation was the most significant contributor to the water consumption patterns in Braidwood.

The production model was then hindcast over a 50-year period of available climatic data of temperature and rainfall to estimate the annual demands if the current conditions of lot size, household size, number of assessments and usage patterns were to prevail. The hindcast is shown in Figure 4.1.

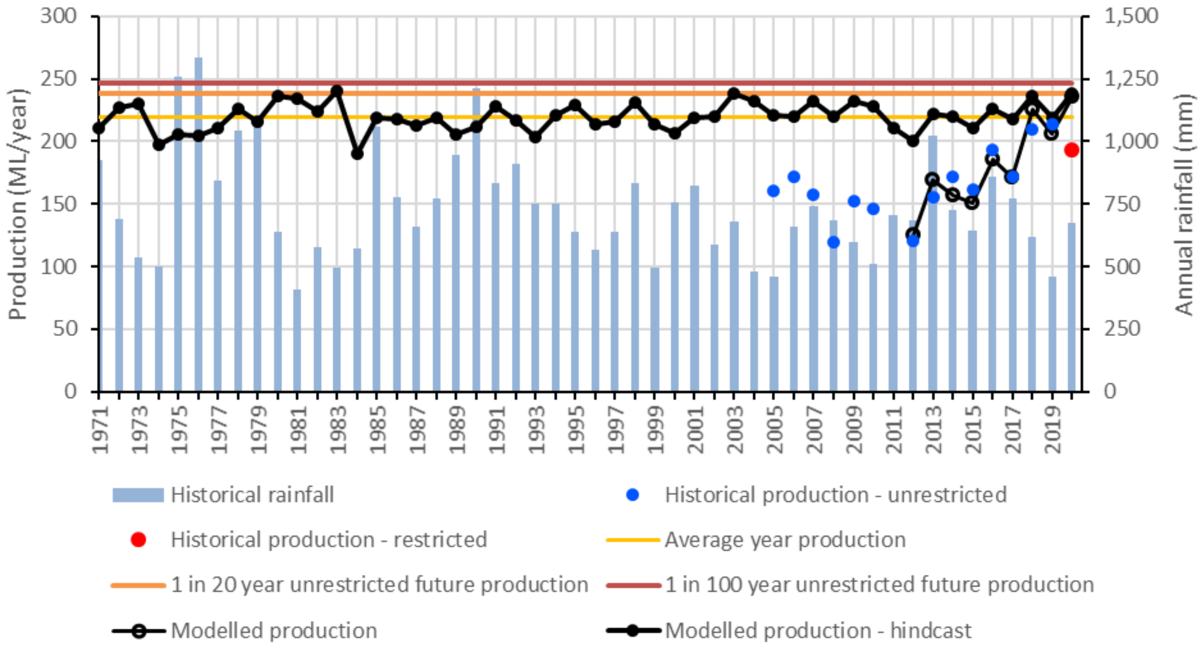


Figure 4.1: Production model hindcast – Braidwood WSS

It is notable that the production prior to 2019 is significantly lower than the hindcast. This is because there was an increase in number of assessments over this period, which was determined to cause a significant increase in production.

For subsequent analysis and as a starting point for forecasts, the 99th percentile (1 in 100 year) production was selected as the unrestricted future production.

The model results, along with the actual average and maximum yearly production from historical data are compared in Table 4.1.

Table 4.1: Modelled unrestricted production compared to actual values - Braidwood WSS

Results from model		Results from historical data (from 2012/13)	
Average year production (ML/year)	Unrestricted future production (ML/year)	Average Year production (ML/year)	Max Year production (ML/year) – 2018/19
219	246	183	214

The model estimates a current average year and unrestricted future year production higher than the historical values, because of the increase in assessments that has occurred over the last several years.

4.1.2 Modelling of customer usage

Customer usage patterns were modelled in a similar way to production data. The modelling showed that the outdoor lawn irrigation was the most significant contributor to the water demand patterns in Braidwood WSS. Increase in assessments was also a significant factor for the water demand.

For subsequent analysis and as a starting point for forecasts, the 99th percentile (1 in 100 year) demand was selected as the unrestricted future demand.

The model results, along with the actual average and maximum yearly demands from historical data are compared in Table 4.2. The historical demand from the user classes *residential* and *parks and gardens*, and the combined *total* historical demand from all user classes was determined to be significantly climate dependent. The historical demand from all other user classes were not significantly climate dependent, and their demand has been grouped under non-residential in the table below.

Table 4.2: Estimated customer usage from climate correction

User Class	Results from model		Results from historical data (from 2012/13)	
	Average Year Demand (ML/year)	Unrestricted future demand (ML/year)	Average Year Demand (ML/year)	Max Year Demand (ML/year) – 2017/18
Residential	85	100	73	87
Parks and Gardens	13	19	11	16
Non-residential	34	38	30	33
Total	131	158	114	136

The model estimates a current average year and unrestricted future year production higher than the historical values, because of the increase in assessments that has occurred over the last several years.

4.2 Effect of Water Restrictions

Severe water restrictions were applied in Braidwood as a result of the cessation of flows within the Shoalhaven River. In the period between early November and mid-February, water restrictions for Braidwood were progressively ramped up to stage 4 (the highest level).

To assess the impact of restrictions, the production model (developed to simulate **unrestricted** production) was hindcast over the restriction period, using historical climate data. The modelled unrestricted production was compared to the actual restricted production to determine the impact that the Restriction Stage had in reducing the production requirements.

Figure 4.2 illustrates the reduction in production due to water restrictions.

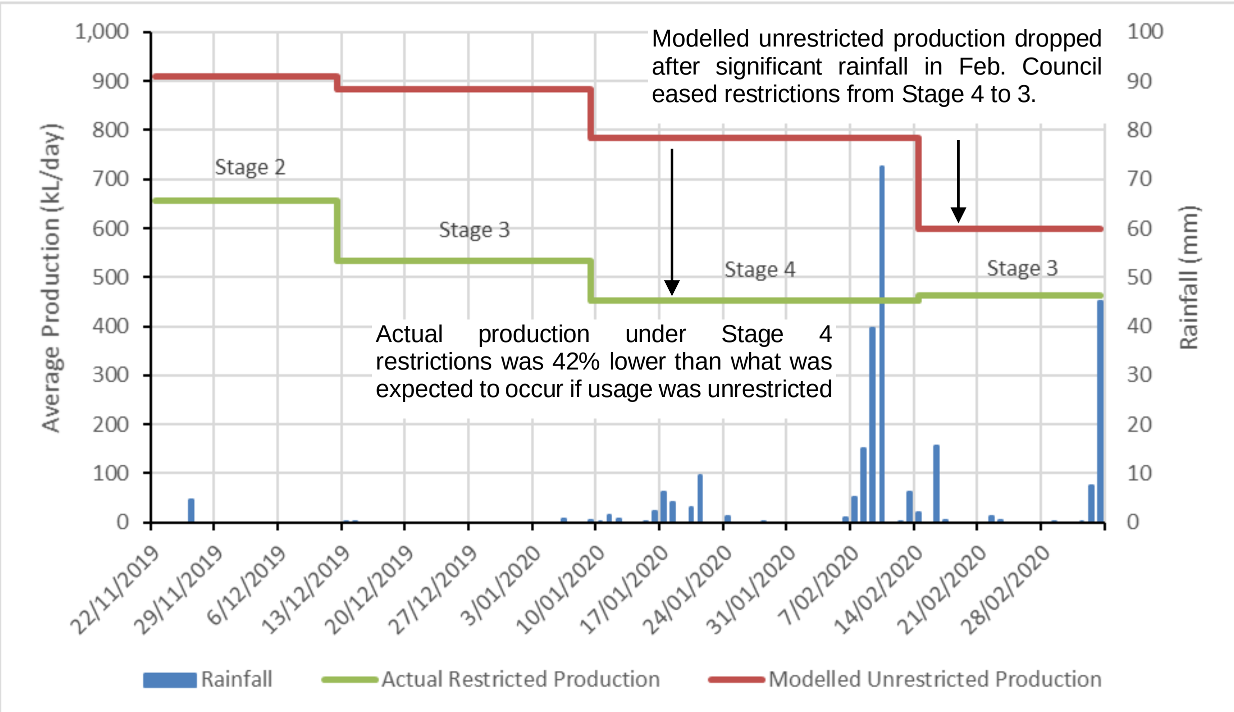


Figure 4.2: Difference between actual restricted and modelled unrestricted production

Table 4.3 below shows the differences in the actual restricted and modelled unrestricted production values, and how this relates to the expected reduction in Council's Water Restriction Measures Policy.

Table 4.3: Comparison of modelled and actual production during Water Restrictions

Water Restriction Stage	Period	Number of Days	Actual Restricted Production (kL/day)	Modelled Unrestricted Production (kL/day)	Demand reduction during restriction period (%)	Target reduction in Council's restriction policy (%)
Stage 2	22/11/2019 – 13/12/2019	21	655	909	28	25
Stage 3	13/12/2019 – 10/10/2020	28	534	883	40	35
Stage 4	10/01/2020 – 14/02/2020	35	452	785	42	55
Stage 3	14/02/2020 – 5/03/2020	20	462	599	23	35

The reduction in demand for Stage 2 and Stage 3 water restrictions had good agreement with the target reduction in Council's Water Restriction Measures Policy. However, this was not the case for the Stage 4 restrictions.

Stage 4 restrictions include measures such as no external watering of lawns and plants using potable water for all types of private and public lawns and gardens, no use of private or public ponds or fountains, no top-up of swimming pools or other water storages, and no washing of vehicles, windows, buildings etc.

It is estimated that if all external demands by parks and gardens, residential and non-residential users were to be taken off the potable water supply, the reduction in demand would be around 40%. This is shown in Table 4.4. This correlates well with the 42% demand reduction during the Stage 4 restriction period.

Table 4.4: Modelled unrestricted future demand by user class for Braidwood WSS (ML/year)

User Class	Baseline internal demand	Climate dependent (external) demand	Total
Residential	66	34	**100**
Parks and Gardens	6	13	**19**
Non-residential	28	10	**38**
Total	**100**	**58**	**158**

Based on the above analysis, a 40% reduction in demand has been used as the target reduction in demand for Stage 4 restrictions in the water security mode, see Section 6. Council has advised that the 55% reduction target in the restriction policy was obtained from an ACTEW (the ACT Government's water authority, now Icon Water) policy which is about 15 years old.

4.3 Effect of Climate Change

To assess likely future water demands that result from climate change, 15 different Global Climate Models (GCMs) based on 1°C warming were used in PWA's simulated water use model described in Section 4.1. DPIE Water provided the dataset which is from the NSW and ACT Regional Climate (NARClim) Model.

The historical water requirements for grass irrigation were calculated using PWA's simulated water use model for each of the GCMs as well as the historical data set. The results were then input to the water production model developed for Braidwood WSS.

The highest result from the 15 different GCM datasets was for the CSIRO data set. The production calculated for the historic climate, compared to the results calculated using the CSIRO dataset for 1-degree warming is shown in Table 4.5.

Table 4.5: Estimated increase in production as a result of climate change (1° warming)

Historic Climate		CSIRO 1-degree warming scenario	
Average year production (ML/year)	Unrestricted future production (ML/year)	Average year production (ML/year)	Unrestricted future production (ML/year)
219	246	225 (3% increase)	252 (2% increase)

4.4 Residential unit demands

The residential unit demands for each scheme were assessed by climate correcting historical data for active residential assessments. Using a threshold of 60 L/assessment/day for an active connected residential property resulted in 90% of the assessments in Braidwood WSS being active.

The residential unit demands are given in Table 4.6.

Table 4.6: Unit demand per active residential assessment

Average Year Demand (kL/year)	Unrestricted Future Demand (kL/year)	Average Day Demand (kL/day)	Peak Day Demand (kL/day)	Baseline Internal Demand (kL/day)	Baseline Internal demand per person (kL/day)
170	185	0.47	1.16	0.40	0.17

The baseline internal demand of 170 L/person/day corresponds to the usage from a house with an average 2 Star fittings and appliances WELS rating. There is potential to further reduce residential internal demand using water efficient fittings and appliances.

4.5 Projections

The demands estimated from climate correcting production and customer usage are used as the starting point for projections.

The residential demand is projected by multiplying the estimated increase in occupied residential dwellings (see Table 3.4) by the residential unit demand calculated for Braidwood (see Table 4.6). The non-residential demand was not projected to increase based on Council's advice that no non-residential growth is expected.

The customer usage projection for average annual demand and unrestricted future annual demand is given in Table 4.7.

Table 4.7: Braidwood WSS customer usage projection (ML/year)

Financial Year	‘20	‘25	‘30	‘35	‘40	‘45	‘50
Average Year Demand							
Residential	85	90	96	102	108	115	122
Parks and Gardens	13	13	13	13	13	13	13
Non-residential	34	34	34	34	34	34	34
Total	131	136	142	148	154	161	168
Unrestricted Future Demand							
Residential	100	106	113	120	127	134	143
Parks and Gardens	19	19	19	19	19	19	19
Non-residential	38	38	38	38	38	38	38
Total	158	164	170	177	184	192	200

The water production is projected by adding a baseline NRW of 257 L/assessment/day, calculated in Section 2.1.3.2, to the customer usage. The production projection is shown in Appendix A.3.

The forecast average and unrestricted annual water extraction is given in Table 4.8 for the historical climate and the 1°C climate warming. An allowance of 7% is added to the production to account for losses within the WTP, to obtain the extraction.

Table 4.8: Braidwood WSS water extraction projection

Financial Year	‘20	‘25	‘30	‘35	‘40	‘45	‘50
Historical climate							
Average Year Extraction (ML/year)	235	244	253	263	274	285	297
Unrestricted Future Extraction (ML/year)	264	273	283	294	306	318	331
1°C climate warming							
Average Year Extraction (ML/year)	241	250	260	270	281	292	305
Unrestricted Future Extraction (ML/year)	270	279	290	301	313	325	338

5. Water security assessment

5.1 Secure Yield Studies

A Secure Yield Study was undertaken in 2015 by NSW Urban Water Services (NUWS), to estimate the secure yield of Braidwood off-stream storage based off historical streamflows. The secure yield was estimated to satisfy the 5/10/10 rule set out in DPIE Water's draft guidelines for "*Assuring future urban water security – Assessment and adaption guidelines for NSW local water utilities*". Following the extreme drought conditions that led Council to apply severe water restrictions in Braidwood over the summer of 2019/20, Council requested the secure yield be re-examined by including data from the more recent weather patterns.

NUWS updated the secure yield estimates based on extending the flow series used for the 2015 Yield Study from 29/3/2015 to 6/7/2020. The updated secure yield results are provided in Table 5.1 together with the previous secure yield estimates. The results show about a 20% reduction in estimated secure yield has occurred since the 2015 study.

Table 5.1: Braidwood off stream storage secure yield estimate summary

System	Case	Secure Yield (5/10/10) ML/a
2015 Yield Study	Historic Climate 1890 - 2015 streamflows	394
	1°C climate warming	357 (9.4% reduction)
Current 2020 Yield Study	Historic Climate 1890 - **2020** streamflows	334
	1°C climate warming	320 (4.2% reduction)

Current 2020 Yield Study – Historic Climate 1890 - 2020 streamflows

The Braidwood off-stream storage volume is 72 ML, and Council operates the storage such that when the level drops to around 95% (68 ML) water is pumped from the Shoalhaven River to refill the storage. Figure 5.1 provides the storage behaviour diagram for a repeat of the historic climate while meeting the demand equivalent to the secure yield (334 ML/year).

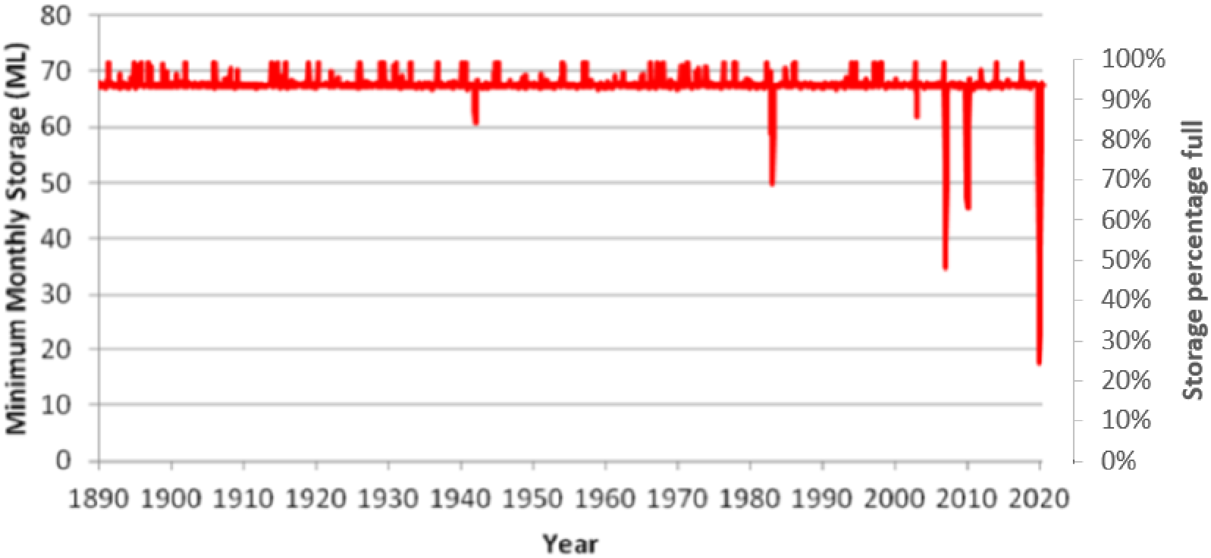


Figure 5.1: Modelled Braidwood storage behaviour diagram when supplying a secure yield of 334 ML/year

The storage behaviour diagram shows that the 2019/2020 drought is the critical drought. With this restriction regime, the storage would draw down to about 25% for the 2019/2020 drought based on the 5/10/10 operating rules.

5.2 Water Security Assessment

Water for Braidwood Water Supply Scheme is sourced from the Shoalhaven River with a WAL entitlement of 360 ML/year (from Table 2.7). The secure yield was estimated to be 334 ML/year for the historical climate, and 320 ML/year for 1°C climate warming (from Table 5.1).

The water security was assessed by comparing the forecasted dry year extraction (for both historical climate and 1°C climate warming) with the respective secure yields for Braidwood off-stream storage. The results are shown in Figure 5.2.

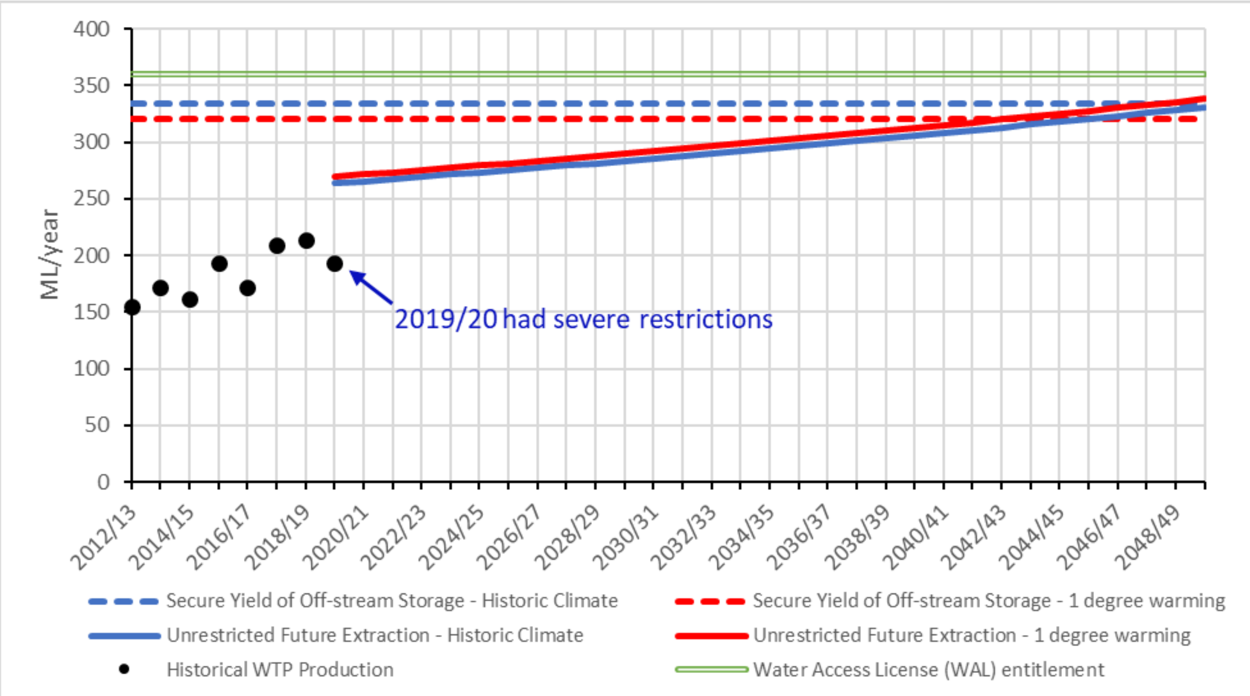


Figure 5.2: Braidwood water supply - projected dry year extraction compared to Secure Yield

The WAL entitlement is not expected to be exceeded in the next 30 years. However, the forecast unrestricted annual extraction is expected to exceed the secure yield for the 1°C climate warming around 2043.

6. Short Term Drought Contingency Planning

Over the past summer (2019/20) Braidwood experienced some severe water restrictions as a result of the cessation of flows within the Shoalhaven River. In the period between early November and mid-February, water restrictions for Braidwood were progressively ramped up to stage 4 (the highest level). At this time Council were manually pumping natural water holes within the Shoalhaven to the pump suction hole. By early February Council had started carting water from Bungendore to Braidwood under the State's subsidised arrangements.

At the time Council did not know how long the drought was going to persist and did not have a drought contingency plan which includes water restriction triggers based on levels in the storage, to ensure that the town did not run out of water.

Part of the short-term solution is to develop a restriction implementation plan for the Braidwood water supply based on the levels in the storage. This will also provide Council with the necessary lead time to implement actions to ensure the town does not run out of water.

Proposed restriction policy

A proposed restriction policy (which gives restriction triggers based on dam level and associated target reduction in demand) was developed to determine trigger levels for restrictions. The target reductions in demand are taken from Council's Water Restriction Measures Policy, except for the Stage 4 reduction which has been nominated as 40% reduction instead of 55% reduction. This is explained in Section 4.2.

An iterative process was used to develop a restriction policy. The process was informed by the following conditions:

Condition 1 – Avoid Stage 4 restrictions if possible, as this is severe and provides Council with something in reserve should any future drought be significantly worse.

Condition 2 – Restrictions satisfy the 5/10/10 rule as closely as possible noting that any future drought may be more severe than those on record.

Condition 3 – The time between different restriction levels and triggers is maximised. This condition means that Council will have as much lead time as possible to communicate with the community before moving on to a higher restriction level.

The nominated trigger levels are given in Table 6.1.

Table 6.1: Proposed restriction policy

Restrictions	Unrestricted	Stage 1	Stage 2	Stage 3	Stage 4
Trigger dam level (% full)		85%	75%	65%	50%
Target reduction in demand	0%	10%	25%	35%	40%
Annual future extraction (ML/a)	270	243	203	176	162

Figure 6.1 provides the modelled Braidwood off-stream storage behaviour diagram applying the proposed restriction policy for an unrestricted extraction of 270 ML/a for the existing Braidwood headworks system for a repeat of the historic climate (1890-2020). The historical climate was used in the simulation as this is being assessed as a short-term solution. The report by *NSW Urban Water Services* is given in Appendix B.

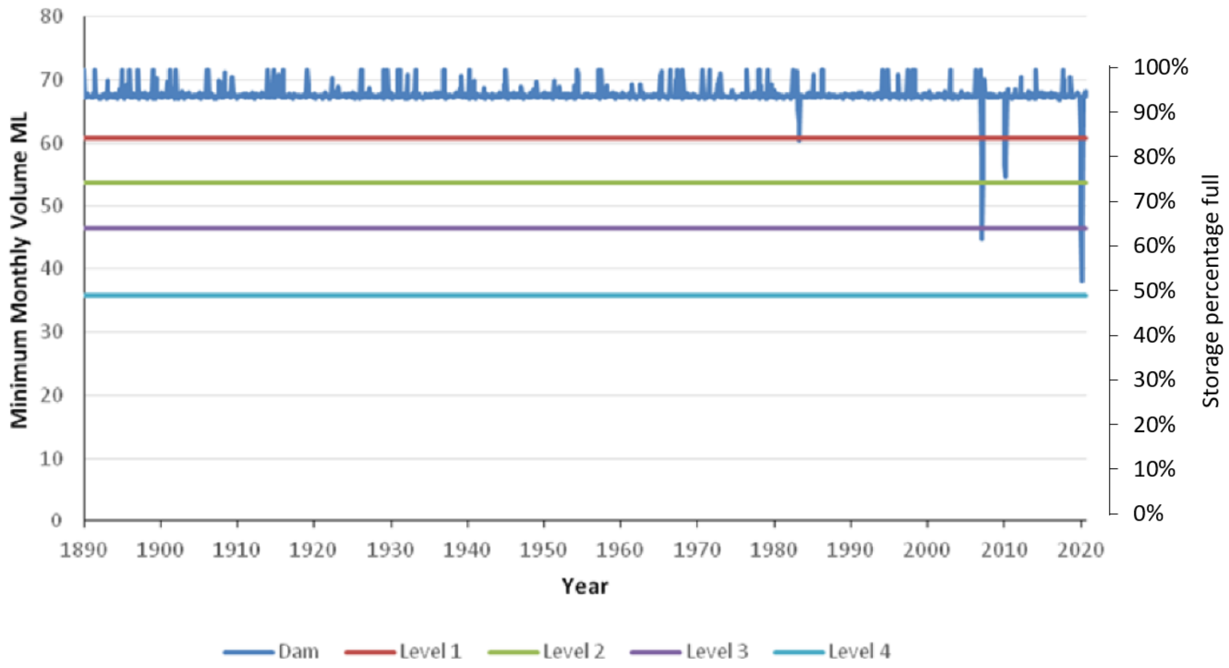


Figure 6.1: Modelled storage level in Braidwood Dam – extraction of 270 ML/year with proposed restriction policy

With this restriction regime, the storage would draw down to 52% for a repeat of the 2019/2020 (critical) drought. This compares to a storage drawdown to about 25% (Figure 5.1) for the 2019/2020 drought based on the 5/10/10 operating rules. A discussion on how these triggers relate to the conditions specified, is provided below:

Condition 1 - Stage 4 restrictions would not be implemented during any drought from 1890 to 2020

Based on the modelling, the dam level reached the proposed trigger level for restrictions during four droughts, in 1983, 2006/07, 2009/10, and 2019/20. The trigger for Stage 4 restrictions was not reached during any drought.

Condition 2 - Restrictions meet the first two criteria of the 5/10/10 rule

Table 6.2 summarises the application of restrictions from modelling the proposed regime for an annual demand of 270 ML/a for a repeat of the historic climate (1890-2020) and compares them with those for the 5/10/10 rule.

Table 6.2: Restrictions Comparison – Proposed Policy with Historic Climate

Case	Duration of restrictions % of time	% of years with restrictions applied	Restrictions on demand %
5/10/10 rule	5	10	10
Proposed policy for 270 ML/a for historic climate	0.38 [1]	3.1 [2]	18.5 [3]

1. Based on model results of 180 days on restrictions out of a total of 47,482 days (130 years) modelled
2. Restrictions in four water years (1983/84, 2006/07, 2009/10, and 2019/20) out of 130 years modelled
3. Average based on model results of 100 days on Stage 1 restrictions (10% reduction in demand), 47 days on Stage 2 (25%), 33 days on Stage 3 (35%) and 0 days on Stage 4 (50%) restrictions

The proposed restriction policy meets the first two criteria of the 5/10/10 design planning rules but does not meet the last criteria. It is noted however that the third criteria is not fully comparable as the third criteria allows for a much worse drought then has occurred in the past (1890-2020) and uses a constant demand reduction.

Condition 3 - The time at each Stage of restrictions before the next trigger level is met is maximised

The time before each trigger level is met for the 2019/20 drought is shown in Figure 6.2.

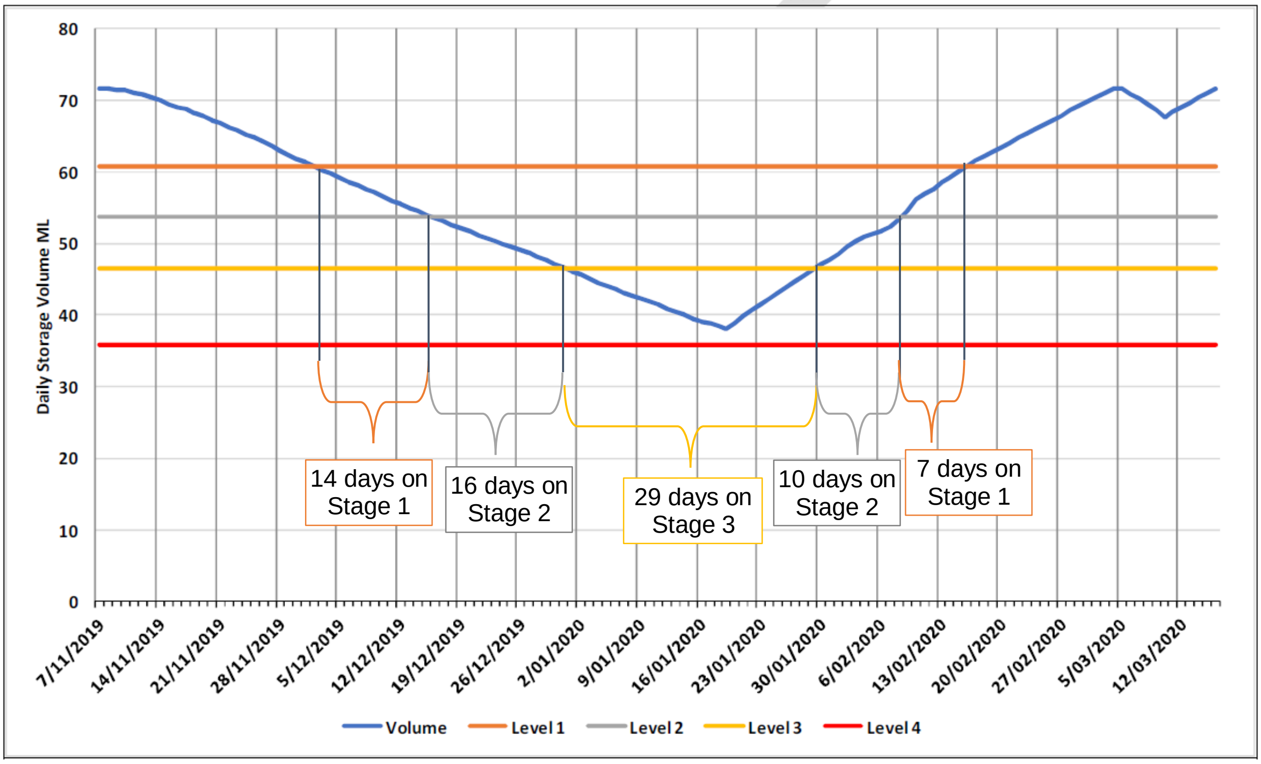


Figure 6.2: Braidwood storage volume during 2019/20 drought with proposed restriction policy

In addition to the using the dam levels as triggers Council can, as part of their drought contingency planning, use the levels in the Shoalhaven River as an indicator to begin preparing for restrictions by communicating with the community. Based on a desktop analysis of historical stream flows at River Gauge 215002 (Shoalhaven River at Warri) which is the closest to Braidwood, for the past four droughts (1983, 2006/07, 2009/10, and 2019/20) the level in the river drops to 0.3 m about one month before the Stage 1 trigger level in the storage was met. Council may use such a trigger to begin communicating to the public that restrictions may soon be put in place.

The river levels for each year since 1980 are shown in Figure 6.3.

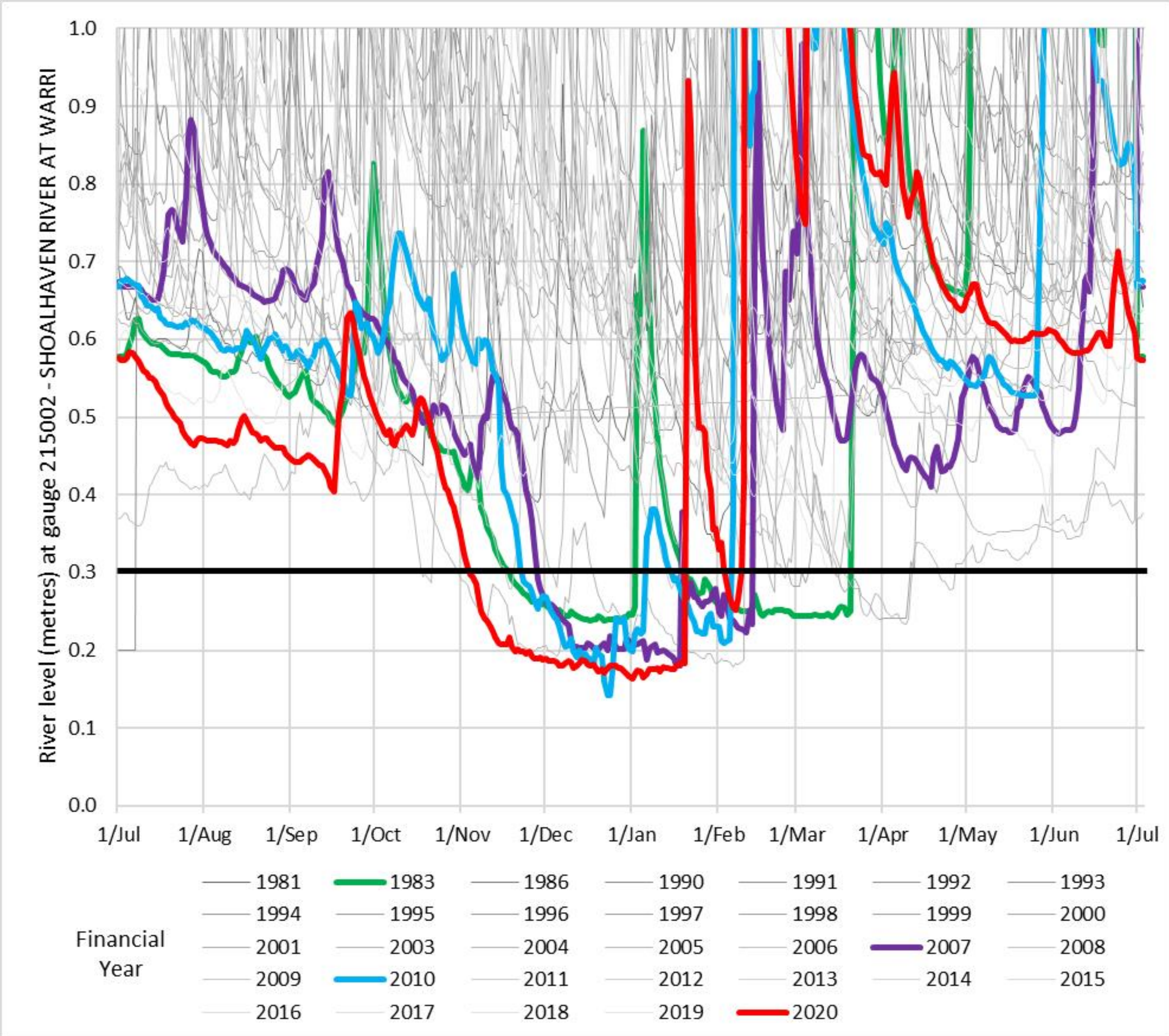


Figure 6.3: Historical river level (metres) recorded at gauge 215002 - Shoalhaven River at Warri, showing four droughts that triggered restrictions

It should be noted that there are years where the river level dropped below 0.3 m but the restriction trigger level in the storage was not reached.

7. Long Term Water Security

7.1 Reduction in Non-revenue Water

As discussed in Section 2.3.2, the NRW for Braidwood is estimated to be around 36% of the annual WTP production. Typical NRW for water supply schemes is around 10 to 15% of annual production. PWA have confirmed with Council, using night-time reservoir telemetry data, that actual losses in the system are close to the NRW volumes estimated by PWA, indicating significant real losses in the system. These losses could be network losses or customer service line leakage.

The high NRW presents an opportunity for Council to significantly reduce the forecast water extraction from the Braidwood off-stream storage. Council has indicated that they aim to reduce NRW to 20% in the short term. If this occurs, the 30-year forecast extraction (for the 1°C climate change scenario) would be less than the climate change secure yield of the headworks. This means that the existing headworks would be sufficient to provide water security to Braidwood for the 30-year planning horizon.

The unrestricted future extraction from Braidwood off-stream storage for the current and reduced NRW is shown in Table 7.1. The Table also shows the forecast extraction for Council's short term aim of NRW as 20% of annual production, and best practise of NRW as 10% of annual production.

Table 7.1: Unrestricted Future Extraction from Braidwood off-stream storage with 1 degree climate warming for different NRW scenarios (ML/year)

Financial Year	'20	'25	'30	'35	'40	'45	'50
Current NRW (36% annual production)	270	279	290	301	313	325	338
Reduced NRW (20% annual production)	215	223	232	241	251	261	272
Best practise NRW (10% annual production)	192	199	206	214	223	232	242

The above projected future extraction volumes are shown against the secure yield calculated for Braidwood off-stream storage of 320 ML/year (from Section 5) in Figure 7.1.

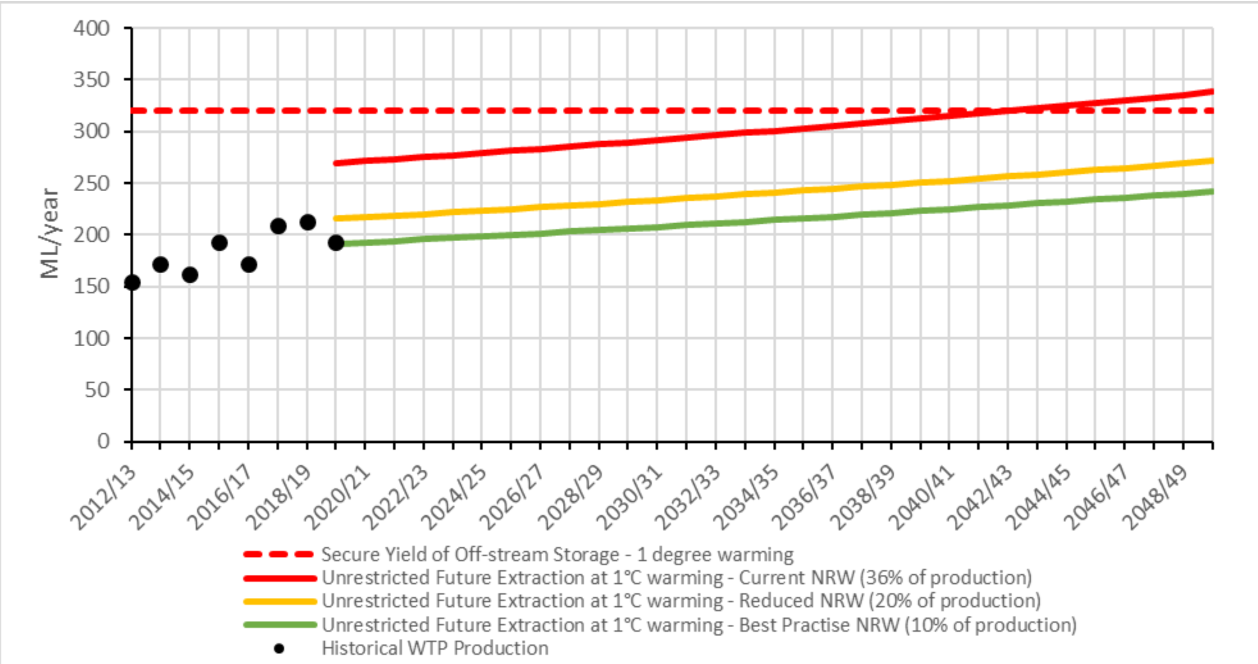


Figure 7.1: Projected dry year extraction for Braidwood compared to Secure Yield for different NRW scenarios

7.2 Effect of Climate Change

To assess the impact that climate change will have on the long-term water security, the future unrestricted extraction (with Council's aim reduction of NRW as 20% of annual production) and the proposed water restriction policy were simulated using river flows reduced to allow for 1°C climate warming. The report by *NSW Urban Water Services* is given in Appendix B.

Restrictions

The nominated trigger levels are given in Table 6.1.

Table 7.2: Proposed restriction policy – 2050 future extraction

Restrictions	Unrestricted	Stage 1	Stage 2	Stage 3	Stage 4
Trigger dam level (% full)		85%	75%	65%	50%
Target reduction in demand	0%	10%	25%	35%	40%
2050 annual future extraction (ML/a)	272	245	204	177	163

Simulating 1°C climate warming

The 15 different Global Climate Models (GCMs) described previously estimated changed climate values only until 2008, and therefore did not capture the recent critical drought. Thus the GCMs would not be useful in examination of the proposed restriction regime.

To resolve this, the climate values (i.e. rainfall and evaporation) were not used to estimate changed stream flows, and instead historical stream flows were reduced by 20%.

The simulated secure yield using the GCMs to 2008 is 4.2% lower than the secure yield using historic data, see Table 5.1. The simulated secure yield using stream flows reduced by 20% is 7.6% lower than the secure yield using historic data. Therefore the 20% reduction in stream flows appears to be a reasonable conservative estimate to reflect 1°C climate warming.

Results

Figure 7.2 provides the modelled Braidwood off-stream storage behaviour diagram applying the proposed restriction policy for an unrestricted extraction of 272 ML/a for the existing Braidwood headworks system for 1°C climate warming.

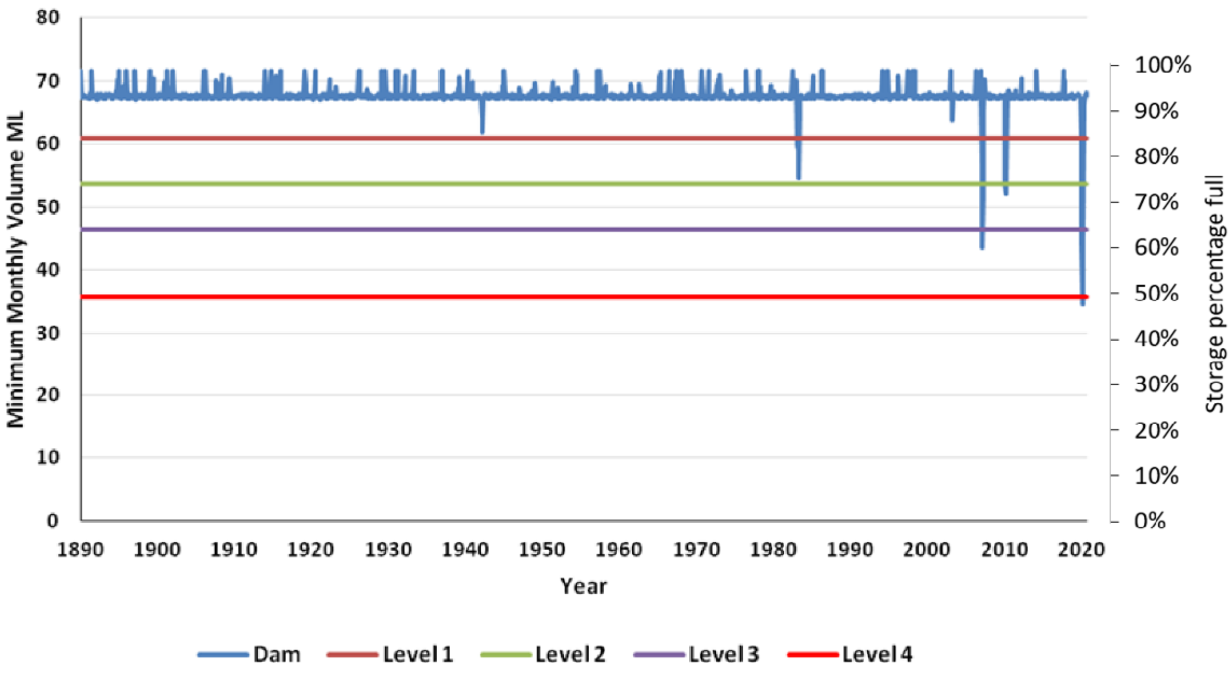


Figure 7.2: Modelled storage level in Braidwood Dam – extraction of 272 ML/year with proposed restriction policy and 1°C climate warming.

With this restriction regime, the storage would draw down to 48% for a repeat of the 2019/2020 (critical) drought. This compares to a storage drawdown to about 52% (Figure 6.1) for the 2019/2020 drought based off the modelling for the historic climate.

Table 7.3 summarises the application of restrictions from modelling the proposed regime for an annual demand of 272 ML/a for a 1°C warmer climate and compares them with those for the 5/10/10 rule.

Table 7.3: Restrictions Comparison – Proposed Policy for unrestricted future extraction and 1°C climate warming

Case	Duration of restrictions % of time	% of years with restrictions applied	Restrictions on demand %
5/10/10 rule	5	10	10
Proposed policy for 272 ML/a for historic climate *(flows reduced by 20%, assumed to reflect 1°C climate warming)*	0.52 [1]	3.1 [2]	18.8 [3]

1. Based on model results of 246 days on restrictions out of a total of 47,482 days (130 years) modelled
2. Restrictions in four water years (1983/84, 2006/07, 2009/10, and 2019/20) out of 130 years modelled
3. Average based on model results of 134 days on Stage 1 restrictions (10% reduction in demand), 65 days on Stage 2 (25%), 43 days on Stage 3 (35%) and 4 days on Stage 4 (50%) restrictions

The 1°C climate warming does not appear to have a large effect on duration of restrictions. The most notable change compared to the restriction policy using the historical climate (see Table 6.2) is that the Stage 4 restriction is triggered, albeit for only four days.

The proposed restriction policy meets the first two criteria of the 5/10/10 design planning rules but does not meet the last criteria. It is noted however that the third criteria is not fully comparable as the third criteria allows for a much worse drought then has occurred in the past (1890-2020) and uses a constant demand reduction. This is the same as for the historic climate.

8. References

[1] NSW DPI Water, “2014-15 NSW Water Supply and Sewerage Benchmarking Report,” 2016.

[2] UTS Institute for Sustainable Futures, “LWU Options: System Water Efficiency Estimation Tool "SWEET",” 2020.

[3] D. Fitzgerald, “An investigation into factors influencing participation in water-conservativ programs: Participation in Victoria's Showerhead Exchange Program,” 2019.

[4] Australian Arid Lands Botanic Garden, “AridSmart Display Gardens,” [Online]. Available: https://www.aalbg.org/aridsmart-display-gardens.html. [Accessed 7 October 2020].

[5] Richmond Valley Council, “Water and Sewer Strategic Plan,” 2018.

[6] “NSW Guidance for Recycled Water Management Systems,” Department of Primary Industries.

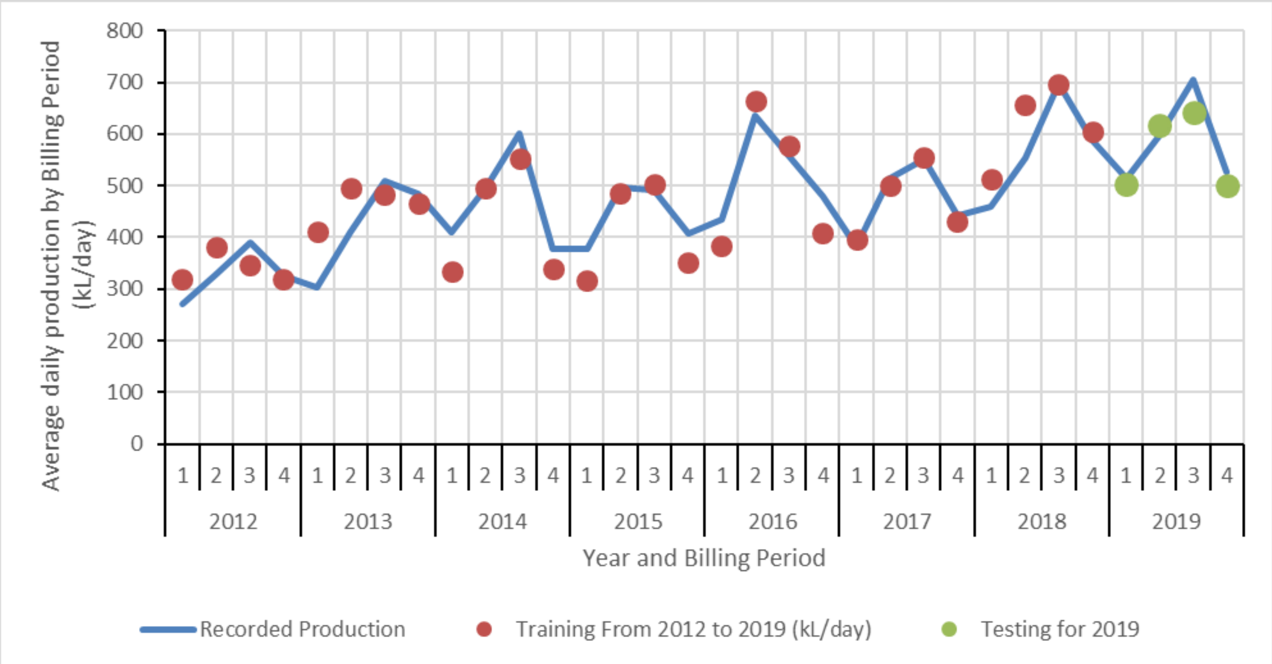
Appendix A Water Demand Analysis – additional information

A.1 Non-revenue water

Financial Year	‘12	‘13	‘14	‘15	‘16	‘17	‘18	‘19	‘20
Production (ML/year)	120.3	155.3	171.9	161.7	193.0	172.3	209.6	213.5	193.7
Customer Usage (ML/year)	97	109	114	104	123	112	136	132	118
Standpipe Usage (ML/year)	0	0	0	0	0.7	1.5	2.6	2.5	4.0
NRW (ML/year)	24	46	58	58	69	59	71	79	71
NRW (% of production)	20%	30%	34%	36%	36%	34%	34%	37%	37%
Assessments	595	617	617	609	624	633	663	646	655
Unit NRW (L/assessment/day)	109	206	257	260	302	254	295	335	298

A.2 Production Modelling

Using the climate correction methodologies, the model was found to be highly significant with R^2 values of 0.80.



Appendix Figure A-1: Braidwood production modelled with irrigation and EC - R^2 = 0.80

The model was trained over an unrestricted period (2012 – 2018). The tested data has an R squared value of 0.85 against the actual data.

A.3 Braidwood WTP production projection

The production projection values before factoring in the extraction factor are displayed in Appendix Table 1-1 below.

Appendix Table 1-1: Braidwood WTP production projection

Financial Year	'20	'25	'30	'35	'40	'45	'50
Historical climate							
Average Year Production (ML/year)	219	228	236	246	256	266	277
Unrestricted Future Production (ML/year)	246	255	265	275	286	297	309
1^0C climate warming							
Average Year Production (ML/year)	225	234	243	252	262	273	285
Unrestricted Future Production (ML/year)	252	261	271	281	292	304	316

Appendix B Secure Yield Reports

working together to ensure water supply security

NUWS

NSW Urban Water Services

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BRAIDWOOD WATER SUPPLY

Second Addendum to Captains Flat and Braidwood Yield Study Report

Prepared for
Public Works Advisory on behalf of
Queanbeyan-Palerang Regional Council

Report No. 14024 (Second Addendum) Draft 1.0
December 2020
NSW Urban Water Services Pty Ltd

SECOND ADDENDUM TO REPORT:

PALERANG COUNCIL WATER SUPPLY, Captains Flat and Braidwood Yield Study Report, Prepared by NSW Urban Water Services for Palerang Council
Report No: 14013, December 2015

Summary

As part of the hydrology modelling undertaken for developing the Drought Management Plan for Braidwood Water supply Scheme two conditions used for the previous yield modelling were updated and thus the secure yield was updated (*from that given in the July 2020 Addendum*).

The two updated conditions are:

1. Pumping from the river recommences when storage falls to 95% full (and ceases when 100% full) previously pumping recommenced when storage was 90% full.

2. Updated storage volume surface area data were provided with different surface areas. For example current surface area at full (71.549 ML) is 12,732 m^2 whereas previously it was at full (72.88 ML) 13,291 m^2. The updated data are provided in Table 2.

This Addendum provides the updated secure yield estimates based on using the updated conditions.

The updated data has led to a slight increase in secure yield from the slight increase in effective storage volume (at the start of a drought) and or a slight reduction in evaporation loss from reduced surface areas.

The updated secure yield results are provided in Table S1 together with the previous secure yield estimates. It shows about an 8% increase in secure yield for the historic climate and an increase of about 14% for the 1 ^{o}C climate warming scenario.

Table S1: Braidwood Secure Yield Estimates

System	Secure Yield (5/10/10) ML/a	Case
July 2020 Yield Study Addendum:		
Existing *(72.88 ML offstream storage)*	**310**	Historic Climate 1890 -2020 streamflows
Existing *(72.88 ML offstream storage)*	**281**	1^{o}C climate warming
December 2020 Yield Study Addendum (Current):		
Existing *(71.55 ML offstream storage)*	**334**	Historic Climate 1890 -2020 streamflows
Existing *(71.55 ML offstream storage)*	**320**	1^{o}C climate warming

The results are dependent on the operating rules, data and assumptions as discussed in the previous NUWS report and Addedum:

1. *PALERANG COUNCIL WATER SUPPLY, Captains Flat and Braidwood Yield Study Report, Prepared by NSW Urban Water Services for Palerang Council, Report No: 14013, December 2015*

2. *BRAIDWOOD WATER SUPPLY, Addendum to Captains Flat and Braidwood Yield Study Report, Prepared by NSW Urban Water Services for Public Works Advisory on behalf of Queanbeyan-Palerang Regional Council, Report No: 14024(Addendum) July 2020.*

The yield modelling essentially used the methodology given in DPIE Water/ NSW Office of Water's[1] (NOW) Draft (December 2013) guidelines "*Assuring future urban water security - Assessment and adaption guidelines for NSW local water utilities.*"

Qualifications

The work contained in this Addendum is considered valid within the context of the study purposes, but caution should be exercised if aspects of this Addendum, including data and estimates, are abstracted out of context or are to be used for some other purpose. Hydrology is not an exact science and necessarily involves some uncertainty and the results should be regarded as estimates within the limitations of the study and available data to be used as indications in a much larger decision making process.

The yield of a headworks system is dependent on the assumed streamflows and operating constraints. For this study observed streamflows were provided by others and the operating constraints are as specified. While the yield estimates are based on established methodology, NSW Urban Water Services Pty Ltd does not warrant or accept any liability in relation to the quality or accuracy of the yield estimates which are reliant on provided information and no responsibility is accepted by NSW Urban Water Services Pty Ltd for the accuracy, currency, reliability and correctness of any information in this publication provided by the client or third parties.

It is noted that the approach used to develop the required hydrometeorological data was designed to be commensurate with determining Secure Yield (which is a defined term) for feasibility purposes for this Study and thus may not necessarily be appropriate for other models or purposes.

1. *NSW Office of Water roles migrated to NSW Department of Planning, Industry and Environment (DPIE) over 2017-2019.*

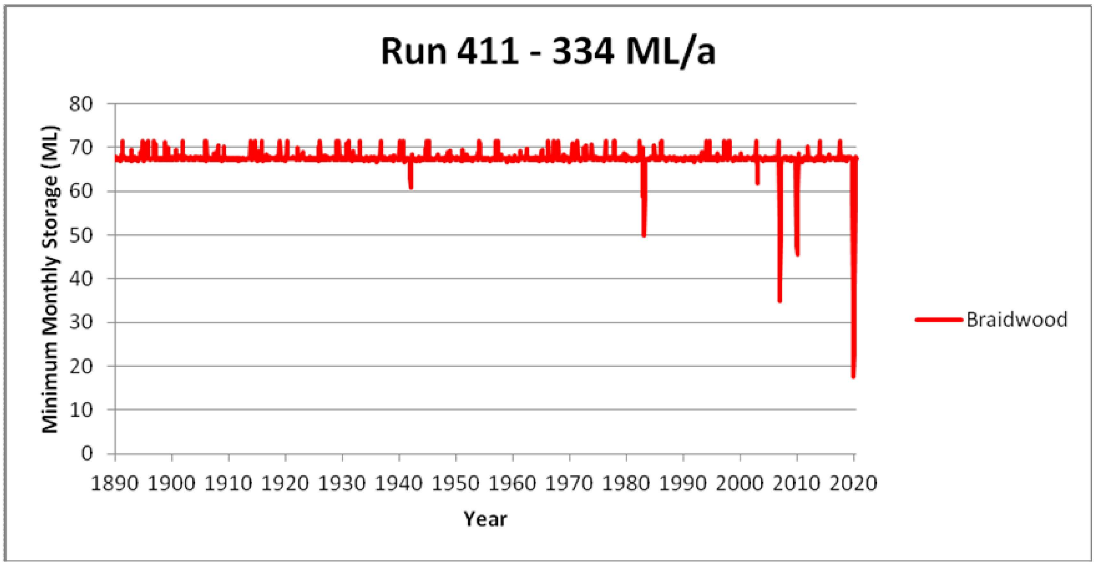
Modelling

Table 1 provides the secure yield results for the new conditions and Figure 1 provides the storage behaviour diagram for a repeat of the historic climate while meeting the demand equivalent to the secure yield (*with restrictions in accordance with 5/10/10 rules*).

Table 1: Secure Yield Results (Historic Climate)

Run No.	Storage Use	Secure Yield (ML/a)	Restrictions			Critical Drought	
			Applied at storage (% full)	Duration (%)	% of Years	From	To
Run 411	*Pumping stops when storage 100% full and re-starts when it drops to 95% full*	**334**	85	0.79	3.03	26/10/2019	19/01/2020
Flow Series BRWOOD2-UPD Off stream Storage Size 71.55 ML 0 ML/d Releases							

Figure 1: Storage Behaviour Diagram – Run 411



Details of the climate change methodology and data are provided in the original 2015 Yield Study report. The individual results for the 15 GCMs and corresponding historic data base are provided in Attachment A. Following the methodology the adjustment factor (0.9592) for climate change was based on the ratio of the median GCM (470 ML/a) to the historic data base (490 ML/a). The median GCM value was used as it was lower than the lowest GCM with 10/15/25 rule.

Table 2 provides the updated storage data used.

Table 2: Storage Area Data

Height m	Storage ML	Storage Area m^2
704.37	0.00	0
704.5	0.01	613
704.75	0.66	3314
705	1.55	3781
705.25	2.54	4132
705.5	3.62	4451
705.75	4.77	4751
706	5.99	5044
706.25	7.29	5335
706.5	8.66	5627
706.75	10.10	5910
707	11.61	6178
707.25	13.19	6438
707.5	14.83	6691
707.75	16.54	6945
708	18.30	7205
708.25	20.14	7469
708.5	22.04	7740
708.75	24.01	8020
709	26.05	8304
709.25	28.16	8593
709.5	30.35	8881
709.75	32.60	9167
710	34.93	9457
710.25	37.33	9759
710.5	39.81	10058
710.75	42.36	10358
711	44.99	10656
711.25	47.69	10956
711.5	50.46	11251
711.75	53.31	11530
712	56.23	11767
712.25	59.19	11971
712.5	62.21	12166
712.75	65.28	12358
713	68.39	12546
713.25	71.55	12732

Source: PWA 27/11/2020

Recommendations

The results presented in this Addendum should be used keeping in mind the assumptions on which the estimates are based.

ATTACHMENT A
Model Results for 15 GCMs and corresponding Historic Base

Note that in each case shown on the following pages the data is based on modelled flow information (from a data base of daily rainfall and daily evapotranspiration) and not observed flow data. The adopted historical secure yields uses a longer period and are those in Table 1 . The following data is normally used to adjust the yields in Table 1 in accordance with the DPIE Water Guidelines

BraidwoodNew, Run 411CC F:\Results\Braidwood\Data\CLIMATE\brwood_

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					Restricted		Critical Drought	
	Run	Storage Capacity	Secure Yield	% Restricted at	% of duration	% of years	Start	End
HISTORICAL	1	71.549	490	75	0.73	9.57	15/10/1928	11/02/1929
	2	71.549	487	75	0.59	3.48	15/10/1928	11/02/1929
	3	71.549	479	80	0.67	7.83	15/10/1928	11/02/1929
LOWEST	4	71.549	435	85	0.71	3.48	03/12/1928	11/02/1929
	5	71.549	452	85	0.97	6.96	10/12/1928	11/02/1929
	6	71.549	459	85	0.74	9.57	15/10/1928	11/02/1929
MEDIAN	7	71.549	470	80	0.64	3.48	15/10/1928	11/02/1929
	8	71.549	474	80	0.64	3.48	15/10/1928	11/02/1929
	9	71.549	455	85	0.73	6.96	15/10/1928	11/02/1929
	10	71.549	480	80	0.79	9.57	15/10/1928	11/02/1929
	11	71.549	475	80	0.59	1.74	15/10/1928	11/02/1929
	12	71.549	466	80	0.61	2.61	15/10/1928	11/02/1929
	13	71.549	449	85	0.63	3.48	03/12/1928	11/02/1929
	14	71.549	460	85	0.78	9.57	15/10/1928	11/02/1929
	15	71.549	489	75	0.79	8.70	15/10/1928	11/02/1929
	16	71.549	479	80	0.63	7.83	15/10/1928	11/02/1929
10/15/25	4	71.549	481	80	0.72	14.78	15/10/1928	11/02/1929

.

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Braidwood Drought Management Plan – Hydrology Modelling Report

Prepared for Public Works Advisory on behalf of Queanbeyan-Palerang Regional Council

Report No. 20010 Draft 2.0
December 2020
NSW Urban Water Services Pty Ltd

Summary

Queanbeyan-Palerang Regional Council are in the process of developing a Drought Management Plan for Braidwood water supply and as part of this required modelling of their water supply headworks system for nominated restriction regimes to assess the performance of these regimes.

NSW Urban Water Services (NUWS) were engaged through Public Works Advisory (PWA) to run the Braidwood Headworks System Model that NUWS had previously used to model the system secure yield for Braidwood water supply.

This report summarises the modelling undertaken and provides the results for assessing the performance of the restriction regimes.

Headworks System Model

The Headworks System Model was developed to assess the secure yield of the Braidwood water supply headworks system. Details of the model, data used and assumptions are provided in the NUWS 2015 Report *"Palerang Council Water Supply, Captains Flat and Braidwood Yield Study Report",* (*Report No. 14013, December 2015), prepared for Palerang Council and the July 2020 and December Addendums to that report (Report No 14024) prepared for Queanbeyan-Palerang Regional Council.*

Essentially the model is a computer program that balances continuity equations between all the water sources and demands while incorporating the defined procedures to determine *secure yield*. The model simulates on a daily basis the behaviour of the system by accounting for and balancing the available water. The hydrological cycle is modelled external to the model and the required hydrometeorological data is provided as input to the system behaviour model. In essence the system model is driven by operating conditions such as the need to meet a particular demand while satisfying constraints such as environmental flow objectives and available flow.

Secure Yield

For the past 25 years or so most urban water supply headworks in country NSW have been sized on a robust Security of Supply basis. This security of supply basis was developed to cost-effectively provide sufficient dam storage capacity to allow the water utility to effectively manage its water supply in future droughts of greater severity than experienced over the past 100 or more years. '*Secure Yield*' is the water demand that can be expected to be supplied with only moderate restrictions during a significantly more severe drought than has been experienced since about 1895 (from when generally reliable rainfall records are available). The required water restrictions must not be too severe, not too frequent, nor of excessive duration. It has been argued that the definition of *Secure Yield* in effect allows meeting demand with moderate restrictions through a severe drought akin to a '1 in 1000 year' drought[1].

1 *It is noted that '1 in 1000 year drought' does not mean it only occurs once every thousand years but means it has a 0.1% probability of occurring any year.*

Under the NSW Security of Supply basis (commonly referred to as the '5/10/20 rule'), water supply headworks system were normally sized so that:

a) Duration of restrictions does not exceed 5% of the time; and

b) Frequency of restrictions does not exceed 10% of years (ie 1 year in 10 on average)

c) Severity of restrictions does not exceed 20%. Systems must be able to meet 80% of the unrestricted water demand (ie 20% average reduction in consumption due to water restrictions) through a repetition of the worst recorded drought, commencing with the storage drawn down to the level at which restrictions need to be imposed to satisfy a) and b) above.

'Secure Yield' was defined as the highest annual water demand that can be supplied from a water supply headworks system while meeting the above '5/10/20' rule.

Over the last 20 years there has been a significant reduction in residential water consumption per property and thus it is considered it will be difficult to achieve a 20% reduction in consumption as implied by the earlier '5/10/20'rule . Consequently DPI Water recommends that future planning should be based on a 10% reduction in consumption through a repetition of the worst drought commencing with the storage already drawn down to satisfy the 5% duration and 10% frequency criteria. Thus the '5/10/20'rule has now become a '5/10/10'rule.

It is also noted that more recently the 10% frequency rule has been slightly refined by NSW Office of Water[2] from frequency of restrictions occurring 1 in 10 years on average to only being applied in 10% of years. For a sample of test cases this was of little consequence, and was desired to fit in with NOWs requirements for Performance Reporting of restrictions and thus was also based on the financial year.

Modelling

The current scenario modelled (*after revising an earlier trial scenario*) was:

1. Applying proposed restriction policy for existing Braidwood Water Headworks System (*Run 411 conditions, ie pumping from river stops when storage 100% full and re-starts when storage drops to 95% full) transfer to keep storage 90% full)* for annual demand of 270 ML/a for repeat of historic flows.

2 *NSW Office of Water roles migrated to NSW Department of Planning, Industry and Environment (DPIE) over 2017-2019.*

Restrictions

The proposed restriction regime provided by PWA that was modelled is provided in Table 1.

Table 1: Proposed Restriction Regime

Restrictions	Normal demand	Level 1	Level 2	Level 3	Level 4
Trigger dam level (%full)		85%	75%	65%	50%
Target reduction in demand	0	10%	25%	35%	40%
Annual* unrestricted demand (ML/a)	270	243	203	176	162

** Annual then subject to seasonal pattern in Table 3.1 of 2015 Yield study report*

Results

Table 2 summarises the application of restrictions from modelling the proposed regime for an annual demand of 270 ML/a for a repeat of the historic climate (1890-2020) and compares them with those for the 5/10/10 rule.

Table 2: Restrictions Comparison – Proposed Policy with Historic Climate

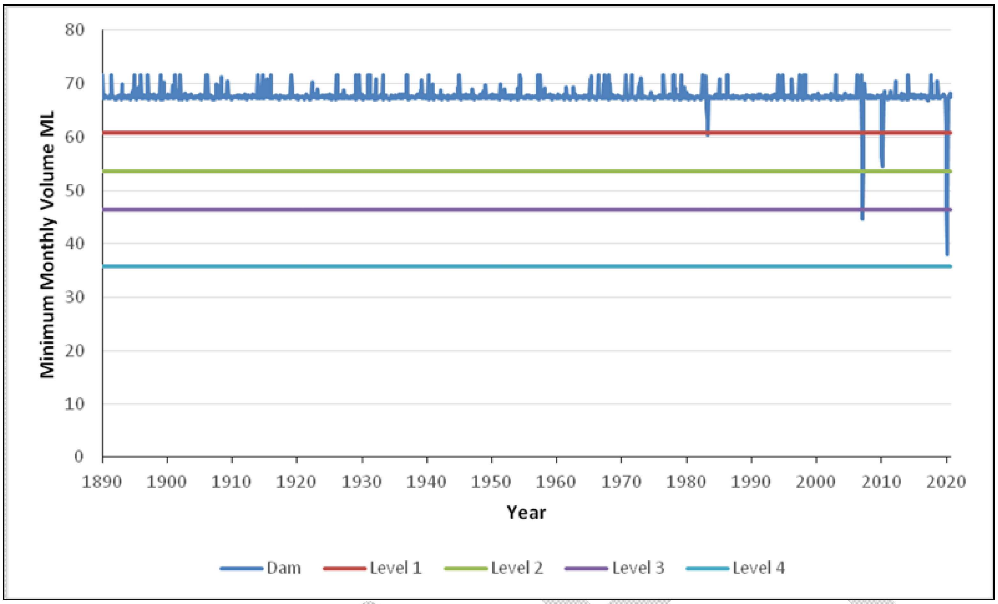
Case	Duration of Restrictions % of time	% of Years Restrictions Applied	Restrictions on demand %
5/10/10 rule	5	10	10
Proposed policy for 270 ML/a for historic climate	0.38	3.1	18.5[1]

1. Average based on 100 days on Level 1 (10%), 47 days on Level 2 (25%), 33 days on Level 3 (35%) and 0 days on Level 4 (40%) restrictions

The proposed restriction policy meets the first two criteria of the 5/10/10 design planning rules but appears to not meet the last criteria. It is noted however that the third criteria is not fully comparable as the third criteria allows for a much worse drought then has occurred in the past (1890-2020) and uses a *constant* demand reduction. It is understood that in the development of the 5/10/10 rules it was recognised that when a drought is occurring it is unknown whether it will be worse than has been designed for and thus progressive restrictions should be applied (*and thus these were purposefully not included in the design rule)* .

Figure 1 provides the modelled Braidwood offstream storage behaviour diagram applying the proposed restriction policy for a demand of 270 ML/a for the existing Braidwood headworks system for a repeat of the historic climate (1890-2020).

Figure 1: Storage Behaviour Diagram – Historic Climate



Figures 2 to 5 provide the storage behaviour at an enhanced daily scale for the four events (*from when storage last full to when full again*) where the restrictions were applied.

Figure 2: Storage Restriction Behaviour 1983 Drought

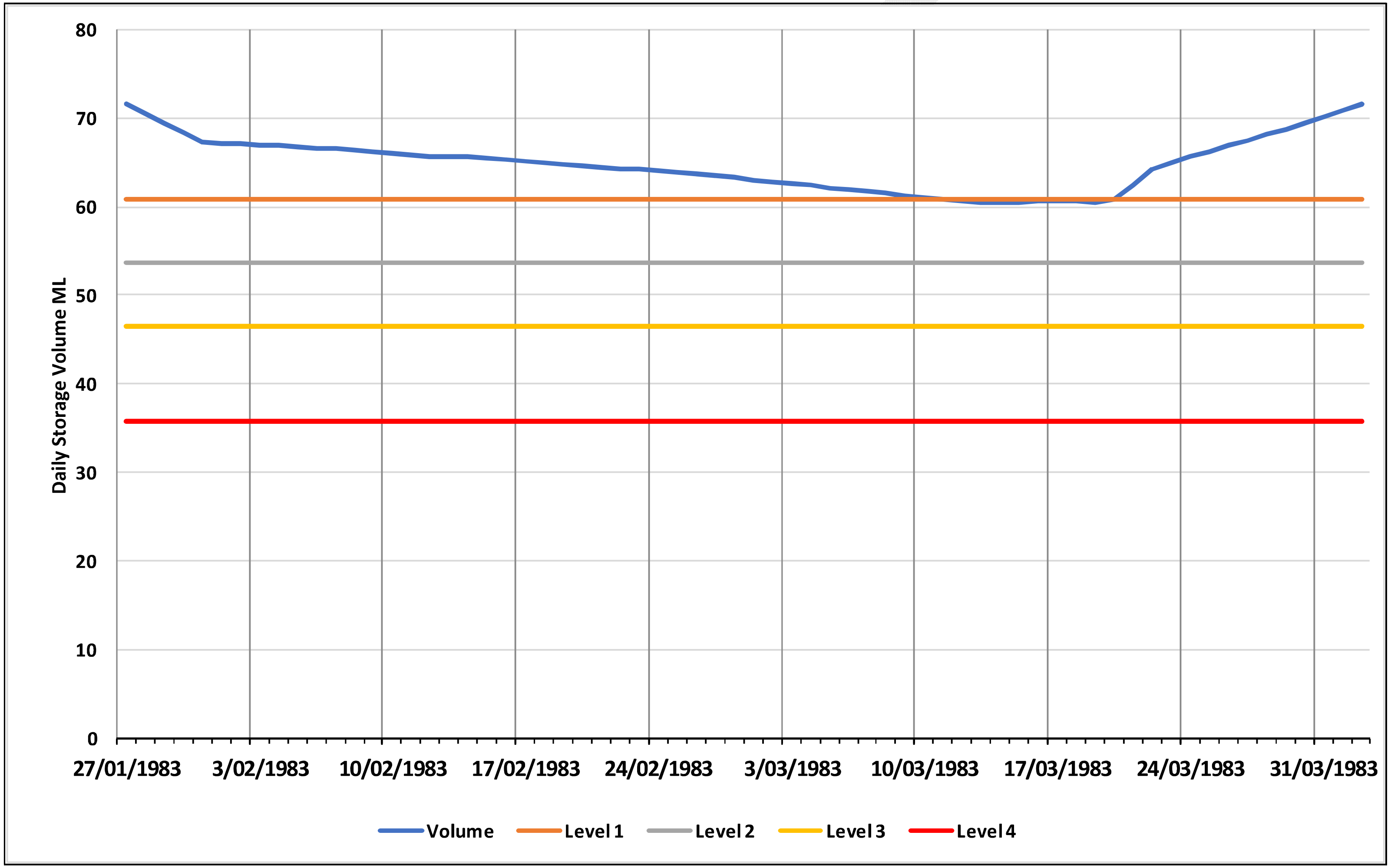


Figure 3: Storage Restriction Behaviour 2006/07 Drought

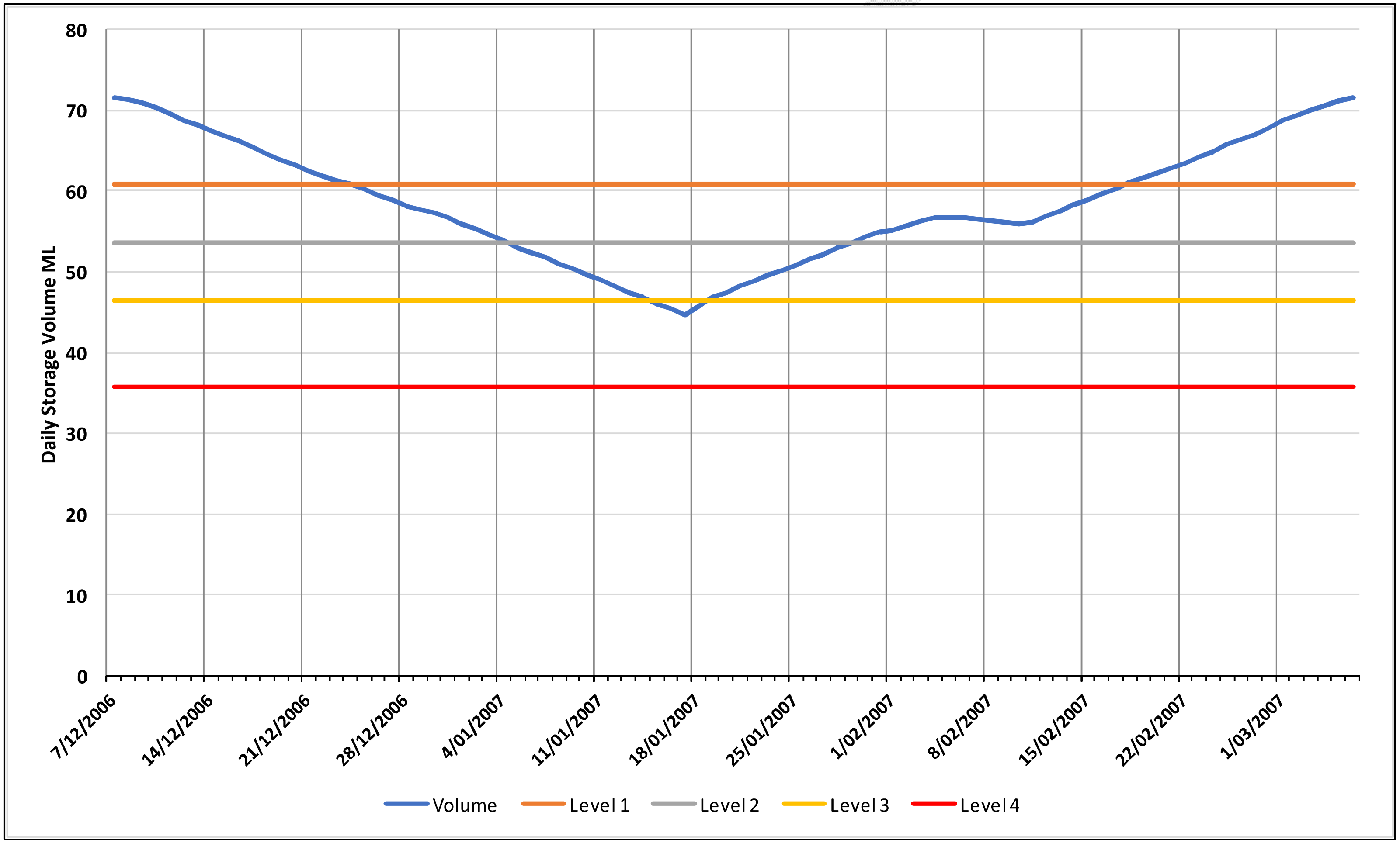


Figure 4: Storage Restriction Behaviour 2009/10 Drought

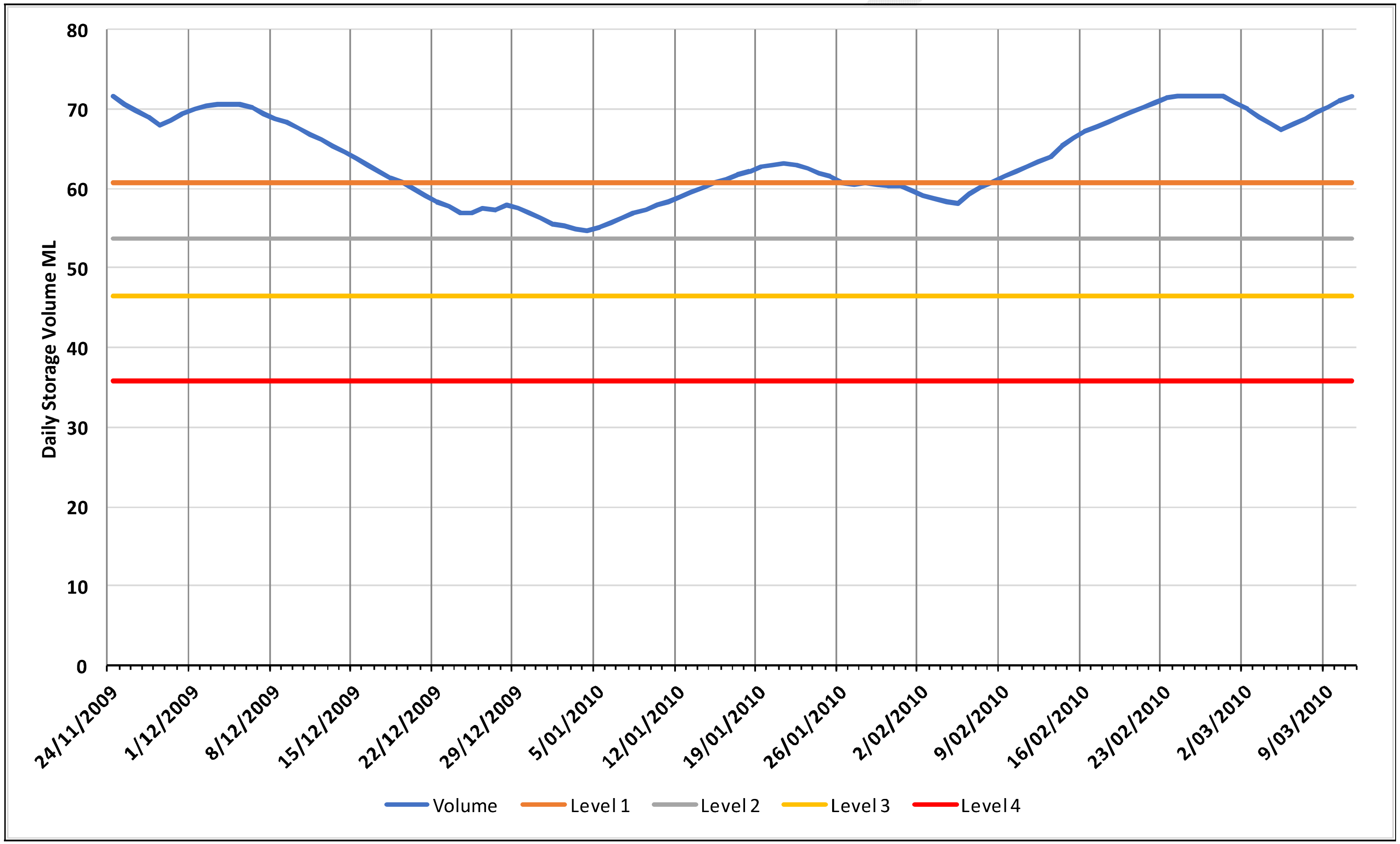
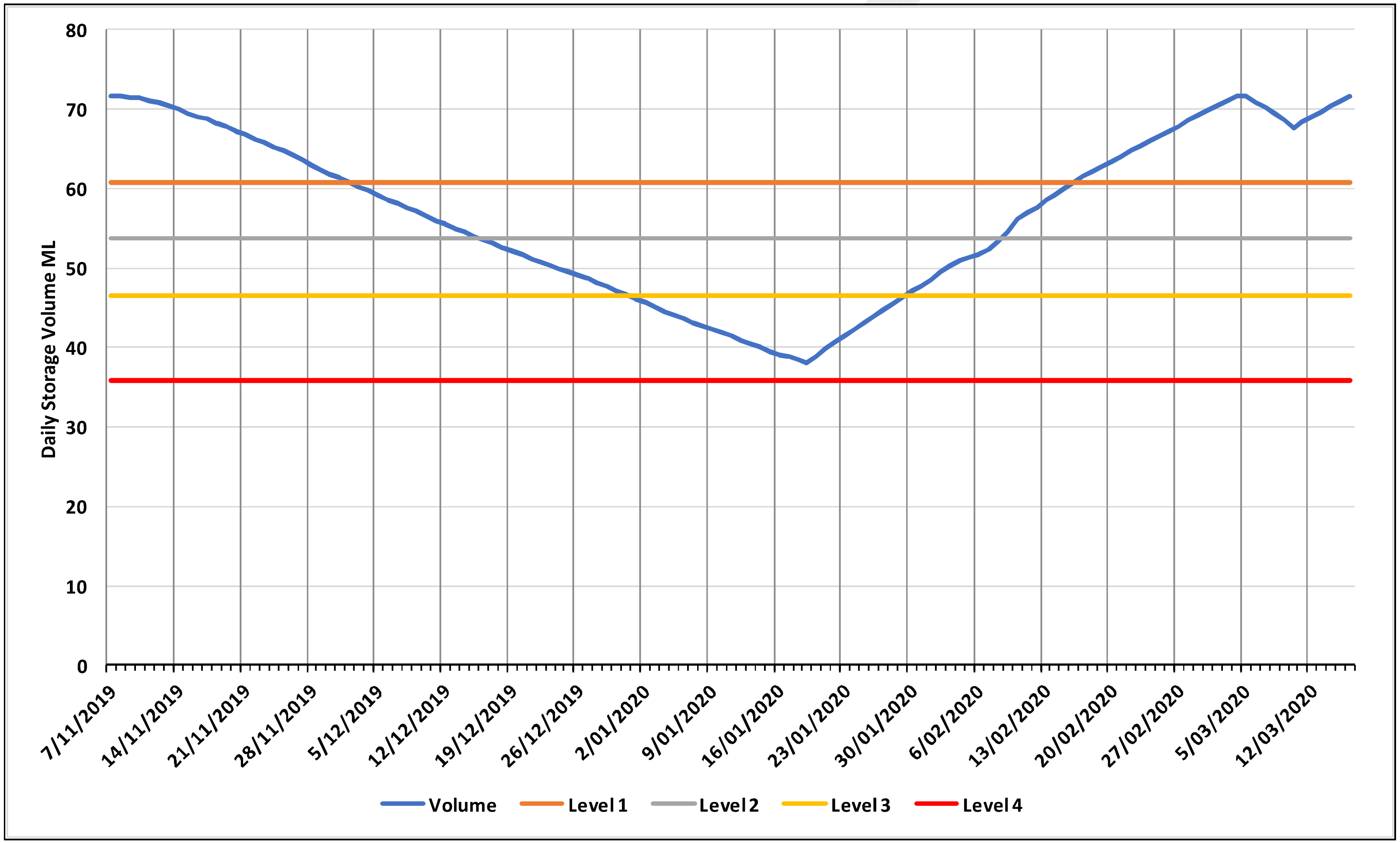


Figure 5: Storage Restriction Behaviour 2019/20 Drought



Frequency and Duration of Restrictions

Table 3 provides details of the frequency and duration of the different restriction levels for the modelled repeat of the historic climate for the proposed restriction policy.

Table 3: Operational Run with Restriction Policy

Run No.	Annual Demand ML/a	Restrictions Duration % and Frequency % of Years	RESTRICTION LEVELS AND DEMAND REDUCTION RATIO				
			0	**1**	**2**	**3**	**4**
			1	**0.90**	**0.75**	**0.65**	**0.60**
412	270	Duration %	99.62	0.21	0.10	0.07	0.00
	Historic Climate	No of years with Restrictions	-	4	2	2	0
		% of Years	-	3.1	1.5	1.5	0.0

Tables 4 to 7 provide the daily storage volumes and the days they are on the different restriction levels for the four droughts shown in Figures 2 to 5.

Table 4: 1983 Drought Restrictions

Date	Storage Volume ML	Restriction Level
27/01/1983	71.55	**0**
28/01/1983	70.49	**0**
29/01/1983	69.42	**0**
30/01/1983	68.34	**0**
31/01/1983	67.27	**0**
1/02/1983	67.14	**0**
2/02/1983	67.01	**0**
3/02/1983	66.94	**0**
4/02/1983	66.84	**0**
5/02/1983	66.74	**0**
6/02/1983	66.59	**0**
7/02/1983	66.52	**0**
8/02/1983	66.33	**0**
9/02/1983	66.14	**0**
10/02/1983	65.98	**0**
11/02/1983	65.78	**0**
12/02/1983	65.64	**0**
13/02/1983	65.72	**0**
14/02/1983	65.7	**0**
15/02/1983	65.51	**0**
16/02/1983	65.24	**0**
17/02/1983	65.04	**0**
18/02/1983	64.86	**0**

19/02/1983	64.68	**0**
20/02/1983	64.53	**0**
21/02/1983	64.41	**0**
22/02/1983	64.27	**0**
23/02/1983	64.25	**0**
24/02/1983	64.11	**0**
25/02/1983	63.94	**0**
26/02/1983	63.75	**0**
27/02/1983	63.52	**0**
28/02/1983	63.28	**0**
1/03/1983	63.05	**0**
2/03/1983	62.83	**0**
3/03/1983	62.6	**0**
4/03/1983	62.36	**0**
5/03/1983	62.14	**0**
6/03/1983	61.91	**0**
7/03/1983	61.7	**0**
8/03/1983	61.48	**0**
9/03/1983	61.25	**0**
10/03/1983	61.04	**0**
11/03/1983	60.86	**0**
12/03/1983	60.66	**1**
13/03/1983	60.52	**1**
14/03/1983	60.45	**1**
15/03/1983	60.47	**1**
16/03/1983	60.58	**1**
17/03/1983	60.64	**1**
18/03/1983	60.59	**1**
19/03/1983	60.5	**1**
20/03/1983	60.77	**1**
21/03/1983	62.49	**0**
22/03/1983	64.29	**0**
23/03/1983	64.95	**0**
24/03/1983	65.6	**0**
25/03/1983	66.25	**0**
26/03/1983	66.89	**0**
27/03/1983	67.52	**0**
28/03/1983	68.15	**0**
29/03/1983	68.78	**0**
30/03/1983	69.41	**0**
31/03/1983	70.06	**0**
1/04/1983	70.83	**0**
2/04/1983	71.55	**0**

Table 5: 2006/07 Drought Restrictions

Date	Storage Volume ML	Restriction Level
7/12/2006	71.55	0
8/12/2006	71.46	0
9/12/2006	71.04	0
10/12/2006	70.3	0
11/12/2006	69.55	0
12/12/2006	68.85	0
13/12/2006	68.11	0
14/12/2006	67.34	0
15/12/2006	66.78	0
16/12/2006	66.17	0
17/12/2006	65.42	0
18/12/2006	64.64	0
19/12/2006	63.88	0
20/12/2006	63.2	0
21/12/2006	62.56	0
22/12/2006	61.82	0
23/12/2006	61.29	0
24/12/2006	60.95	0
25/12/2006	60.25	1
26/12/2006	59.57	1
27/12/2006	58.89	1
28/12/2006	58.19	1
29/12/2006	57.68	1
30/12/2006	57.35	1
31/12/2006	56.76	1
1/01/2007	56	1
2/01/2007	55.28	1
3/01/2007	54.56	1
4/01/2007	53.93	1
5/01/2007	53.07	2
6/01/2007	52.37	2
7/01/2007	51.71	2
8/01/2007	51.1	2
9/01/2007	50.4	2
10/01/2007	49.66	2
11/01/2007	48.94	2
12/01/2007	48.22	2
13/01/2007	47.51	2
14/01/2007	46.78	2
15/01/2007	46.04	3
16/01/2007	45.38	3
17/01/2007	44.72	3
18/01/2007	45.66	3
19/01/2007	46.88	2
20/01/2007	47.44	2
21/01/2007	48.15	2
22/01/2007	48.84	2
23/01/2007	49.53	2
24/01/2007	50.29	2

25/01/2007	50.86	**2**
26/01/2007	51.53	**2**
27/01/2007	52.23	**2**
28/01/2007	52.92	**2**
29/01/2007	53.62	**2**
30/01/2007	54.31	**1**
31/01/2007	54.88	**1**
1/02/2007	55.06	**1**
2/02/2007	55.75	**1**
3/02/2007	56.43	**1**
4/02/2007	56.69	**1**
5/02/2007	56.73	**1**
6/02/2007	56.75	**1**
7/02/2007	56.61	**1**
8/02/2007	56.39	**1**
9/02/2007	56.16	**1**
10/02/2007	55.85	**1**
11/02/2007	56.18	**1**
12/02/2007	56.9	**1**
13/02/2007	57.61	**1**
14/02/2007	58.29	**1**
15/02/2007	58.97	**1**
16/02/2007	59.67	**1**
17/02/2007	60.36	**1**
18/02/2007	61.03	**0**
19/02/2007	61.64	**0**
20/02/2007	62.27	**0**
21/02/2007	62.86	**0**
22/02/2007	63.47	**0**
23/02/2007	64.15	**0**
24/02/2007	64.8	**0**
25/02/2007	65.75	**0**
26/02/2007	66.38	**0**
27/02/2007	67.09	**0**
28/02/2007	67.71	**0**
1/03/2007	68.7	**0**
2/03/2007	69.32	**0**
3/03/2007	69.93	**0**
4/03/2007	70.55	**0**
5/03/2007	71.21	**0**
6/03/2007	71.55	**0**

Table 6: 2009/10 Drought Restrictions

Date	Storage Volume ML	Restriction Level
24/11/2009	71.55	0
25/11/2009	70.64	0
26/11/2009	69.74	0
27/11/2009	68.92	0
28/11/2009	68.02	0
29/11/2009	68.66	0
30/11/2009	69.35	0
1/12/2009	69.99	0
2/12/2009	70.4	0
3/12/2009	70.57	0
4/12/2009	70.65	0
5/12/2009	70.51	0
6/12/2009	70.14	0
7/12/2009	69.47	0
8/12/2009	68.7	0
9/12/2009	68.42	0
10/12/2009	67.69	0
11/12/2009	66.87	0
12/12/2009	66.12	0
13/12/2009	65.3	0
14/12/2009	64.54	0
15/12/2009	63.72	0
16/12/2009	62.9	0
17/12/2009	62.06	0
18/12/2009	61.42	0
19/12/2009	60.65	1
20/12/2009	59.96	1
21/12/2009	59.21	1
22/12/2009	58.43	1
23/12/2009	57.65	1
24/12/2009	56.91	1
25/12/2009	56.88	1
26/12/2009	57.49	1
27/12/2009	57.42	1
28/12/2009	58	1
29/12/2009	57.61	1
30/12/2009	56.94	1
31/12/2009	56.24	1
1/01/2010	55.59	1
2/01/2010	55.36	1
3/01/2010	54.95	1
4/01/2010	54.62	1
5/01/2010	55.17	1
6/01/2010	55.71	1
7/01/2010	56.28	1
8/01/2010	56.83	1
9/01/2010	57.37	1
10/01/2010	57.9	1
11/01/2010	58.43	1

12/01/2010	58.96	1
13/01/2010	59.53	1
14/01/2010	60.12	1
15/01/2010	60.69	1
16/01/2010	61.25	0
17/01/2010	61.75	0
18/01/2010	62.21	0
19/01/2010	62.68	0
20/01/2010	63.05	0
21/01/2010	63.11	0
22/01/2010	63.02	0
23/01/2010	62.56	0
24/01/2010	62.05	0
25/01/2010	61.52	0
26/01/2010	60.84	0
27/01/2010	60.54	1
28/01/2010	60.85	0
29/01/2010	60.63	1
30/01/2010	60.38	1
31/01/2010	60.27	1
1/02/2010	59.73	1
2/02/2010	59.14	1
3/02/2010	58.7	1
4/02/2010	58.26	1
5/02/2010	58.11	1
6/02/2010	59.34	1
7/02/2010	60.05	1
8/02/2010	60.8	1
9/02/2010	61.48	0
10/02/2010	62.07	0
11/02/2010	62.68	0
12/02/2010	63.3	0
13/02/2010	64.03	0
14/02/2010	65.41	0
15/02/2010	66.47	0
16/02/2010	67.24	0
17/02/2010	67.83	0
18/02/2010	68.43	0
19/02/2010	69.03	0
20/02/2010	69.62	0
21/02/2010	70.2	0
22/02/2010	70.79	0
23/02/2010	71.37	0
24/02/2010	71.55	0
25/02/2010	71.55	0
26/02/2010	71.55	0
27/02/2010	71.55	0
28/02/2010	71.55	0
1/03/2010	70.81	0
2/03/2010	69.94	0
3/03/2010	69.05	0
4/03/2010	68.17	0
5/03/2010	67.31	0

6/03/2010	68.13	**0**
7/03/2010	68.79	**0**
8/03/2010	69.63	**0**
9/03/2010	70.29	**0**
10/03/2010	70.93	**0**
11/03/2010	71.55	**0**

Table 7: 2019/20 Drought Restrictions

Date	Storage Volume ML	Restriction Level
7/11/2019	71.55	**0**
8/11/2019	71.54	**0**
9/11/2019	71.5	**0**
10/11/2019	71.36	**0**
11/11/2019	71.11	**0**
12/11/2019	70.79	**0**
13/11/2019	70.38	**0**
14/11/2019	69.94	**0**
15/11/2019	69.5	**0**
16/11/2019	69.1	**0**
17/11/2019	68.74	**0**
18/11/2019	68.3	**0**
19/11/2019	67.78	**0**
20/11/2019	67.28	**0**
21/11/2019	66.77	**0**
22/11/2019	66.28	**0**
23/11/2019	65.75	**0**
24/11/2019	65.24	**0**
25/11/2019	64.69	**0**
26/11/2019	64.18	**0**
27/11/2019	63.59	**0**
28/11/2019	63.02	**0**
29/11/2019	62.42	**0**
30/11/2019	61.86	**0**
1/12/2019	61.29	**0**
2/12/2019	60.74	**1**
3/12/2019	60.22	**1**
4/12/2019	59.7	**1**
5/12/2019	59.15	**1**
6/12/2019	58.62	**1**
7/12/2019	58.09	**1**
8/12/2019	57.62	**1**
9/12/2019	57.1	**1**
10/12/2019	56.56	**1**
11/12/2019	56.03	**1**
12/12/2019	55.5	**1**
13/12/2019	55.03	**1**
14/12/2019	54.53	**1**
15/12/2019	54.02	**1**
16/12/2019	53.48	**2**
17/12/2019	53.05	**2**

18/12/2019	52.61	2
19/12/2019	52.13	2
20/12/2019	51.67	2
21/12/2019	51.2	2
22/12/2019	50.75	2
23/12/2019	50.33	2
24/12/2019	49.93	2
25/12/2019	49.51	2
26/12/2019	49.06	2
27/12/2019	48.62	2
28/12/2019	48.15	2
29/12/2019	47.69	2
30/12/2019	47.19	2
31/12/2019	46.67	2
1/01/2020	46.08	3
2/01/2020	45.61	3
3/01/2020	45.11	3
4/01/2020	44.56	3
5/01/2020	44.08	3
6/01/2020	43.63	3
7/01/2020	43.16	3
8/01/2020	42.71	3
9/01/2020	42.28	3
10/01/2020	41.79	3
11/01/2020	41.38	3
12/01/2020	40.95	3
13/01/2020	40.49	3
14/01/2020	40.03	3
15/01/2020	39.56	3
16/01/2020	39.12	3
17/01/2020	38.8	3
18/01/2020	38.45	3
19/01/2020	38.04	3
20/01/2020	38.94	3
21/01/2020	39.82	3
22/01/2020	40.61	3
23/01/2020	41.43	3
24/01/2020	42.26	3
25/01/2020	43.07	3
26/01/2020	43.86	3
27/01/2020	44.67	3
28/01/2020	45.47	3
29/01/2020	46.27	3
30/01/2020	47.07	2
31/01/2020	47.77	2
1/02/2020	48.59	2
2/02/2020	49.42	2
3/02/2020	50.25	2
4/02/2020	50.95	2
5/02/2020	51.39	2
6/02/2020	51.74	2
7/02/2020	52.29	2
8/02/2020	53.31	2

9/02/2020	54.58	1
10/02/2020	56.16	1
11/02/2020	56.88	1
12/02/2020	57.64	1
13/02/2020	58.46	1
14/02/2020	59.23	1
15/02/2020	59.95	1
16/02/2020	60.87	0
17/02/2020	61.54	0
18/02/2020	62.17	0
19/02/2020	62.82	0
20/02/2020	63.44	0
21/02/2020	64.07	0
22/02/2020	64.75	0
23/02/2020	65.39	0
24/02/2020	66.02	0
25/02/2020	66.65	0
26/02/2020	67.28	0
27/02/2020	67.9	0
28/02/2020	68.52	0
29/02/2020	69.15	0
1/03/2020	69.77	0
2/03/2020	70.41	0
3/03/2020	71.07	0
4/03/2020	71.55	0
5/03/2020	71.55	0
6/03/2020	70.87	0
7/03/2020	70.28	0
8/03/2020	69.43	0
9/03/2020	68.58	0
10/03/2020	67.69	0
11/03/2020	68.32	0
12/03/2020	68.95	0
13/03/2020	69.57	0
14/03/2020	70.37	0
15/03/2020	71.02	0
16/03/2020	71.55	0

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Braidwood Drought Management Plan – Hydrology Modelling Report Case 2

Prepared for Public Works Advisory on behalf of Queanbeyan-Palerang Regional Council

Report No. 20010/2 Draft 1.0
February 2021
NSW Urban Water Services Pty Ltd

Summary

Queanbeyan-Palerang Regional Council (QPRC) are in the process of developing a Drought Management Plan for Braidwood water supply and as part of this required modelling of their water supply headworks system for nominated restriction regimes to assess the performance of these regimes.

NSW Urban Water Services (NUWS) were engaged through Public Works Advisory (PWA) to run the Braidwood Headworks System Model that NUWS had previously used to model the system secure yield for Braidwood water supply.

This report summarises the modelling undertaken and provides the results for assessing the performance of the restriction regimes.

Headworks System Model

The Headworks System Model was developed to assess the secure yield of the Braidwood water supply headworks system. Details of the model, data used and assumptions are provided in the NUWS 2015 Report *"Palerang Council Water Supply, Captains Flat and Braidwood Yield Study Report",* (*Report No. 14013, December 2015), prepared for Palerang Council and the July 2020 and December Addendums to that report (Report No 14024) prepared for Queanbeyan-Palerang Regional Council.*

Essentially the model is a computer program that balances continuity equations between all the water sources and demands while incorporating the defined procedures to determine *secure yield*. The model simulates on a daily basis the behaviour of the system by accounting for and balancing the available water. The hydrological cycle is modelled external to the model and the required hydrometeorological data is provided as input to the system behaviour model. In essence the system model is driven by operating conditions such as the need to meet a particular demand while satisfying constraints such as environmental flow objectives and available flow.

Secure Yield

For the past 25 years or so most urban water supply headworks in country NSW have been sized on a robust Security of Supply basis. This security of supply basis was developed to cost-effectively provide sufficient dam storage capacity to allow the water utility to effectively manage its water supply in future droughts of greater severity than experienced over the past 100 or more years. '*Secure Yield*' is the water demand that can be expected to be supplied with only moderate restrictions during a significantly more severe drought than has been experienced since about 1895 (from when generally reliable rainfall records are available). The required water restrictions must not be too severe, not too frequent, nor of excessive duration. It has been argued that the definition of *Secure Yield* in effect allows meeting demand with moderate restrictions through a severe drought akin to a '1 in 1000 year' drought[1].

1 *It is noted that '1 in 1000 year drought' does not mean it only occurs once every thousand years but means it has a 0.1% probability of occurring any year.*

Under the NSW Security of Supply basis (commonly referred to as the ‘5/10/20 rule’), water supply headworks system were normally sized so that:

a) Duration of restrictions does not exceed 5% of the time; and

b) Frequency of restrictions does not exceed 10% of years (ie 1 year in 10 on average)

c) Severity of restrictions does not exceed 20%. Systems must be able to meet 80% of the unrestricted water demand (ie 20% average reduction in consumption due to water restrictions) through a repetition of the worst recorded drought, commencing with the storage drawn down to the level at which restrictions need to be imposed to satisfy a) and b) above.

‘Secure Yield’ was defined as the highest annual water demand that can be supplied from a water supply headworks system while meeting the above ‘5/10/20’ rule.

Over the last 20 years there has been a significant reduction in residential water consumption per property and thus it is considered it will be difficult to achieve a 20% reduction in consumption as implied by the earlier ‘5/10/20’rule . Consequently DPI Water recommends that future planning should be based on a 10% reduction in consumption through a repetition of the worst drought commencing with the storage already drawn down to satisfy the 5% duration and 10% frequency criteria. Thus the ‘5/10/20’rule has now become a ‘5/10/10’rule.

It is also noted that more recently the 10% frequency rule has been slightly refined by NSW Office of Water[2] from frequency of restrictions occurring 1 in 10 years on average to only being applied in 10% of years. For a sample of test cases this was of little consequence, and was desired to fit in with NOWs requirements for Performance Reporting of restrictions and thus was also based on the financial year.

Modelling

Two scenarios were modelled.

The Case 1 scenario modelled was:

1. Applying proposed restriction policy for existing Braidwood Water Headworks System (*Run 411 conditions, ie pumping from river stops when storage 100% full and re-starts when storage drops to 95% full)* for annual demand of 270 ML/a for repeat of historic flows.

The results of Case 1 were provided in the NUWS Report:

Braidwood Drought Management Plan- Hydrology Modelling Report , December 2020 ,Report No. 20010, Draft 2.0 , December 2020 prepared for PWA on behalf of QPRC.

2 NSW Office of Water roles migrated to NSW Department of Planning, Industry and Environment (DPIE) over 2017-2019.

Subsequently the Case 2 scenario modelled and reported herein was:

2. Applying proposed restriction policy for existing Braidwood Water Headworks System (*Run 411 conditions, ie pumping from river stops when storage 100% full and re-starts when storage drops to 95% full)* for annual demand of 272 ML/a for repeat of historic flows reduced by 20%.

The slight increase in demand from Case 1 of 270 ML/a to Case 2 of 272 ML/a was to reflect the estimated year 2050 unrestricted extraction.

The 20% reduction in the historic flows was used to allow for 1 °C climate warming as it was not considered appropriate to use the flow series obtained from the GCMs that are used to adjust the historic climate secure yield for 1 °C climate warming. The methodology for adjusting is detailed in the DPIE Water Guidelines:

> *Assuring future urban water security, Assessment and Adaption guidelines for NSW local water utilities.*

The GCM flow series did not capture the recent critical droughts and thus would not be a useful examination of the proposed restriction regime.

The 20% reduction based on judgement appears reasonable as use of the 20% reduced flows resulted in the historic secure yield being reduced by 7.6 %. Applying the guidelines resulted in the historic secure yield being reduced by 4.2% (*see Second Addendum to Yield Study Report*).

Restrictions

The proposed restriction regime provided by PWA that was modelled is provided in Table 1.

Table 1: Proposed Restriction Regime (Case 2)

Restrictions	Normal demand	Level 1	Level 2	Level 3	Level 4
Trigger dam level (%full)		85%	75%	65%	50%
Target reduction in demand	0	10%	25%	35%	40%
Annual* unrestricted demand (ML/a)	272	245	204	177	163

** Annual then subject to seasonal pattern in Table 3.1 of 2015 Yield study report*

Results

Table 2 summarises the application of restrictions from modelling the proposed regime for an annual demand of 272 ML/a for a repeat of the historic climate (1890-2020) (*with flows reduced by 20% assumed to reflect 1 °C climate warming*) and compares them with those for the 5/10/10 rule.

Table 2: Restrictions Comparison – Proposed Policy

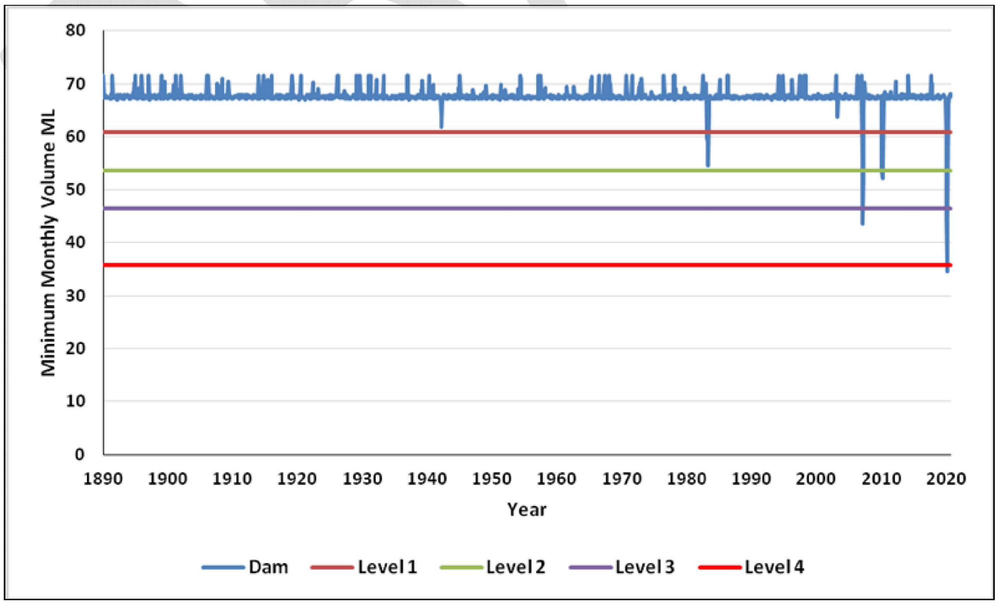
Case	Duration of Restrictions % of time	% of Years Restrictions Applied	Restrictions on demand %
5/10/10 rule	5	10	10
Proposed policy for 272 ML/a for historic climate (*with flows reduced by 20% assumed to reflect 1 °C climate warming*)	0.52	3.1	18.8[1]

1. Average based on 134 days on Level 1 (10%), 65 days on Level 2 (25%), 43 days on Level 3 (35%) and 4 days on Level 4 (40%) restrictions

The proposed restriction policy meets the first two criteria of the 5/10/10 design planning rules but appears to not meet the last criteria. It is noted however that the third criteria is not fully comparable as the third criteria allows for a much worse drought then has occurred in the past (1890-2020) and uses a *constant* demand reduction. It is understood that in the development of the 5/10/10 rules it was recognised that when a drought is occurring it is unknown whether it will be worse than has been designed for and thus progressive restrictions should be applied (*and thus these were purposefully not included in the design rule)* .

Figure 1 provides the modelled Braidwood offstream storage behaviour diagram applying the proposed restriction policy for a demand of 272 ML/a for the existing Braidwood headworks system for a repeat of the historic climate (1890-2020) (*with flows reduced by 20% assumed to reflect 1 °C climate warming).*

Figure 1: Storage Behaviour Diagram



Figures 2 to 5 provide the storage behaviour at an enhanced daily scale for the four events (*from when storage last full to when full again*) where the restrictions were applied.

Figure 2: Storage Restriction Behaviour 1982/83 Drought

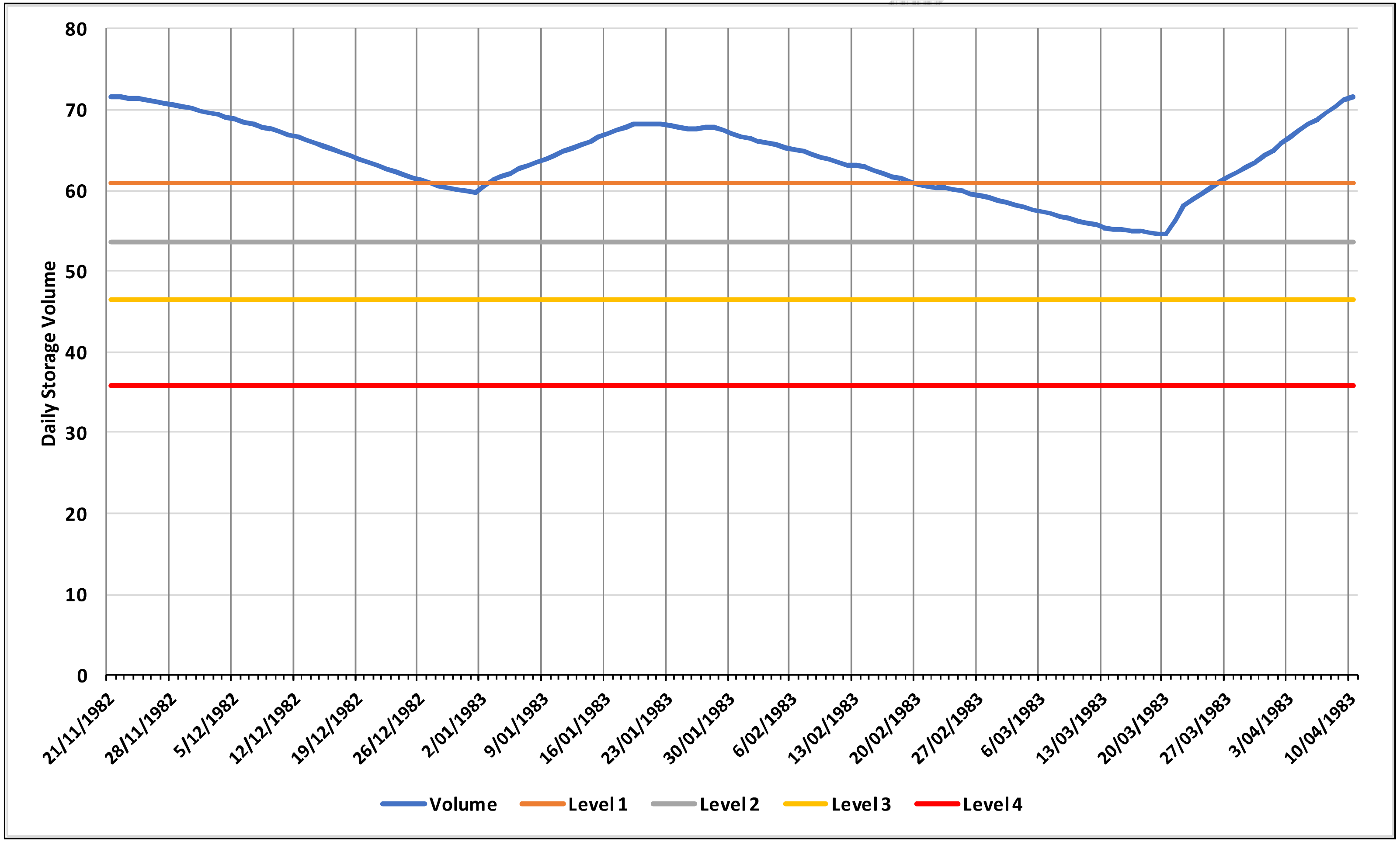


Figure 3: Storage Restriction Behaviour 2006/07 Drought

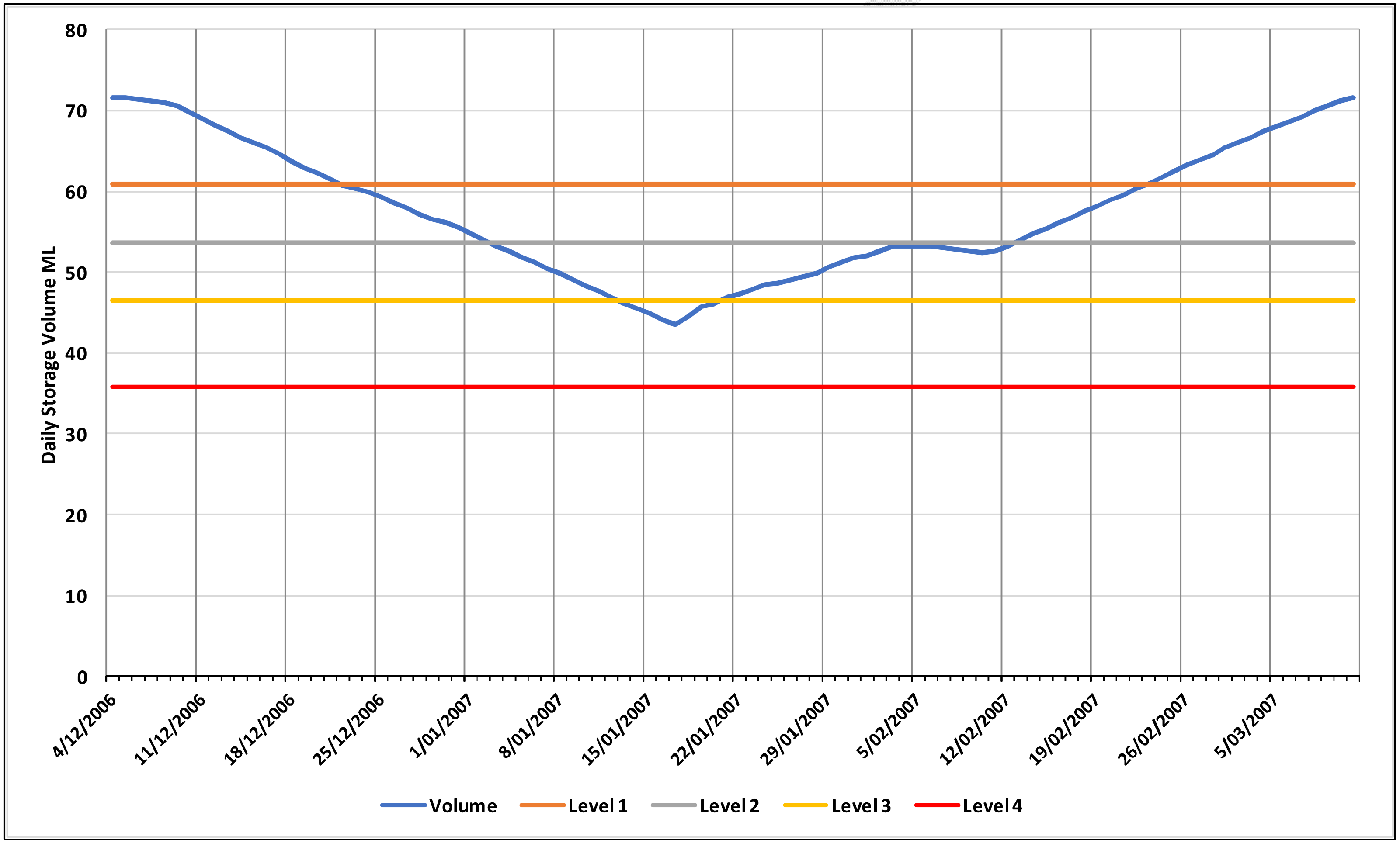


Figure 4: Storage Restriction Behaviour 2009/10 Drought

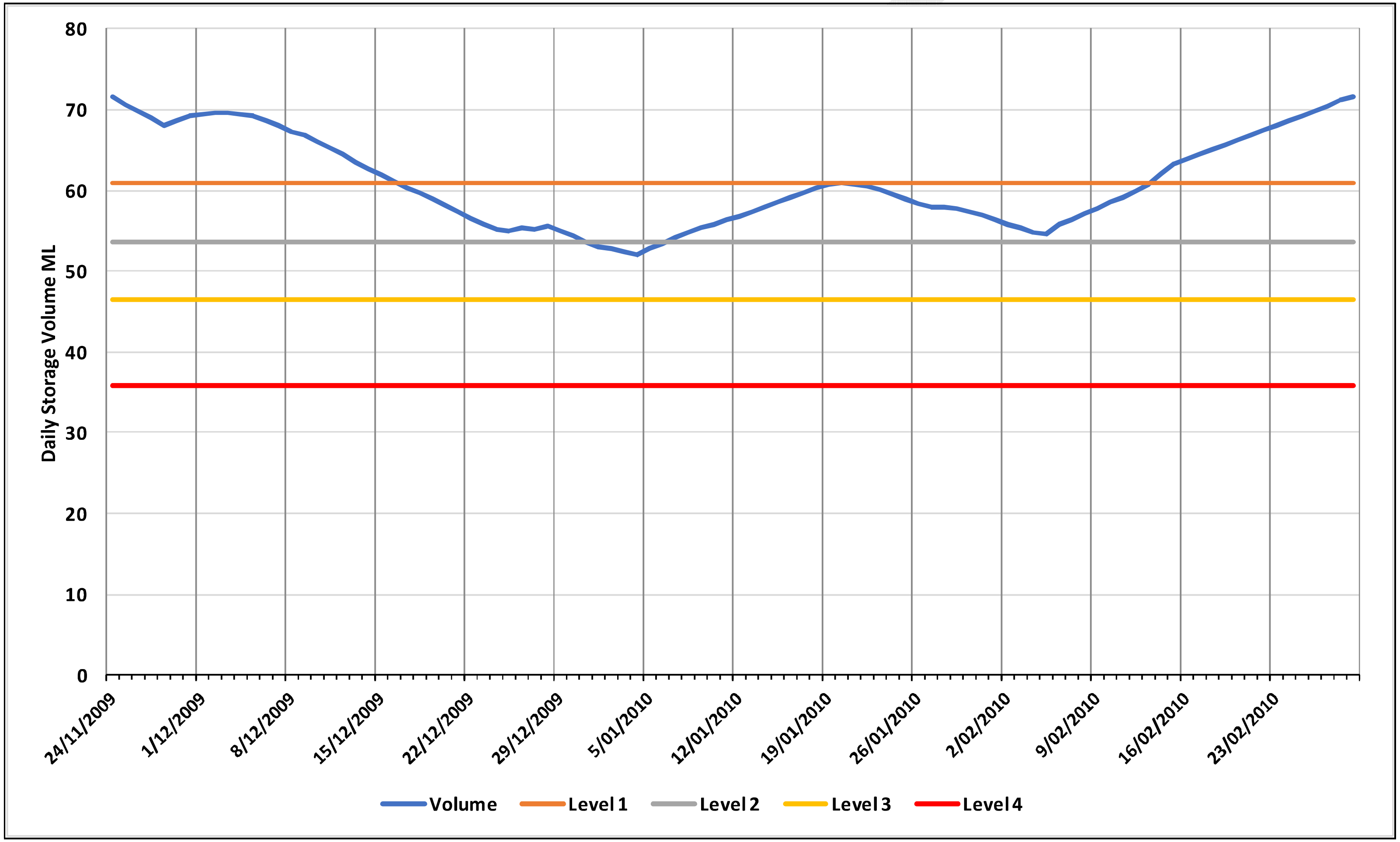
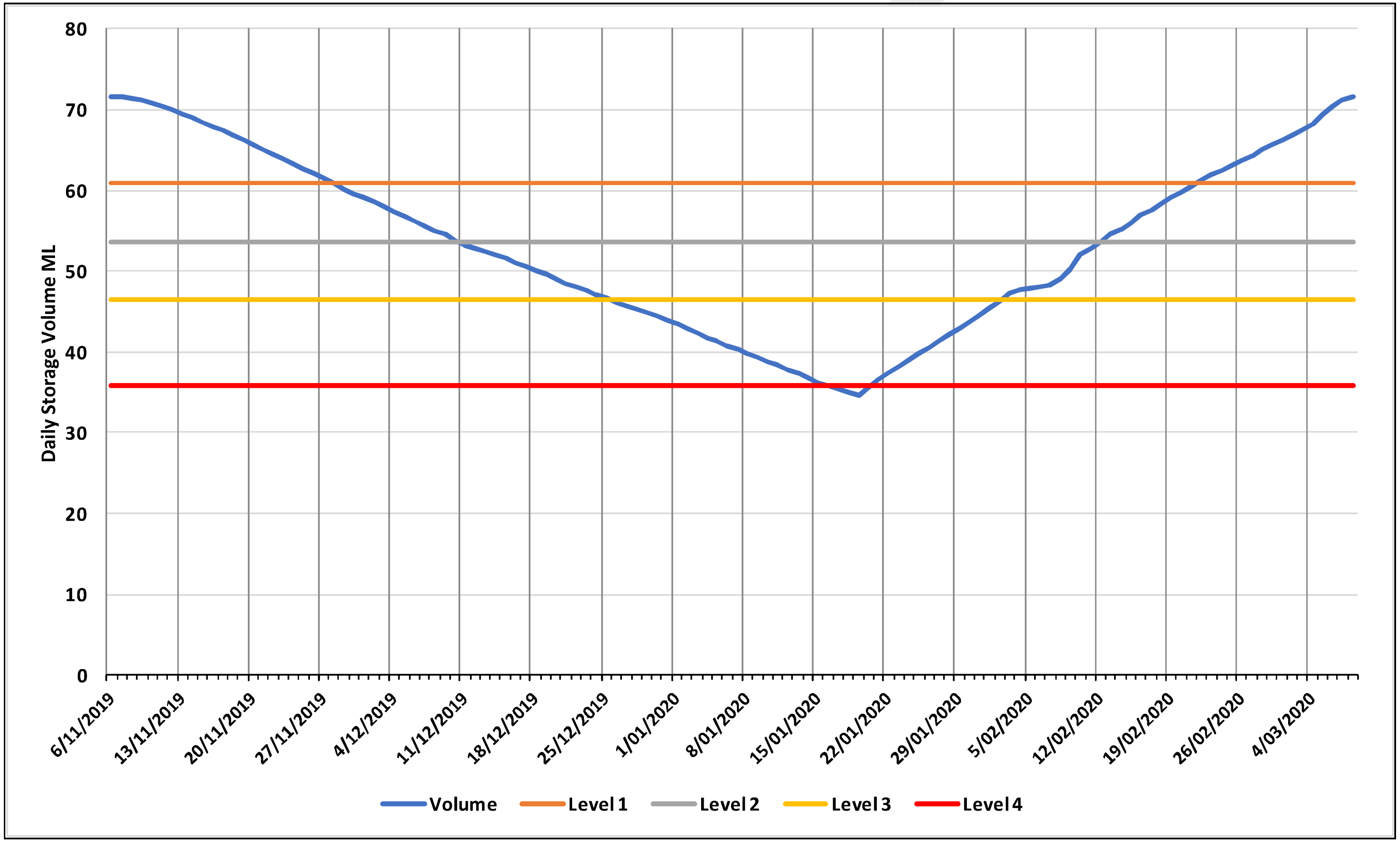


Figure 5: Storage Restriction Behaviour 2019/20 Drought



Frequency and Duration of Restrictions

Table 3 provides details of the frequency and duration of the different restriction levels for the modelled repeat of the historic climate (*with flows reduced by 20% assumed to reflect 1 °C climate warming* for the proposed restriction policy.

Table 3: Operational Run with Restriction Policy

Run No.	Annual Demand ML/a	Restrictions Duration % and Frequency % of Years	RESTRICTION LEVELS AND DEMAND REDUCTION RATIO				
			0	**1**	**2**	**3**	**4**
			1	**0.90**	**0.75**	**0.65**	**0.60**
414	272	Duration %	99.48	0.28	0.14	0.09	0.01
	Historic Climate (*with flows reduced by 20% assumed to reflect 1 °C climate warming*)	No of years with Restrictions	-	4	3	2	1
		% of Years	-	3.1	2.3	1.5	0.8

Tables 4 to 7 provide the daily storage volumes and the days they are on the different restriction levels for the four droughts shown in Figures 2 to 5.

Table 4: 1983 Drought Restrictions

Date	Storage Volume ML	Restriction Level
21/11/1982	71.55	**0**
22/11/1982	71.51	**0**
23/11/1982	71.41	**0**
24/11/1982	71.27	**0**
25/11/1982	71.11	**0**
26/11/1982	70.91	**0**
27/11/1982	70.72	**0**
28/11/1982	70.57	**0**
29/11/1982	70.35	**0**
30/11/1982	70.1	**0**
01/12/1982	69.87	**0**
02/12/1982	69.64	**0**
03/12/1982	69.37	**0**
04/12/1982	69.06	**0**
05/12/1982	68.76	**0**
06/12/1982	68.46	**0**
07/12/1982	68.13	**0**
08/12/1982	67.81	**0**

09/12/1982	67.55	**0**
10/12/1982	67.24	**0**
11/12/1982	66.92	**0**
12/12/1982	66.55	**0**
13/12/1982	66.16	**0**
14/12/1982	65.77	**0**
15/12/1982	65.42	**0**
16/12/1982	65	**0**
17/12/1982	64.59	**0**
18/12/1982	64.2	**0**
19/12/1982	63.85	**0**
20/12/1982	63.5	**0**
21/12/1982	63.11	**0**
22/12/1982	62.7	**0**
23/12/1982	62.3	**0**
24/12/1982	61.92	**0**
25/12/1982	61.57	**0**
26/12/1982	61.24	**0**
27/12/1982	60.88	**0**
28/12/1982	60.53	**0**
29/12/1982	60.28	**0**
30/12/1982	60.06	**0**
31/12/1982	59.98	**0**
01/01/1983	59.7	**0**
02/01/1983	60.59	**0**
03/01/1983	61.31	**0**
04/01/1983	61.74	**0**
05/01/1983	62.16	**0**
06/01/1983	62.61	**0**
07/01/1983	63.04	**0**
08/01/1983	63.46	**0**
09/01/1983	63.88	**0**
10/01/1983	64.32	**0**
11/01/1983	64.79	**0**
12/01/1983	65.23	**0**
13/01/1983	65.67	**0**
14/01/1983	66.11	**0**
15/01/1983	66.55	**0**
16/01/1983	66.99	**0**
17/01/1983	67.42	**0**
18/01/1983	67.87	**0**
19/01/1983	68.15	**0**
20/01/1983	68.22	**0**
21/01/1983	68.24	**0**
22/01/1983	68.22	**0**
23/01/1983	68.05	**0**
24/01/1983	67.86	**0**
25/01/1983	67.68	**0**
26/01/1983	67.63	**0**
27/01/1983	67.82	**0**
28/01/1983	67.73	**0**
29/01/1983	67.47	**0**
30/01/1983	67.11	**0**

31/01/1983	66.71	**0**
01/02/1983	66.41	**0**
02/02/1983	66.12	**0**
03/02/1983	65.88	**0**
04/02/1983	65.62	**0**
05/02/1983	65.34	**0**
06/02/1983	65.03	**0**
07/02/1983	64.8	**0**
08/02/1983	64.46	**0**
09/02/1983	64.12	**0**
10/02/1983	63.81	**0**
11/02/1983	63.46	**0**
12/02/1983	63.16	**0**
13/02/1983	63.05	**0**
14/02/1983	62.85	**0**
15/02/1983	62.5	**0**
16/02/1983	62.1	**0**
17/02/1983	61.75	**0**
18/02/1983	61.42	**0**
19/02/1983	61.09	**0**
20/02/1983	60.78	**1**
21/02/1983	60.6	**1**
22/02/1983	60.39	**1**
23/02/1983	60.3	**1**
24/02/1983	60.09	**1**
25/02/1983	59.86	**1**
26/02/1983	59.61	**1**
27/02/1983	59.32	**1**
28/02/1983	59.03	**1**
01/03/1983	58.74	**1**
02/03/1983	58.46	**1**
03/03/1983	58.18	**1**
04/03/1983	57.89	**1**
05/03/1983	57.61	**1**
06/03/1983	57.32	**1**
07/03/1983	57.06	**1**
08/03/1983	56.78	**1**
09/03/1983	56.5	**1**
10/03/1983	56.24	**1**
11/03/1983	55.99	**1**
12/03/1983	55.74	**1**
13/03/1983	55.46	**1**
14/03/1983	55.25	**1**
15/03/1983	55.12	**1**
16/03/1983	55.06	**1**
17/03/1983	54.96	**1**
18/03/1983	54.76	**1**
19/03/1983	54.52	**1**
20/03/1983	54.58	**1**
21/03/1983	56.26	**1**
22/03/1983	58.1	**1**
23/03/1983	58.84	**1**
24/03/1983	59.56	**1**

25/03/1983	60.29	**1**
26/03/1983	61.01	**0**
27/03/1983	61.64	**0**
28/03/1983	62.27	**0**
29/03/1983	62.89	**0**
30/03/1983	63.52	**0**
31/03/1983	64.16	**0**
01/04/1983	64.92	**0**
02/04/1983	65.81	**0**
03/04/1983	66.57	**0**
04/04/1983	67.34	**0**
05/04/1983	68.15	**0**
06/04/1983	68.89	**0**
07/04/1983	69.62	**0**
08/04/1983	70.37	**0**
09/04/1983	71.12	**0**
10/04/1983	71.55	**0**

Table 5: 2006/07 Drought Restrictions

Date	Storage Volume ML	Restriction Level
04/12/2006	71.55	**0**
05/12/2006	71.54	**0**
06/12/2006	71.44	**0**
07/12/2006	71.25	**0**
08/12/2006	71	**0**
09/12/2006	70.48	**0**
10/12/2006	69.7	**0**
11/12/2006	68.91	**0**
12/12/2006	68.18	**0**
13/12/2006	67.41	**0**
14/12/2006	66.61	**0**
15/12/2006	66.01	**0**
16/12/2006	65.35	**0**
17/12/2006	64.57	**0**
18/12/2006	63.75	**0**
19/12/2006	62.97	**0**
20/12/2006	62.25	**0**
21/12/2006	61.56	**0**
22/12/2006	60.79	**1**
23/12/2006	60.27	**1**
24/12/2006	59.93	**1**
25/12/2006	59.28	**1**
26/12/2006	58.57	**1**
27/12/2006	57.85	**1**
28/12/2006	57.13	**1**
29/12/2006	56.56	**1**
30/12/2006	56.16	**1**
31/12/2006	55.52	**1**

01/01/2007	54.73	1
02/01/2007	53.97	1
03/01/2007	53.19	2
04/01/2007	52.64	2
05/01/2007	51.9	2
06/01/2007	51.17	2
07/01/2007	50.49	2
08/01/2007	49.83	2
09/01/2007	49.11	2
10/01/2007	48.35	2
11/01/2007	47.6	2
12/01/2007	46.86	2
13/01/2007	46.13	3
14/01/2007	45.48	3
15/01/2007	44.82	3
16/01/2007	44.15	3
17/01/2007	43.47	3
18/01/2007	44.41	3
19/01/2007	45.62	3
20/01/2007	46	3
21/01/2007	46.81	2
22/01/2007	47.31	2
23/01/2007	47.84	2
24/01/2007	48.4	2
25/01/2007	48.7	2
26/01/2007	49.07	2
27/01/2007	49.5	2
28/01/2007	49.91	2
29/01/2007	50.58	2
30/01/2007	51.27	2
31/01/2007	51.84	2
01/02/2007	51.94	2
02/02/2007	52.55	2
03/02/2007	53.11	2
04/02/2007	53.27	2
05/02/2007	53.26	2
06/02/2007	53.24	2
07/02/2007	53.09	2
08/02/2007	52.88	2
09/02/2007	52.64	2
10/02/2007	52.36	2
11/02/2007	52.62	2
12/02/2007	53.24	2
13/02/2007	54.07	1
14/02/2007	54.75	1
15/02/2007	55.43	1
16/02/2007	56.12	1
17/02/2007	56.8	1
18/02/2007	57.47	1
19/02/2007	58.16	0
20/02/2007	58.87	0
21/02/2007	59.55	0
22/02/2007	60.23	0

23/02/2007	60.99	**0**
24/02/2007	61.64	**0**
25/02/2007	62.57	**0**
26/02/2007	63.2	**0**
27/02/2007	63.9	**0**
28/02/2007	64.51	**0**
01/03/2007	65.5	**0**
02/03/2007	66.11	**0**
03/03/2007	66.71	**0**
04/03/2007	67.33	**0**
05/03/2007	67.98	**0**
06/03/2007	68.6	**0**
07/03/2007	69.26	**0**
08/03/2007	69.89	**0**
09/03/2007	70.55	**0**
10/03/2007	71.17	**0**
11/03/2007	71.55	**0**

Table 6: 2009/10 Drought Restrictions

Date	Storage Volume ML	Restriction Level
24/11/2009	71.55	**0**
25/11/2009	70.63	**0**
26/11/2009	69.72	**0**
27/11/2009	68.9	**0**
28/11/2009	68	**0**
29/11/2009	68.53	**0**
30/11/2009	69.11	**0**
1/12/2009	69.47	**0**
2/12/2009	69.61	**0**
3/12/2009	69.56	**0**
4/12/2009	69.44	**0**
5/12/2009	69.15	**0**
6/12/2009	68.67	**0**
7/12/2009	67.95	**0**
8/12/2009	67.15	**0**
9/12/2009	66.79	**0**
10/12/2009	66.02	**0**
11/12/2009	65.18	**0**
12/12/2009	64.39	**0**
13/12/2009	63.55	**0**
14/12/2009	62.77	**0**
15/12/2009	61.93	**0**
16/12/2009	61.09	**0**
17/12/2009	60.23	**1**
18/12/2009	59.64	**1**
19/12/2009	58.93	**1**
20/12/2009	58.21	**1**
21/12/2009	57.44	**1**
22/12/2009	56.65	**1**

23/12/2009	55.86	1
24/12/2009	55.11	1
25/12/2009	54.94	1
26/12/2009	55.34	1
27/12/2009	55.14	1
28/12/2009	55.47	1
29/12/2009	54.99	1
30/12/2009	54.28	1
31/12/2009	53.56	2
1/01/2010	52.99	2
2/01/2010	52.77	2
3/01/2010	52.41	2
4/01/2010	52.1	2
5/01/2010	52.79	2
6/01/2010	53.48	2
7/01/2010	54.19	1
8/01/2010	54.73	1
9/01/2010	55.27	1
10/01/2010	55.79	1
11/01/2010	56.32	1
12/01/2010	56.84	1
13/01/2010	57.4	1
14/01/2010	58	1
15/01/2010	58.56	1
16/01/2010	59.11	1
17/01/2010	59.71	1
18/01/2010	60.26	1
19/01/2010	60.7	1
20/01/2010	60.87	0
21/01/2010	60.7	1
22/01/2010	60.51	1
23/01/2010	60.01	1
24/01/2010	59.49	1
25/01/2010	58.95	1
26/01/2010	58.29	1
27/01/2010	57.93	1
28/01/2010	58	1
29/01/2010	57.7	1
30/01/2010	57.31	1
31/01/2010	57.02	1
1/02/2010	56.42	1
2/02/2010	55.78	1
3/02/2010	55.27	1
4/02/2010	54.76	1
5/02/2010	54.49	1
6/02/2010	55.7	1
7/02/2010	56.41	1
8/02/2010	57.16	1
9/02/2010	57.83	1
10/02/2010	58.5	1
11/02/2010	59.19	1
12/02/2010	59.88	1
13/02/2010	60.7	1

14/02/2010	62.15	**0**
15/02/2010	63.19	**0**
16/02/2010	63.95	**0**
17/02/2010	64.54	**0**
18/02/2010	65.13	**0**
19/02/2010	65.73	**0**
20/02/2010	66.31	**0**
21/02/2010	66.89	**0**
22/02/2010	67.47	**0**
23/02/2010	68.05	**0**
24/02/2010	68.64	**0**
25/02/2010	69.23	**0**
26/02/2010	69.81	**0**
27/02/2010	70.4	**0**
28/02/2010	71.19	**0**
1/03/2010	71.55	**0**

Table 7: 2019/20 Drought Restrictions

Date	Storage Volume ML	Restriction Level
6/11/2019	71.55	**0**
7/11/2019	71.49	**0**
8/11/2019	71.3	**0**
9/11/2019	71.09	**0**
10/11/2019	70.8	**0**
11/11/2019	70.42	**0**
12/11/2019	69.98	**0**
13/11/2019	69.46	**0**
14/11/2019	68.93	**0**
15/11/2019	68.39	**0**
16/11/2019	67.88	**0**
17/11/2019	67.42	**0**
18/11/2019	66.88	**0**
19/11/2019	66.28	**0**
20/11/2019	65.69	**0**
21/11/2019	65.1	**0**
22/11/2019	64.53	**0**
23/11/2019	63.92	**0**
24/11/2019	63.33	**0**
25/11/2019	62.7	**0**
26/11/2019	62.13	**0**
27/11/2019	61.47	**0**
28/11/2019	60.82	**0**
29/11/2019	60.16	**1**
30/11/2019	59.61	**1**
1/12/2019	59.07	**1**
2/12/2019	58.52	**1**
3/12/2019	57.95	**1**
4/12/2019	57.37	**1**
5/12/2019	56.76	**1**
6/12/2019	56.18	**1**

7/12/2019	55.59	1
8/12/2019	55.05	1
9/12/2019	54.48	1
10/12/2019	53.88	2
11/12/2019	53.29	2
12/12/2019	52.83	2
13/12/2019	52.42	2
14/12/2019	51.98	2
15/12/2019	51.54	2
16/12/2019	51.06	2
17/12/2019	50.58	2
18/12/2019	50.09	2
19/12/2019	49.56	2
20/12/2019	49.05	2
21/12/2019	48.55	2
22/12/2019	48.05	2
23/12/2019	47.58	2
24/12/2019	47.13	2
25/12/2019	46.65	2
26/12/2019	46.15	3
27/12/2019	45.75	3
28/12/2019	45.32	3
29/12/2019	44.9	3
30/12/2019	44.44	3
31/12/2019	43.98	3
1/01/2020	43.45	3
2/01/2020	42.92	3
3/01/2020	42.39	3
4/01/2020	41.8	3
5/01/2020	41.28	3
6/01/2020	40.78	3
7/01/2020	40.26	3
8/01/2020	39.77	3
9/01/2020	39.29	3
10/01/2020	38.76	3
11/01/2020	38.29	3
12/01/2020	37.82	3
13/01/2020	37.31	3
14/01/2020	36.8	3
15/01/2020	36.28	3
16/01/2020	35.8	3
17/01/2020	35.41	4
18/01/2020	35.06	4
19/01/2020	34.63	4
20/01/2020	35.58	4
21/01/2020	36.51	3
22/01/2020	37.3	3
23/01/2020	38.12	3
24/01/2020	38.95	3
25/01/2020	39.75	3
26/01/2020	40.55	3
27/01/2020	41.36	3
28/01/2020	42.16	3

29/01/2020	42.95	**3**
30/01/2020	43.76	**3**
31/01/2020	44.55	**3**
1/02/2020	45.45	**3**
2/02/2020	46.36	**3**
3/02/2020	47.21	**2**
4/02/2020	47.63	**2**
5/02/2020	47.84	**2**
6/02/2020	48	**2**
7/02/2020	48.31	**2**
8/02/2020	49.02	**2**
9/02/2020	50.28	**2**
10/02/2020	51.95	**2**
11/02/2020	52.79	**2**
12/02/2020	53.66	**2**
13/02/2020	54.48	**1**
14/02/2020	55.24	**1**
15/02/2020	55.96	**1**
16/02/2020	56.87	**1**
17/02/2020	57.61	**1**
18/02/2020	58.33	**1**
19/02/2020	59.05	**1**
20/02/2020	59.74	**1**
21/02/2020	60.46	**1**
22/02/2020	61.21	**0**
23/02/2020	61.85	**0**
24/02/2020	62.47	**0**
25/02/2020	63.1	**0**
26/02/2020	63.72	**0**
27/02/2020	64.34	**0**
28/02/2020	64.96	**0**
29/02/2020	65.58	**0**
1/03/2020	66.19	**0**
2/03/2020	66.83	**0**
3/03/2020	67.49	**0**
4/03/2020	68.23	**0**
5/03/2020	69.47	**0**
6/03/2020	70.3	**0**
7/03/2020	71.21	**0**
8/03/2020	71.55	**0**

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