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Urban demand models for the Fish River-Wywandy System

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Abstract: The New South Wales Government has developed regional water strategies for 10 regions and is in the process of preparing for 3 more regions to plan and manage each region's water needs for the next 20 to 40 years. The Regional Water Strategy program utilises daily river system models, which are run over extended periods (130-10,000 years). These models assess water security risks due to climate variability and projected change. To maintain consistency across the different regional water strategies, a consistent modelling approach has been implemented. The daily river system models apply a climate adjust monthly demand pattern model (Bethune, 2016) for urban demand modelling.

To better understand urban water security risks, it's essential to meet both average and extreme demands, especially in dry conditions. The standard model handles seasonal averages well but does not model extreme wet and dry demands adequately. To address this, two approaches were developed: monthly regression between demand and climate metrics, and quantile scaling of the climate metric.

This paper investigates the necessary modifications to the urban demand model to accurately represent 5 urban areas in the Fish River-Wywandy System: Blue Mountains, Lithgow Region, Oberon, Bathurst, and Orange. These towns had a combined population of 145,514 in 2021, which is expected to increase to 173,499 by 2065. Evaluating the security of water supply for these towns presently and in the future is crucial for effective water supply planning. The models utilised in this study have enabled the quantification of water security risks at rare recurrence intervals (e.g. 1 in 1,000 years).

Model validation using observed diversion data and 130 years of daily historical climate data shows reasonable performance in simulating average and monthly demands, though some challenges remain in capturing daily variability and wet extremes for certain towns. Security is evaluated using metrics such as percentage of time at restriction levels and frequency and duration of restrictions. Results show Lithgow and Oberon supplies are secure while Bathurst experiences 94 days at level 5 1 in 100 years and Orange experiences 530 days at level 5 1 in 100 years. No towns reach Critical Human Water Needs (CHWN).

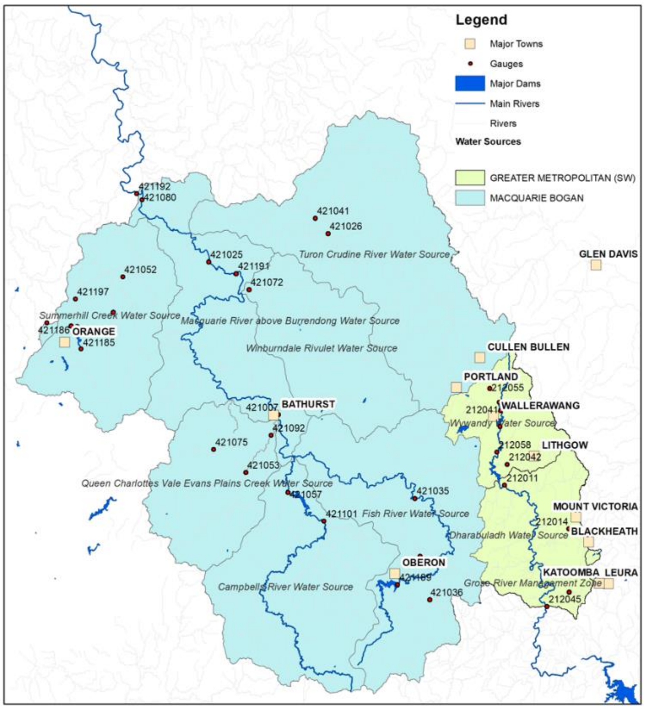


Figure 1 Fish River-Wywandy System

Keywords: *Integrated modelling, eWater Source, river system models, urban water security, regional water strategy*

1. INTRODUCTION

The New South Wales Government has developed regional water strategies for 10 regions and is preparing strategies for 3 additional regions. These initiatives address climate impacts and manage water needs over the next 20 to 40 years. The Fish River-Wywandy Regional Water Strategy is currently being prepared by the NSW Department of Climate Change, Energy, the Environment and Water.

In NSW, the Regional Water Strategy program utilises various river system models. These decision support tools simulate physical and management processes in river systems on a daily basis over extended periods (up to 10,000 years). The models estimate available water, requirements, water security, and allocation of resources. A consistent modelling approach is used across climate scenarios, hydrological modelling, and options assessments throughout NSW to ensure alignment between regional strategies.

Simulating water supply for major towns helps assess water security. River system models extend limited data records to longer timeframes and quantify security at rare intervals (such as 1 in 1,000 years). These models evaluate the effects of population growth, infrastructure, water management, operations, and climate change on water security, supporting Regional Water Strategy decisions about community water supply risks.

A uniform modelling approach for urban demands has been adopted across 13 regions, based on the seasonal climate adjusted demand model (Bethune, 2016).

The Fish River-Wywandy System (FRWS) is located at the headwaters of the Macquarie and Hawkesbury-Nepean river systems. These headwaters begin on both sides of the Great Dividing Range in the central NSW highlands. The Upper Macquarie river system originates at Shooters Hill (southwest of Jenolan Caves) and flows north towards Burrendong Dam, near Wellington, NSW. The Wywandy system starts in the upper reaches of the Cox's River (northwest of Katoomba), initially flowing south and then east into Warragamba Dam, which is part of the Hawkesbury-Nepean system (Figure 1). The model simulates average annual and monthly demand well but may not capture the distribution of demand during extremely wet or dry months.

This system supplies 5 urban centres: BM, Lithgow Region, Oberon, Bathurst, and Orange, with BM located outside the catchment area.

2. URBAN DEMAND OVEREVIEW

The water supplied to the towns is supporting a 2021 population of 145,514 (ABS, 2021) that is expected to grow to 173,497 (NSW Department of Planning, 2025) people by 2065. The town populations 2021 and 2065, Critical Human Water Needs (CHWN), and average annual demand are shown in Table 1.

Table 1 FRWS town populations 2012 and 2065, critical human water needs and average annual demand

Town	Population (2021)	Population (2065)	CHWN (l/person/day)	Average annual demand (ML/year)
BM (CWTP access)	50,116	51,491	197	5,529
Lithgow Region	15,800	16,598	197	2,127
Oberon	2,540	2,745	197	615
Bathurst	36,230	52,272	197	6,478
Orange	40,828	50,391	126	4,931
Total	**145,514**	**173,497**		**19,680**

The Fish River Water Supply Scheme (FRWSS), managed by WaterNSW, provides water for Central Highlands communities in NSW. It captures flows south of Oberon and supplies areas including Mount Piper Power Station, Upper Blue Mountains, Oberon, and Lithgow.

The 5 urban water supplies are discussed below.

2.1. Blue Mountains

The Blue Mountains Water Supply System (BMWSS) is managed by WaterNSW and Sydney Water. It gets water from the Cascade Water treatment Plant (CWTP) and Orchard Hills Water Treatment Plants (OHWTP). CWTP sources include Greaves, Medlow, Upper, Middle and Lower Cascade dams, and the FRWSS. The BMWSS supplies 15 zones: Mt Victoria, Blackheath, Catalina, Yosemite, Katoomba, Wentworth Falls, Bodington, Bullaburra, Lawson, Linden, Woodford, Faulconbridge, Springwood, and Warrimoo. CWTP is prioritised to meet demands, supplying progressively down the mountain, with OHWTP supplementing any shortfalls.

2.2. Lithgow Region

The Lithgow water supply system serves Lithgow and the surrounding region. The system's primary sources of water are the FRWSS, managed by WaterNSW, and Farmer's Creek Dam No. 2, managed by Lithgow City Council, which is supplemented by water from Clarence Colliery. The Lithgow region includes Lithgow, Marrangaroo, Rydal, Wallerawang, Lidsdale, Portland, Cullen Bullen, and Glen Davis. Lithgow and Marrangaroo are mainly supplied by the Oakey Park Water Treatment Plant (OPWTP), while the other towns receive water from the FRWSS. During FRWSS shortages, OPWTP can supply water to these towns. Conversely, Lithgow can receive water from the FRWSS. Transfers between these systems are limited to 5 ML/day.

2.3. Oberon

Oberon Council sources water from the FRWSS at the Oberon Dam outlet.

2.4. Bathurst

Bathurst Regional Council sources water from both surface and groundwater sources to provide potable and raw water supplies to the Bathurst Local Government Area. The two surface water sources are Chifley Dam to the south and Winburndale to the east. The primary source of potable water for Bathurst is Chifley Dam, supplemented by the Fish River, and extracted from the Macquarie River at the water filtration plant. Water sourced from Winburndale Dam, with a limit of 2.6 ML/day (30 l/s), is utilised for industrial purposes, as well as for irrigating parks and ovals, and is not included in this study.

2.5. Orange

Orange City Council sources water from surface catchments at Gosling Creek, Spring Creek, and Suma Park dams; stormwater from Ploughmans and Blackmans Swamp creeks; the Macquarie River to Orange pipeline; and groundwater bores at Shearing Shed and Bore No. 5. The three reservoirs are managed to provide storage, with the final raw water supply being drawn from Suma Park Reservoir but can also be supplied from Spring Creek. The stormwater harvesting system in Ploughmans and Blackmans Swamp creeks is situated in the Orange City catchment and became operational in 2017. Water is extracted from the Macquarie River when flow exceeds 92ML/day and is pumped to Suma Park dam via a pipeline with a capacity of 12 ML/day. The pipeline became operational in 2017.

3. MODELLING APPROACH

The standard urban demand model is based on the daily model utilised by the Murray-Darling Basin Authority (Bethune, 2016). This model includes two components of demand (dem): a fixed component (dem_{base}) and a variable component (dem_{var}). The fixed component represents the portion of demand that remains unaffected by climate, a major component of this is Critical Human Water Needs (CHWN). The variable component accounts for the seasonal demand influenced by climate. Additionally, the model considers water restrictions ($f(restriction)$).

$$dem = (dem_{base} + dem_{var}) * f(restriction) \quad [1]$$

The town water supply restrictions are not standard (Table 2). They are based on volume in relevant storages. BM restrictions are based on the volume in the Greater Sydney Water Supply System, Lithgow on Oberon Dam, Bathurst on Chifley Dam, and Orange based on combined Spring Creek and Suma Park dams. Note Oberon does not have water supply demand restrictions.

Table 2 Town water supply demand restrictions

Blue Mountains			Lithgow			Bathurst			Orange		
Level	Greater Sydney (%)	Restrict (%)	Level	Oberon (%)	Restrict (%)	Level	Chifley (%)	Restrict. (%)	Level	Suma+ Spring (%)	Restrict (%)
W1	>75	0	0	>=15	0	0	>=40	0	2	>=50	0
W2	>60	1	1	>=8	10	1	>=35	9	3	>=40	9
1	>45	4	2	<8	20	2	>=30	18	4	>=30	18
2	>35	10				3	>=25	28	5	>=15	28
3	>25	18				4	>=22	40	6	<15	40
4	>15	25				5	>=15	48			
5	<=15	32				6	<15	58			

The base demand is distributed by a monthly pattern (Table 3), population and CHWN.

$$dem_{base} = \frac{P_{month}}{Days_{month}} * Population * CHWN \quad [2]$$

The variable component is based on the remainder of the annual use (Use_{annual}), distributed by a monthly pattern (Table 3), and factored by a climate variable $f(climate)$.

$$dem_{var} = \frac{P_{month}}{Days_{month}} max(0, Use_{annual} - Population * CHWN) * f(climate) \quad [3]$$

Table 3 Pattern of average monthly urban use (percentage of annual use)

Use (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BM	9.0	7.9	8.3	7.9	8.0	7.4	8.1	8.1	8.4	9.4	8.6	9.1
Lithgow	8.8	7.8	8.6	8.4	8.4	8.1	7.7	8.3	7.5	8.6	8.4	9.4
Oberon	7.9	8.7	8.7	7.9	8.4	7.9	8.4	8.7	8.1	8.8	8.4	8.2
Bathurst	11.5	10.0	9.6	8.2	7.6	6.1	6.3	6.4	7.0	8.3	9.0	9.9
Orange	10.4	9.5	9.2	7.9	7.4	6.9	7.2	7.4	7.2	8.1	8.9	9.9

The climate scaling factor ($f(climate)$) indicates the effect of climate on daily urban usage. It is calculated as the ratio of the rolling climate deficit to the average deficit and cannot be less than zero. The rolling deficit tracks evaporation (E_t) and rainfall (R_t) over the past 7 days, while the average deficit ($\overline{Deficit_m}$) represents the monthly average over 130 years (Table 4).

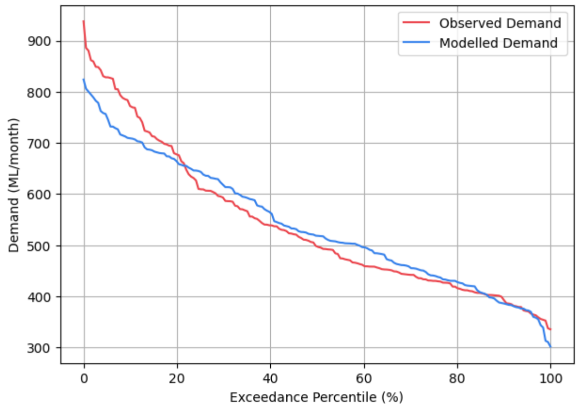
$$f(climate) = max\left(0, \frac{\sum_{t=0}^{6}(E_t - R_t)}{\overline{Deficit_m}}\right) \quad [4]$$

Table 4 Average monthly deficit of evaporation and rainfall

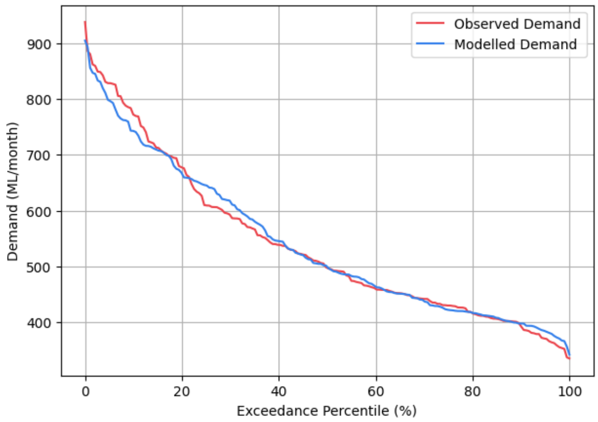
Deficit (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BM	3.25	2.68	1.97	1.69	1.32	0.74	0.89	1.39	2.2	2.72	3.13	3.34
Lithgow	3.97	3.42	2.34	1.96	1.26	0.73	0.92	1.31	2.15	2.94	3.61	3.97
Oberon	4.06	3.38	2.57	1.85	1.11	0.56	0.6	1.01	1.8	2.54	3.15	3.66
Bathurst	4.91	4.22	3.33	2.45	1.59	0.91	0.94	1.38	2.24	3.07	3.74	4.19
Orange	4.94	4.63	3.11	2.25	1.27	0.62	0.68	1.09	1.97	3.01	3.9	4.43

For Bathurst the average monthly demand did not match the extremes well (Figure 2). To improve this performance the standard demand model was modified to use a monthly regression between climate and demand (Table 5).

$$dem_{var} = \frac{m_{month} f(climate) + b_{month}}{Days_{month}} max(0, Use_{annual} - Population * CHWN) \quad [5]$$



a) Standard model



b) Regression model

Figure 2 Bathurst monthly demand (2003-2023) using the standard urban model and regression model.

Note in Table 5 the b value is not zero because of the lack of observed data and an apparent non-linear relationship as the demand approaches CHWN.

Table 5 Bathurst monthly demand regression parameters

Month	m	b
January	28.63199	-12.0057
February	23.48569	-7.91429
March	17.45972	-4.75735
April	11.49339	-1.17787
May	10.09056	-1.7704
June	4.433065	1.366717
July	2.936422	2.752932
August	2.58587	3.315966
September	6.603714	1.082762
October	14.26589	-4.41301
November	17.71814	-5.73828
December	22.14987	-8.83029

For Oberon, Blue Mountains, and Lithgow Region, neither the standard model nor the revised regression model aligned well with climate and demand distributions. This is partly because climate is not the primary driver of demand variability in these areas. Quantile scaling was used to match climate and demand distributions (Table 6). The demand variable is adjusted accordingly. Where the model encounters a climate function outside the calibration range (that is, a quantile value less than 0 or greater than one), the appropriate minimum or maximum quantile scaling value is used.

$$dem_{var} = \frac{P_{month}}{Days_{month}} max(0, Use_{annual} - Population * CHWN) * Quantile\big(f(climate)\big) * f(climate) \qquad [6]$$

Table 6 Climate function quantile scaling

Quantile	Oberon	BM	Lithgow
0.05	0	0	0
0.1	0	0	0
0.15	0.801672	0	0
0.2	1.362436	0	0
0.25	1.107847	0	0
0.3	1.195153	0	0
0.35	1.111573	0.8388	0
0.4	1.073591	0.992852	0.222705
0.45	1.033232	0.902746	0.644505
0.5	0.973638	0.895051	0.936149
0.55	0.974022	0.898157	0.95617
0.6	1.020679	1.003455	1.164072
0.65	1.079664	1.093588	1.283615
0.7	1.122999	1.197188	1.407475
0.75	1.123718	1.321759	1.492615
0.8	1.110695	1.403817	1.55964
0.85	1.106679	1.433555	1.625903
0.9	1.030163	1.531362	1.811317
0.95	0.945019	1.621715	1.96194
1	0.895501	1.882088	2.255039

4. MODEL PERFORMANCE WITH CLIMATE FUNCTION QUANTILE SCALING

Figure 3 illustrates model performance for the 5 towns. The revised Blue Mountains model successfully captures recent variability. Lithgow's model represents average demand but struggles with daily variability. Oberon's model performs well despite minimal climate influence. Bathurst and Orange demonstrate reasonable overall performance, performing better model in recent years. Most models match the monthly demand distribution well, except for Orange, which shows a poor match on wet extremes and a better match on dry ones. The revised models were explored but did not overall yield better results than the standard model.

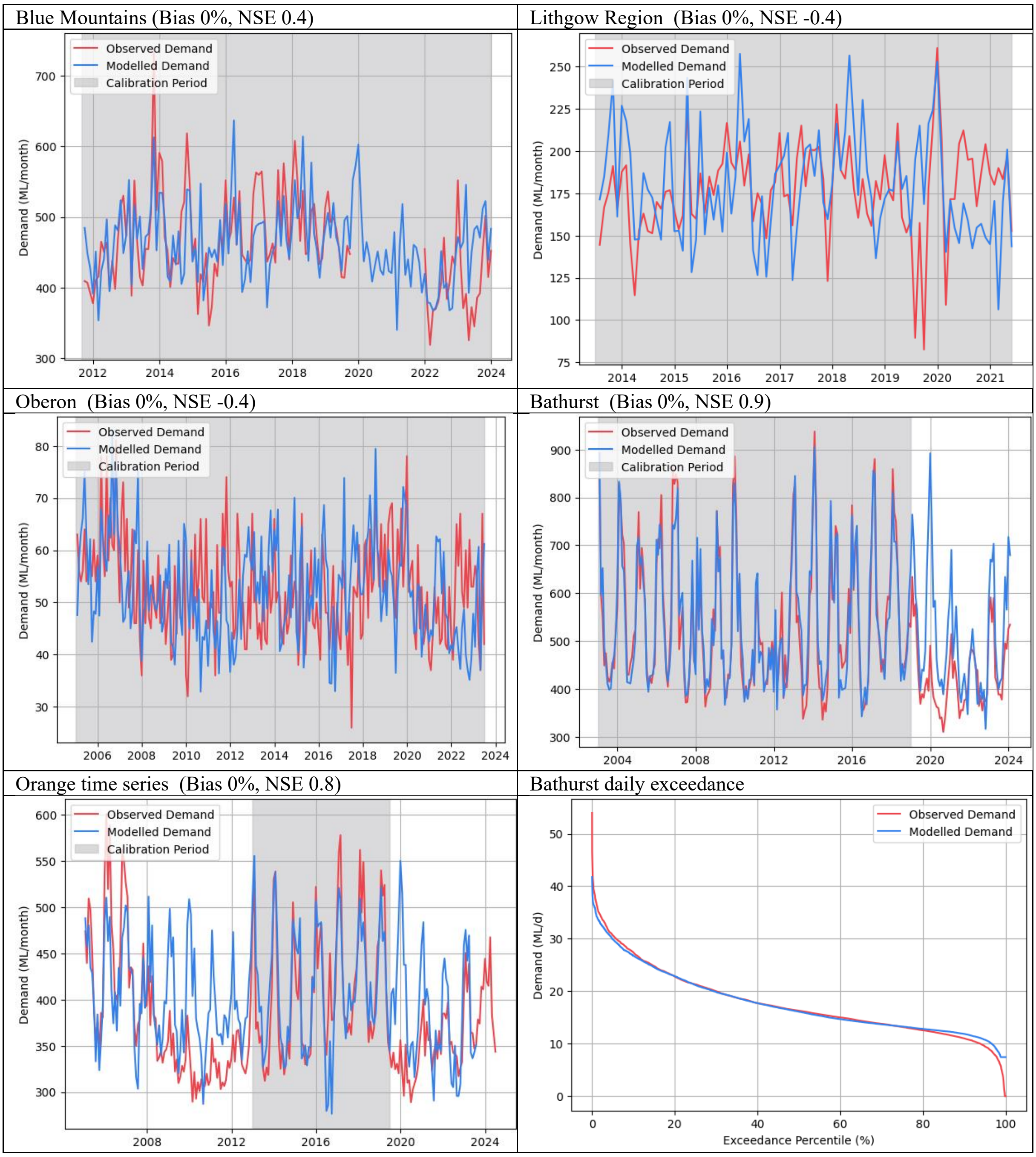


Figure 3 Blue Mountains, Lithgow Region, Oberon, Bathurst and Orange urban demand model performance

5. WATER SECURITY METRICS

Municipalities implement restriction policies based on the reliability of their water supplies, making direct comparisons challenging. It is however possible to make comparisons when CHWN are not met as this is reasonably consistent. Accordingly, we have employed a standardised set of restrictions.

Table 7 Standardised urban demand restrictions for percentage of time at restriction level (1889-2023)

Level	Restriction (%)	Lithgow (%)	Oberon (%)	Bathurst (%)	Orange (%)
1	0	100	100	98.3	0
2	10	0	0	0.6	89.3
3	20	0	0	0.4	5.5
4	30	0	0	0.4	3.8
5	40	0	0	0.3	1.3
CHWN	55	0	0	0	0

There are 2 metrics used to evaluate the security of town water supplies: percentage of time at restriction level (Table 7), and frequency and duration at a restriction level (Table 8). The first metric is useful for monitoring changes in restriction levels, while the second metric is valuable for assessing supply risks, with likelihood represented by frequency and consequence measured by duration.

Table 8 Restriction duration (days) for yearly frequency for Lithgow Region, Oberon, Bathurst and Orange (1889-2023)

Lithgow Region

Frequency	1	2
1:10	0	0
1:25	0	0
1:50	0	0
1:100	0	0

Oberon

Frequency	1	2
1:10	0	0
1:25	0	0
1:50	0	0
1:100	0	0

Bathurst

Frequency	1	2	3	4	5	CHWN
1:10	0	0	0	0	0	0
1:25	125	9	0	0	0	0
1:50	200	101	50	0	0	0
1:100	244	178	136	87	1	0

Orange

Frequency	3	4	5	CHWN
1:10	66	0	0	0
1:25	453	176	1	0
1:50	529	251	12	0
1:100	754	416	79	0

6. DISCUSSION AND CONCLUSION

Applying restrictions to the urban demand model, we observed that reductions in observed demands were both larger and longer-lasting than the restrictions themselves. Water users seem responsive to imposed restrictions, and their behaviour persists.

The restrictions in the model are largely dependent on the storage performance of the broader river system model. This is discussed in (Podger et al. 2025).

The standard urban model performs reasonably well on average metrics but struggles during extreme dry and wet conditions. Two model variations have shown improvements, preserved average statistics while enhanced performance at extremes. Improved dry extreme modelling indicates robust long-term water supply security estimation for towns which is important for regional water strategies.

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REFERENCES

Bethune M. (2016). Representing urban water demand on the Murray and Lower Darling rivers. MDBA Technical Report No. 2016/06. MDBA March 2016.

Australian Bureau of Statistics (2021) General Community Profile Statistical Area 2 (SA2) [DataPacks], accessed 24/02/2025.

NSW Department of Planning (2025). Population projections. Population projections | Planning.

Podger G.M., Cu P., Trim A., Dutta D., Loonat N., Tang Y., Reyes R. and Foneseka C (2025). Developing a Source model of the Upper Macquarie and Upper Coxs river systems, MODSIM 2025

