Submission to:

ICRC Review of Water and Sewerage Demand Forecasting Methods

Frequency of Droughts and ICON Water's ±6% Demand 'Deadband'

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Introduction

The purpose of this submission is to examine whether the allowance of a ±6% demand 'deadband' is consistent with the synoptic scale historic rainfall in the ACT.

ICON Methodology

From the ICON Water presentation, I gather that the ICON analysis is based on 5-year projections of climate. The 5-year period is appropriate for rainfall since it incorporates broadscale synoptic weather patterns and because inflows into ACT dams are dominated by base flow from mountain groundwater systems with have characteristic time scales of order 5 years (White *et al.*, 2006; Daniell and White, 2007). As ICON recognises it also reduces variability. One problem, however, is the reliability of projections of climate over 5-years. The current Australian climate model ACCESS-S projections are more reliable over the following 3 months as they are partly based on sea surface temperatures in the Nino regions in the equatorial Pacific and in Indian Ocean Dipole regions (BoM, 2021).

From the presentation, ICON reset its demand model following the Millenium drought and the 2003 Canberra bushfires. There appears to be an assumption that the Millenium drought was a unique event, and many identified it as evidence of climate change.

An alternate approach to projections of climate is to examine the frequency of extreme events over past 5-year periods. This assumes that the pace of climate change has been slow, an assumption also employed by ICON and demonstrable from rainfall records

Long-term Precipitation in the ACT

The longest-term rainfall record in the ACT region, Queanbeyan Bowling Club (BoM 70072), has a continuous record of monthly rainfall from September 1870 to October 2013 (Fig.1). There is no statistically significant trend in the data so that it can be concluded that there is no significant evidence of climate change in annual precipitation at Queanbeyan. Canberra (70000) has missing data during the Millenium Drought (2000-2009). How relevant is Queanbeyan precipitation to rainfall over and streamflow input into ACT dams? Data for precipitation in the Cotter catchment appears not to be publicly available on the Bureau of Meteorology's web site. Figure 2 shows the correlation between 5-year running totals of rainfall at Cotter Hut (57906), upstream of Bendora Dam, and 5-year running totals of rainfall at Queanbeyan Bowling Club. The correlation, R = 0.90 is strong and highly significant. This demonstrated that using the Queanbeyan data over 5-year periods captures the broadscale, synoptic weather systems that govern long time rainfall variability in the Cotter Catchment and almost certainly in the Queanbeyan River catchment.

Figure 3 shows the complete 5-year rainfall total for Queanbeyan calculated from 1871 to 2012 together with the median and with the 0.1 percentile and the 0.9 percentile 5-year rainfalls. The latter two are designated by the Bureau of Meteorology as very much below normal and very much above normal rainfalls. In the 141-year record there are 8 periods of very much below normal rainfall and 7 periods of very much above normal rainfall. That suggests that very much below normal 5-year rainfall occurs on average every 17 years. No period during the Millennium Drought (2000-2009) registered as very much below normal rainfall. In terms of rainfall, the Millennium Drought was not a unique event. Table 1 lists the 20 lowest 5-year rainfall periods at the Queanbeyan weather station. The first 14 events were below the 0.1 percentile.

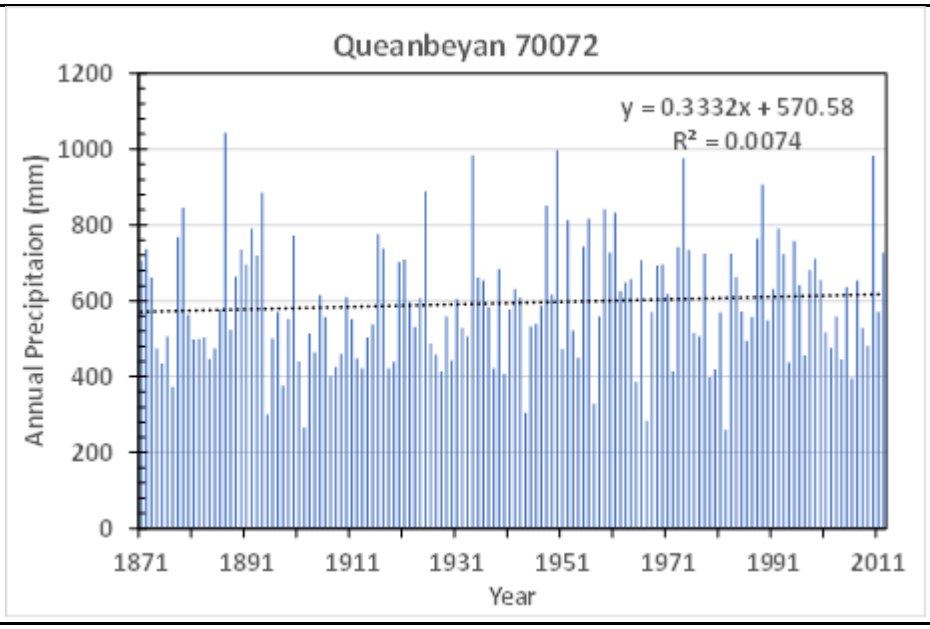


Fig 1. Annual precipitation at Queanbeyan Bowling Club (1871-2012). The dashed line is the linear trend line. It is not statistically significant ($p>0.1$)

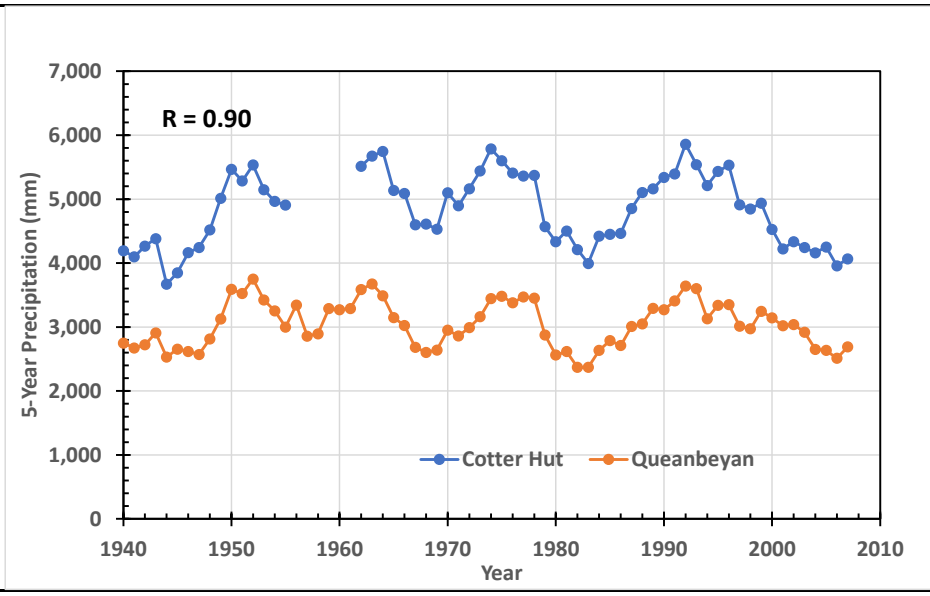


Fig 2. Correlation Annual between the running 5-year precipitation at Queanbeyan Bowling Club and at Cotter Hut (57906) above Bendora Dam (1940 to 2007). The correlation is highly statistically significant ($p<0.000001$)

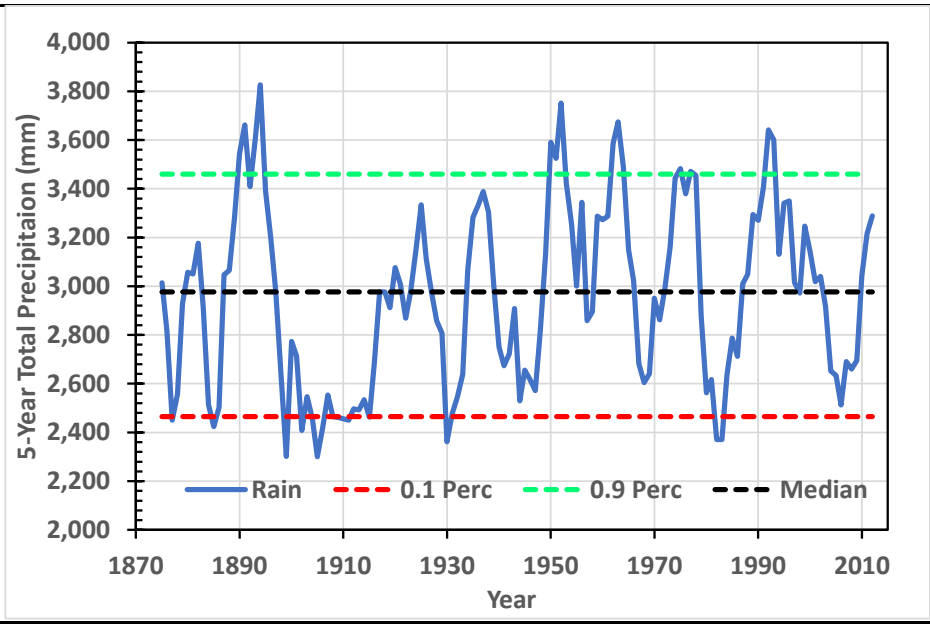


Fig 3. 5-year running precipitation at Queanbeyan compared with the median, 0.1 and 0.9 percentile rainfalls for the period 1871 to 2012. Rainfalls below the 0.1 percentile are very much below normal rainfalls, while above 0.9 percentile are very much above normal rainfalls

Table 1. Ranking of the 20 lowest 5-year precipitations at Queanbeyan (BoM 70072) for the period 1871 to 2012 and their percentile for all 5-year periods. Brown shaded values are precipitations which are classed as very much below normal. The only value during the Millennium Drought is shaded in yellow.

Ranking	Year	5 Year Run	Percentile
1	1905	2301	0.000
2	1899	2301	0.007
3	1930	2361	0.015
4	1982	2371	0.022
5	1983	2371	0.029
6	1902	2408	0.036
7	1906	2417	0.044
8	1885	2424	0.051
9	1877	2450	0.058
10	1911	2451	0.066
11	1910	2456	0.073
12	1904	2457	0.080
13	1909	2462	0.088
14	1915	2462	0.095
15	1908	2465	0.102
16	1931	2478	0.109
17	1913	2492	0.117
18	1912	2497	0.124
19	1886	2502	0.131
20	2006	2513	0.139

Only one 5-year rainfall period during the Millennium Drought, that ending in 2006, ranked 20th and again it was only a below normal rainfall period (0.1<percentile<0.3), not a very a very much below normal event.

Below and Above Normal Rainfall

The Bureau of Meteorology classifies any rainfalls that fall within the band of 0.3 to 0.7 percentile as normal rainfall. Rainfalls which fall between 0.3 and 0.1 percentiles are classed as below normal rainfalls and those between 0.7 and 0.9 percentiles as above normal rainfall. For the Queanbeyan rainfall record period, 1871 to 2012, 42 5-year rainfall periods were below normal rainfall and 42 were above normal rainfall. In our region we can therefore expect on average over 30% of the time there will be below normal 5-year rainfalls.

Duration of Major Droughts in the ACT

We can define the duration of a major drought affecting a groundwater dominated water supply system as a period from when the 5-year rainfall first drops below normal (0.3 percentile) on its way to falling below very much below normal (<0.1 percentile) to when it returns above 0.3 percentile (White *et al.*, 1999). Table 2 lists all the major 5-year drought periods at the Queanbeyan site, the lowest rainfall percentile during the drought and the duration of the drought in years[1].

Table 2 shows the duration of major droughts in the ACT in the period 1871 to 2012 ranged from 2 years to an astonishing 14 years for the so-called Federation drought (1902-15) with a median duration of 3.5 years. In total 30 years in the period were in severe drought, or over 20% of the period.

[1] A more accurate duration can be found if monthly rather than annual data is used.

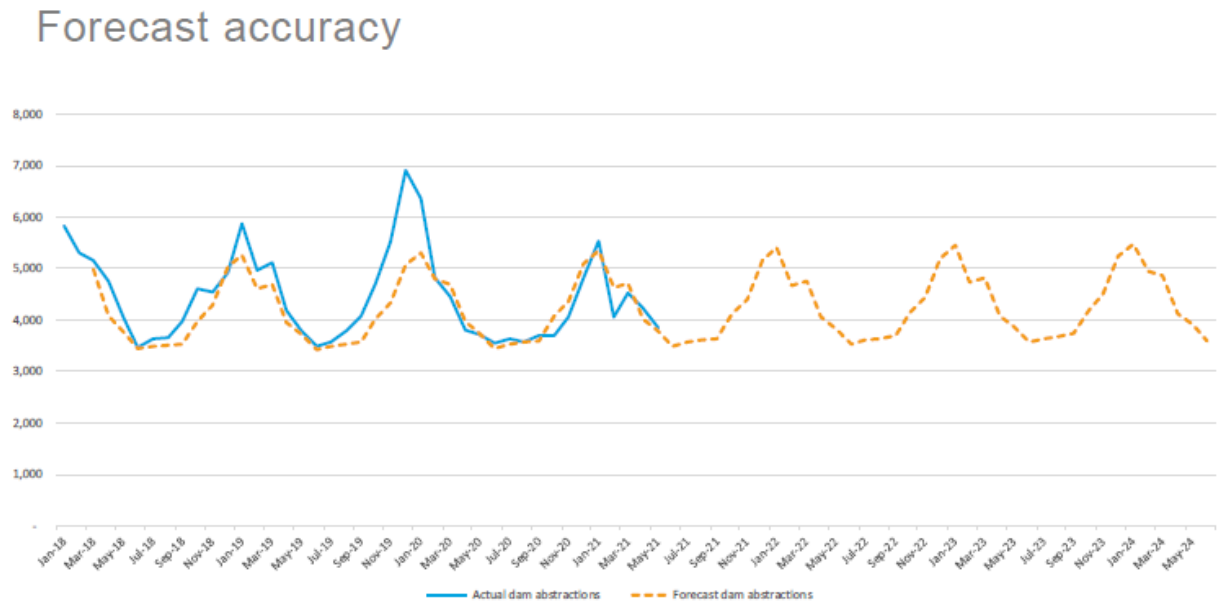
Table 2. The duration of major 5-year rainfall droughts (very much below normal rainfall) at Queanbeyan (BoM 70072) over the period 1871 to 2012, with the lowest percentile reached during the drought.

Drought Period	Lowest Percentile	Duration (years)
1877-78	0.0583	2
1884-86	0.051	3
1898-99	0.0072	2
1902-15	0	14
1930-33	0.0145	4
1980-84	0.0218	5
Total		**30**

In comparison to the durations in Table 2, the Millenium Drought, which on the definition above was only a below normal rainfall event, had a total duration of 4 years, 2004-6 and 2008, similar to the below normal rainfall period from 1944 to 1948 (lowest percentile 0.15).

Accuracy of ICON's Abstraction Forecasts During Dry Periods

ICON Water's presentation shows that in 2019-20 their model underestimated dam abstractions by 30%. While there is no BoM data available for Queanbeyan after May 2019, there is data for Canberra (BoM 70000).



The correlation of 5-year rainfall totals at Queanbeyan with that at Canberra is highly statistically significant, R = 0.90. Canberra 5-year rainfall for 2019, 3075 mm, had a percentile value of 0.3, just on the borderline of below normal rainfall. The annual rainfall for 2019, 409 mm, however, did have a percentile of 0.085, very much below normal for Canberra for the period 1936-2020, but well above the minimum annual rainfall in 1944 of 254 mm. The annual rainfall record for Canberra shows that there were at least 7 years[2] with rainfalls lower than that in 2019. This suggests that 2019 rainfalls on average could be expected, on average, about 1 in 10 years.

To compare the 2019 precipitation in Canberra to the long-term record at Queanbeyan, we can use the very strong correlation between 5-year rainfall at Queanbeyan (BoM 70072)with that at Canberra (BoM 70000) to estimate missing rainfall months in Queanbeyan for the period 2014-20 (Fig. 4).

[2] Missing data at Canberra during the Millennium Drought means that there could have been other lower annual rainfalls

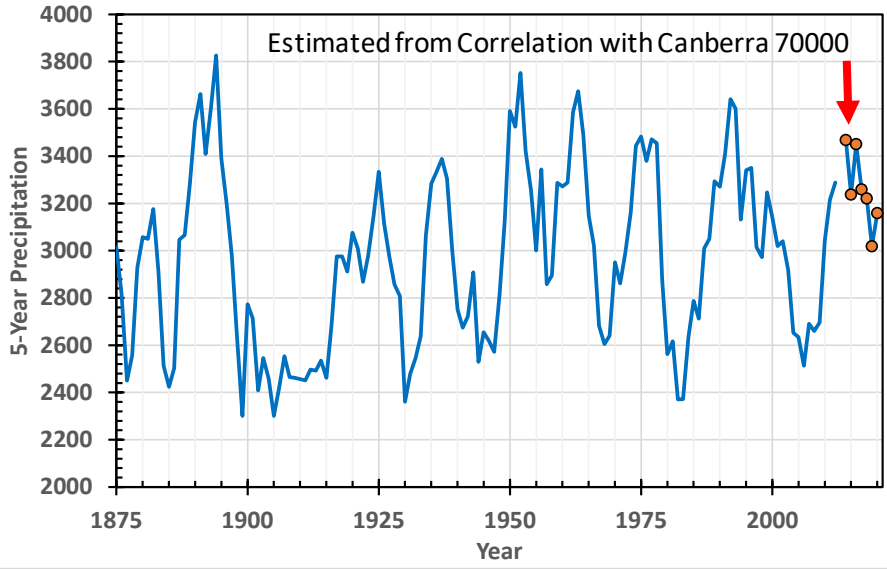


Fig 4. 5-year precipitation record for Queanbeyan (BoM 70072) with data for 2014 to 2020 estimated from the relationship with Canberra 5-year precipitation (BoM 70000).

The estimated data suggests that when compared with all 5-year periods, the 5-year period ending in 2019 had a percentile ranking of 0.55, well within the normal range (0.3<percentile<0.7) and ACT dams should have been able to easily cope with increased seasonal demand.

This mismatch between ICON Waters 2019-20 modelled abstraction and the actual abstraction might suggest that when running 12-month rainfalls drop below 0.1 percentile (say), there is a need to consider staged water restrictions rather than use pricing signals.

Future Droughts in the ACT

ICON Water consider that the pace of climate change is relatively slow and this is supported by the 141-year annual rainfall record for Queanbeyan which shows no statistically significant trend in annual rainfalls (Fig. 1). Sea surface temperatures around Australia have risen by about 1°C over the past century so there is more water vapour in the atmosphere and the projections of more intense rainfall events are well-based. The future frequency and intensity of severe droughts remains a problem for water supply. The large ocean-atmosphere interactions responsible for droughts in the ACT, ENSO events, Indian Ocean Dipole (IOD) events, the Pacific Decadal Oscillation, and changes in the Southern Annular Mode are not well handled by global circulation models.

Work in CSIRO (Cai *et al.* 2014a,b; 2015; 2018) has projected that the intensity of extreme ENSO and IOD events will double over the next century. This suggests that the intensity of droughts in the ACT may also increase. The rainfall record for Queanbeyan is probably too short to make inferences about changes in frequency or intensity of droughts. It does, however, show that the Millennium Drought was ranked 20th in historic 5-year rainfall deficits.

Conclusions

ICON Water uses 5-year projections of climate. The 5-year period is entirely appropriate for the groundwater systems which provide base-flows to ACT dams and for broad synoptic scale weather. It has also been argued here that projections of 5-year climate are problematic since the current BoM ACCESS-S climate model is most reliable for seasonal projections. An apparent assumption in ICON Waters reset of their demand model appears to be that the Millennium Drought was an exceptional event. Using the rainfall data from Queanbeyan, which is the longest available in the region and which has a very significant correlation with available data in the upper Cotter catchment (Fig. 2), it has been shown in terms of 5-year rainfall that the Millennium Drought ranked 20th of all low rainfall events well behind the Federation Drought of 1902-15 which lasted for 14 years (Table 2). On a 5-year basis, the Millennium Drought was a below normal event, whereas there were 14 other periods which were very much below normal (Table 1). This suggests that we should expect very much below normal 5-year periods which impact dam inflow on average every 17 years.

ICON Water have assumed that climate change is a slow process. The 141-year annual rainfall record for Queanbeyan shows no significant trend which supports that assumption. CSIRO modelling suggests the intensity of ENSO and IOD events will increase over the next century with global warming. Such changes are not yet discernible in the rainfall record so that a good working assumption is that the past provides at least a pointer to the future. The past indicates that the ACT experiences below normal 5-year rainfalls frequently, 30% of the time.

ICON Water's modelled abstraction for the 2019-20 dry period underestimated abstraction from dams by 30%. On a 5-year basis, the annual 2019 rainfall was only just a below normal annual event (0.3 percentile) for Canberra. Given the frequency of below normal events in the ACT, it would appear that underestimation of abstractions may be relatively frequent in future. Given the frequency of below normal 5-year rainfalls in the ACT it is suggested that the ±6%"deadband" may be too generous and that a wider "deadband" such as ±8% may be more appropriate.

One of the difficulties with this analysis has been the lack of readily available rainfall data for ACT water supply catchments. For 5-year rainfalls, the long-term Queanbeyan record is appropriate to identify significant dry periods produced by large-scale climate events.

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