

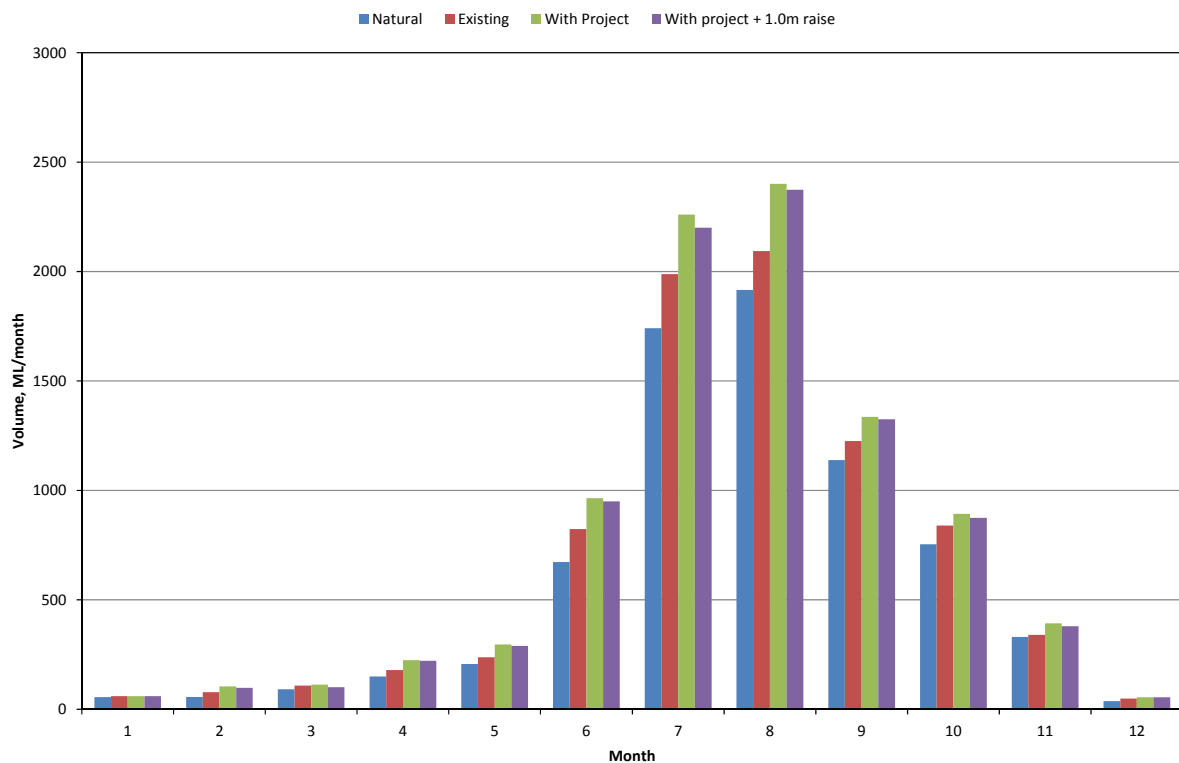


Figure 56: Average Suma Park Dam spill volume per month

Orange City Council has commissioned an environmental flow study for Summer Hill Creek that is currently underway. This study is being undertaken to inform the environmental assessment being undertaken for the Suma Park Dam project.

The study selected two representative locations along Summer Hill Creek and one in Lewis Ponds Creek for hydraulic analysis and assessment of creek flow characteristics (refer to **Figure 57**). Detailed survey from these locations was used to construct HEC-RAS hydraulic models which were used to determine the changes in flow depth, channel velocity, flow area and top width for the flow deciles presented in **Tables 4.10** and **4.11**.

Results of this analysis are presented in **Table 4.13** and show the range of differences calculated for the “existing” and “with project” flows. No results are presented for the maximum and minimum flows due to no, or very minimal, changes in these values.

The modelled changes in flow depth in Reach 1 (immediately downstream of Suma Park Dam) are around 60 mm, with a minimal velocity increase of 0.11 m/s.

The largest flow depth change computed for Reach 2 (Summer Hill Creek) is an increase of 30 mm for the 80th percentile flow. Velocity changes range from a reduction of 0.28 m/s to an increase of 0.25 m/s. There are minimal changes in flow area and top width.

The largest flow depth change computed for Reach 3 (Lewis Ponds Creek) is an increase of 36 mm for the 90th percentile flow. Velocity changes range from a reduction of 0.17 m/s to an increase of 0.24 m/s. There are minimal changes in flow area and top width.

These results indicate insignificant changes in hydraulic characteristics with the predicted flow changes in the Summer Hill/Lewis Ponds Creek system. The assessment is based on the modelled flows from Suma Park Dam and Blackmans Swamp Creek and does not include the influence of tributary inflow downstream of the confluence of these two creeks. Inflow from downstream tributaries would reduce the modelled changes.



Table 4.13 – Summer Hill Creek hydraulic modelling

Percentile	Flow ⁽¹⁾ m ³ /s	Flow depth Difference ⁽¹⁾ m	Channel Velocity Difference ⁽¹⁾ m/s	Flow Area Difference ⁽¹⁾ m ²	Flow Top Width Difference ⁽¹⁾ m
Summer Hill Creek – Reach 1 ^{(2) (3)}					
10	0.117	0 – 0.064	-0.005 – 0.11	0 – 0.41	0 – 3.06
Summer Hill Creek – Reach 2 ⁽⁴⁾					
10	0.046	0 – 0.008	-0.011 – 0.018	0 – 0.12	0 – 0.26
20	0.046	0 – 0.016	0 – 0.057	0 – 0.24	0 – 0.31
30	0.012	0 – 0.018	-0.132 – 0.076	0 – 0.09	0 – 0.19
40	0.011	0 – 0.014	-0.104 – 0.062	0 – 0.11	0 – 0.25
50	0.009	0 – 0.007	-0.015 – 0.056	0 – 0.11	0 – 0.31
60	0.008	0 – 0.008	0 – 0.22	0 – 0.13	0 – 0.32
70	0.007	0 – 0.013	-0.058 – 0.113	0 – 0.12	0 – 0.25
80	0.010	0 – 0.030	-0.276 – 0.246	0 – 0.22	0 – 1.8
90	0.009	0 – 0.024	-0.201 – 0.161	0 – 0.31	0 – 1.08
Lewis Ponds Creek ⁽⁵⁾					
10	0.046	0 – 0.012	0 – 0.074	0 – 0.41	0 – 0.34
20	0.046	0 – 0.023	-0.084 – 0.128	0 – 0.59	0 – 0.69
30	0.012	0 – 0.008	0 – 0.021	0 – 0.22	0 – 0.45
40	0.011	0 – 0.109	-0.043 – 0.073	0 – 0.23	0 – 0.52
50	0.009	0 – 0.019	-0.173 – 0.215	0 – 0.22	0 – 0.55
60	0.008	0 – 0.009	0 – 0.081	0 – 0.24	0 – 0.34
70	0.007	0 – 0.009	-0.01 – 0.056	0 – 0.25	0 – 0.45
80	0.010	0 – 0.019	-0.013 – 0.086	0 – 0.46	0.04 – 0.81
90	0.009	0 – 0.036	0 – 0.235	0 – 0.66	0 – 1.48

1 Positive number means an increase; negative number a decrease

2 Range of modelled changes from 15 model sections over 1,600 m creek centre line

3 No change in other flow deciles – refer to Table 4.10

4 Range of modelled changes from 22 model sections over 1,654 m creek centre line

5 Range of modelled changes from 21 model sections over 1,444 m creek centre line

4.3.7.3 Water Balance Discussion

The water balance modelling demonstrates that the transfer of water from external sources (such as from the Macquarie River to Orange pipeline project) increases the spill from Suma Park Dam. This is because the storage is kept fuller and when natural runoff is received less volume is required to fill the storage resulting in a greater spill volume. The increased total storage volume achieved by raising the dam by 1.0 m reduces this effect by capturing more of the catchment runoff when it occurs.

Water security is more about managing water storages when they are below full supply level rather than when they are full and spilling. The addition of external water to the storage while the storage is less than full supply increases water security. The trade-off is that some of the natural catchment runoff cannot be captured. It essentially comes down to timing: during dry periods when the storage is below full, the additional water sources improve water security and additional water demand can be supplied; when catchment runoff occurs to the extent that it can fill the storage, it does so, with the additional water not required and contributing to improved downstream flows.

A much larger storage would improve this situation. However the engineering investigations undertaken for the dam strengthening have identified that raising the existing dam by more than 1.0 m is not technically feasible. Therefore the maximum volume that can be achieved at Suma Park Dam is 18,970 ML. With the understanding that no further storage can be obtained at Suma Park Dam, the next best method of improving water security is adding additional sources of water to the storage when it is below full supply capacity.

Modelling demonstrates that the increased flow in the Summer Hill Creek system caused by the increased spill would have insignificant impact on the creek system as the hydraulic changes are minimal and would be dampened by inflow from downstream tributaries.

Finally it is noted that the increase in the average annual flow in Summer Hill Creek will flow through to the Macquarie River. The modelled increase is 1,298 ML/year without the dam raising or 1,190 ML/year with the dam raising. This additional system flow will offset the long term average annual extraction from the Macquarie River.

4.3.8 IMPACT OF SCENARIO A MACQUARIE RIVER FLOWS

Assessment of the project is based on the Scenario B Macquarie River flow series. This flow series represents the likely future water availability should the catchment conditions in the future prove to be similar to that of the last ten years. As discussed in **Section 3.3.2**, the flow series derived for Scenario B has lower flows throughout the entire flow regime compared to the historical assessment represented by Scenario A.

If future river conditions closely resemble historical conditions (as represented by Scenario A) there would be more water available in the Macquarie River, with a general increase in daily flows. Under this scenario, the adopted cease to pump level of 38 ML/day would be equivalent to the 93rd percentile flow. Therefore pumping would not occur below the recommended 95th flow percentile cease to pump threshold (Government of New South Wales, 2002) and this would protect the very low flows and the supply to basic right pumpers during dry periods.

The project does not need to operate above the long term average presented in this assessment to provide adequate water security over the next 50 years. Therefore if the higher river flows (similar to historical values) persisted the impact of the project in terms of the proportion of river flow extracted would be less than as assessed in this report.

4.3.9 SUMMARY AND DISCUSSION

4.3.9.1 Summary

Table 4.14 provides a summary of the project during dry, average and wet conditions. The data for dry and wet periods is derived from the assessment presented above.

The water balance results show that the average annual flow in Summer Hill Creek would increase as a result of the project. This additional system flow would offset the long term average annual extraction from the Macquarie River. The modelled increase is approximately 1,300 ML/year without raising Suma Park Dam. This would reduce the average annual extraction from the Macquarie River system to around 320 ML/year, which represents 0.1% of the average annual river flow at the proposed offtake point.

Table 4.14 – Summary of extractions for dry, average and wet conditions

Parameter	Dry	Average	Wet
Average annual transfer, ML/year	~2,300	1,616	700 – 950
Proportion of river flow extracted	1.0% - 2.4%	0.52%	0.1% - 0.2%
No. of pump days per year	150 - 240	135	60 - 80

4.3.9.2 Discussion

As would be expected, the assessment of dry period shows a greater proportion of the river flow is extracted from the Macquarie River compared to the long term average extraction. This is because the streamflow volume is lower and storage levels at Orange such that there is a continued demand for water. While the assessment shows that the proportion of the water transferred is greater, it also demonstrates that the adoption of a cease to pump threshold prevents the project from impacting on low flows. This would protect basic stock and domestic rights along the unregulated section of the Macquarie River through to Burrendong Dam. Not pumping during low flows also preserves environmental flows in the river system.

The fact that the system can keep supplying water for Orange, whilst maintaining low flows indicates that there is adequate resource in the Macquarie River to support the project.

Again it is noted that the project increases the average annual flow in the Summer Hill Creek system which would flow through to the Macquarie River. While this would not occur during the dry periods (as it is most likely that Suma Park Dam would not be spilling) it does offset the long term average water extraction.

Analysis of impacts through the regulated section of the Macquarie River system during dry periods is presented in **Section 4.6.2**.

4.4 WATER SECURITY ASSESSMENT

4.4.1 IMPACT ON ORANGE SECURE YIELD

4.4.1.1 Existing Secure Yield

Orange City Council current water supply system consists of the following elements (**Figure 58**):

- Surface water catchments and the main reservoirs formed by Gosling Creek, Spring Creek and Suma Park Dams
- Groundwater bores at the Showground, Council works depot and Clifton Grove
- The Blackmans Swamp Creek stormwater harvesting scheme – currently approved to operate whenever the level in Suma Park reservoir is below 50%
- The Ploughmans Creek stormwater harvesting scheme – currently approved to operate whenever the level in Suma Park reservoir is below 100%

Secure yield modelling undertaken for the Integrated Water Cycle Management Evaluation Study (Geolyse, 2012a) has determined that the secure yield of the current system is 4,750 ML/year, made up of:

- | | |
|---|---------------|
| • Surface water catchments (Spring Creek Dam and Suma Park Dam) | 3,400 ML/year |
| • Harvesting schemes (Blackmans Swamp Creek and Ploughmans Creek) | 900 ML/year |
| • Bores (Licensed for 462 ML/year) | 450 ML/year |

A summary of the secure yield modelling results is provided in **Appendix A**. It should be noted that the secure yield results for the existing water supply system provide a secure yield of 4,600 ML/year (Run 3-1). This is based on both stormwater harvesting schemes operating whenever Suma Park Reservoir is less than 100% and the bores providing 75 ML/year. Reducing the operation of the Blackmans Swamp Creek stormwater harvesting scheme lowers the secure yield by 200 ML/year, while the additional inflow from the recently licensed bores increases it by 350 ML/year.

Therefore the secure yield of the existing water supply system is 4,750 ML/year (i.e. 4,600 – 200 + 350).

This result indicates that while Orange City Council holds a town water supply entitlement of 7,800 ML/year, the existing water supply system is not able to deliver this volume during drought periods. The project provides an additional independent water supply that is drawing water from the same water source (i.e. the Macquarie catchment) that could help contribute to the water security for Orange. Adding independent water sources to the system increases security.

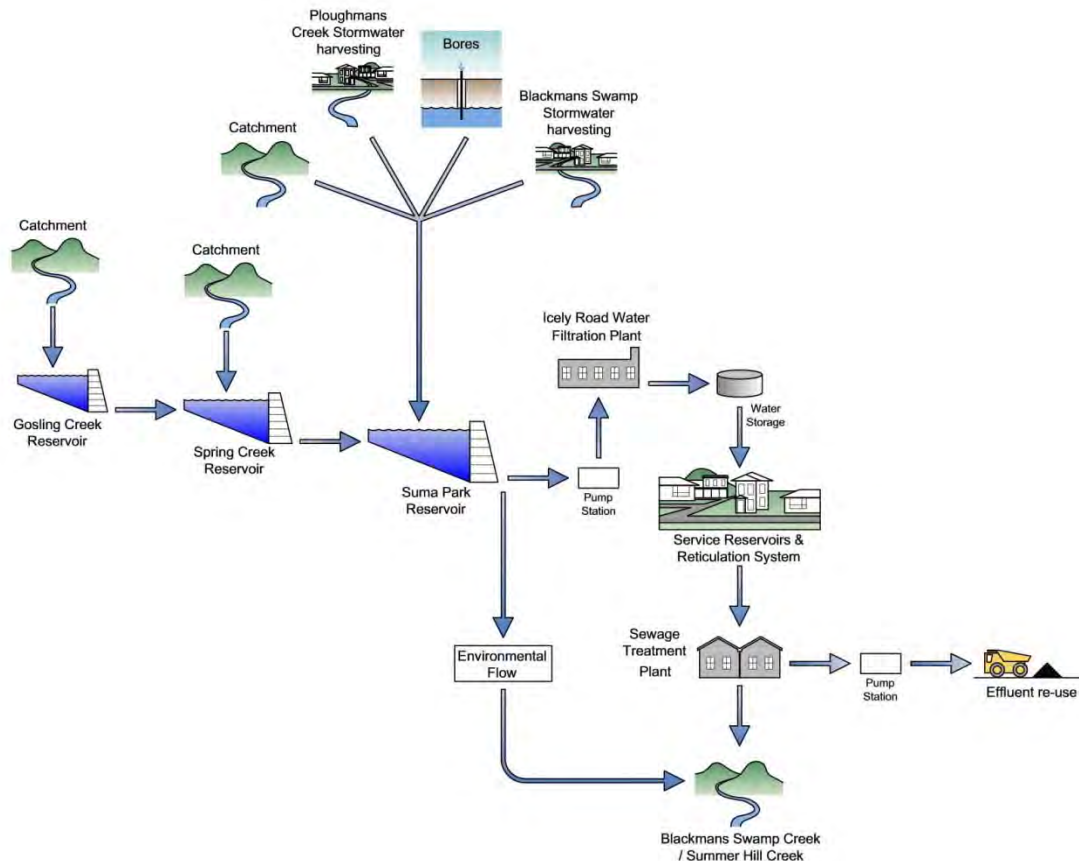


Figure 58: Orange water system schematic

4.4.1.2 Secure Yield Provided by the Project

Secure yield modelling of the project using the 12/34 operating rule, shows that the transfer of water from the Macquarie River increases the Orange water system secure yield by 2,800 ML/year. These results are presented in **Appendix A**.

As noted in **Section 4.2.1**, the cease to pump threshold was raised from 34 to 38 ML/day to ensure the equivalent daily river flow during pumping did not fall below 22 ML/day (the 80th percentile flow) so as to protect low flows. Water balance modelling indicated that raising the river trigger to 38 ML/day would reduce the secure yield by approximately 100 ML/year. Therefore, the estimated secure yield provided by the project is 2,700 ML/year. This would provide a total system secure yield of 7,450 ML/year.

The increase in secure yield provided by the project does not change if the level of Suma Park Dam is raised by 1.0 m. Raising the dam itself increases the secure yield by 150 ML/year, but this option does not have a significant impact on the volume transferred from the Macquarie River.

The current unrestricted annual water demand for the city is 5,400 ML/year (Geolyse, 2012b). Future water demand has been modelled based on medium (0.8% pa) and high (1.1% pa) population growth assumptions and demand management scenarios that lead to a reduction in the per capita consumption over the long term (Geolyse, 2012b). Under these assumptions a secure yield of 7,550 ML/year meets the forecast demand until:

- beyond 2060 for the medium population growth
- 2051 for the high population growth.

This is reflected in **Figure 59**.

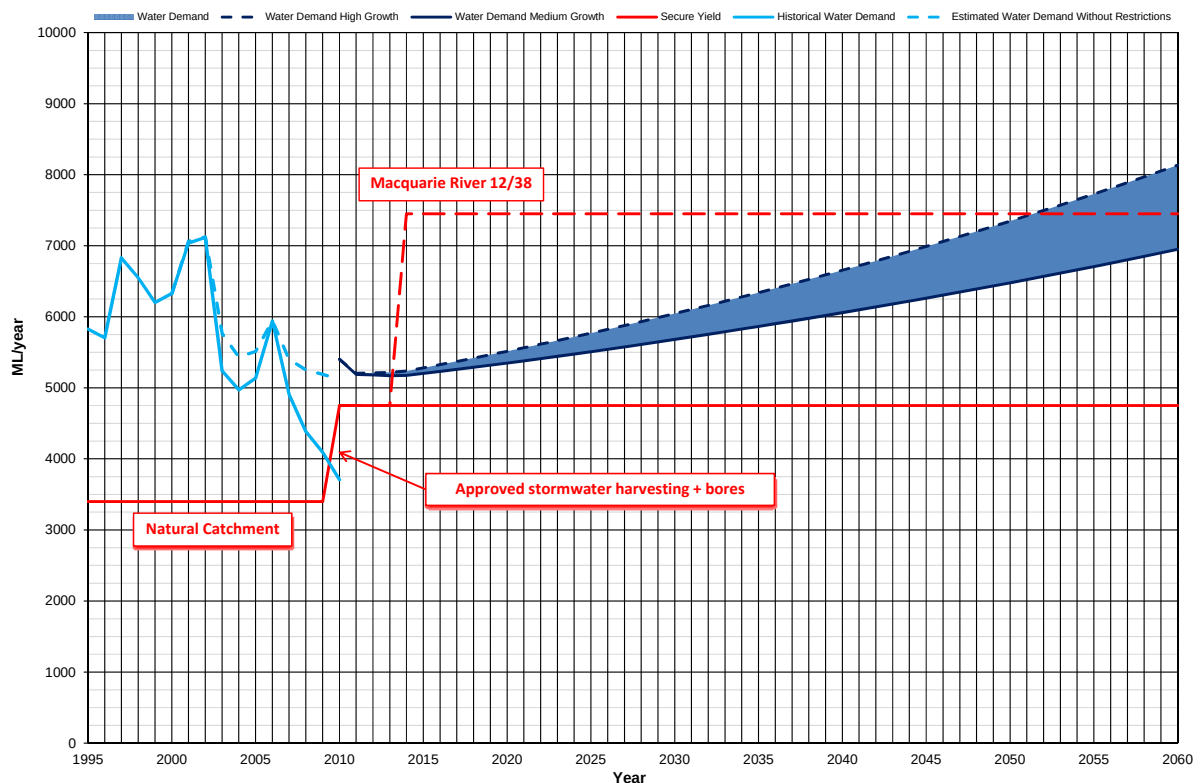


Figure 59: Demand vs secure yield – no climate change

4.4.1.3 Climate Changed Secure Yield

Climate changed secure yield was assessed using the procedures described by Samra and Cloke (2010). This assessment included the addition of inflow from the stormwater harvesting schemes, bores and Macquarie River to Orange pipeline operating on the previous 12/34 operating rule.

A summary of this assessment is provided in **Appendix B** and shows a reduction factor of 6% to 8% can be applied to the best estimate of secure yield. It is considered that the same reduction factor would apply for the proposed 12/38 operating rule.

Adopting the upper end of these results indicates the total secure yield could fall to around 6,850 ML/year by the year 2030.

The Centroc Water Security Study (MWH, 2009) provided an assessment of the possible impact of climate change on water demand. For Orange, this assessment indicated that potable water demand could increase by around 7% or about 400 ML/year (in 2050).

The climate changed secure yield and increased water demand are reflected on **Figure 60** and show the existing system plus the project meets the forecast demand until:

- 2049 for the medium population growth
- 2038 for the high population growth.

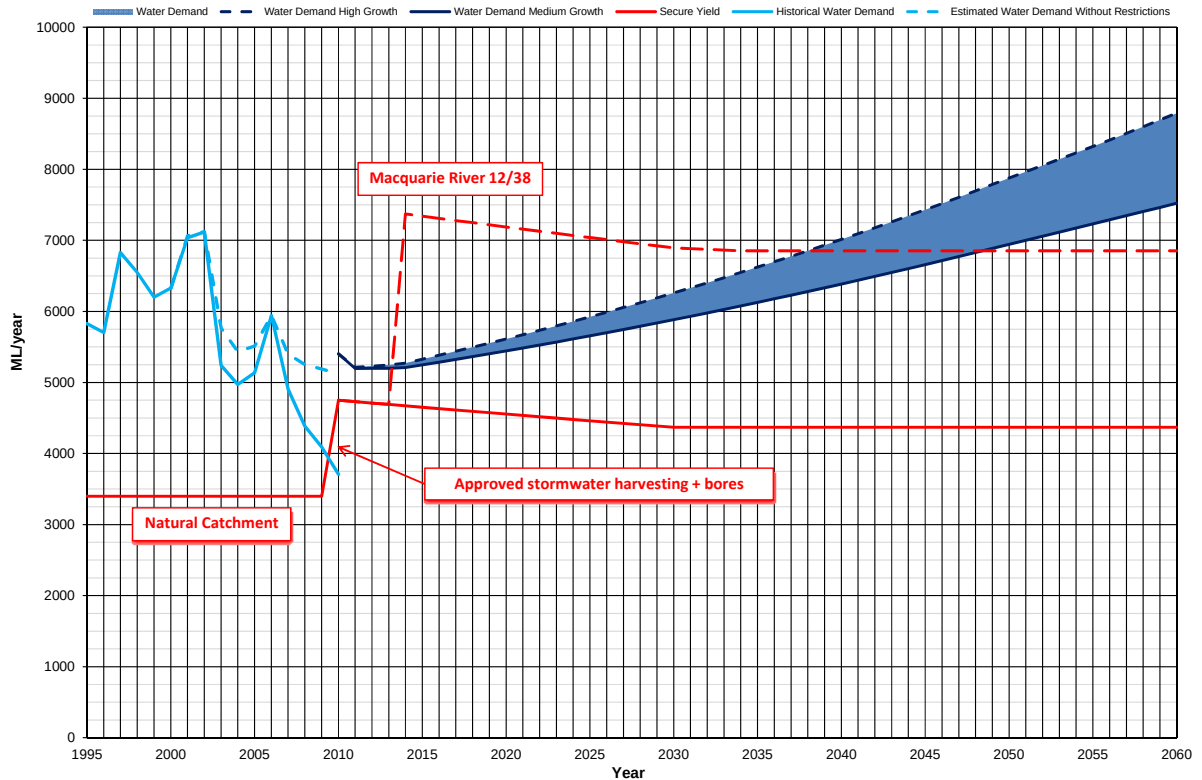


Figure 60: Demand vs secure yield – with climate change

4.4.1.4 Improved Climate Change Resilience

Orange City Council was one of the utilities used in the pilot study to define the methodology for the assessment of climate changed secure yield (Samra and Cloke, 2010). Results from this pilot study indicate that a climate change reduction factor of 26% applies to the existing catchment and storage system (i.e. the existing catchment and storages without additional sources). Results from the climate change secure yield modelling for the previous 12/34 operating rule that the climate change reduction factor reduces to around 6% to 8%. This indicates that by diversifying and augmenting the water sources, the water supply system has become more resilient to the potential impacts of climate change.

4.4.2 THE 2000 TO 2010 DROUGHT

This section presents an assessment of how Orange City Council's combined water storage could have behaved if the project was in operation through the period from January 2000 to December 2010. The assessment is based on actual data recorded over this period for flows in the Macquarie and Turon rivers (using river data from the Bruinbun and Sofala gauges), storage behaviour and water consumption.

How was the Assessment Undertaken?

- Daily Macquarie River flow data was obtained for the gauging station at Bruinbun and for the Turon River at Sofala. These data were added together to provide a daily flow series at the proposed offtake point. The discussion in **Section 3.2** indicates that the straight addition of the daily flow from these two upstream gauges provides a reasonable, and conservative, estimate of flow at the offtake point.
- The potential volume available from the Macquarie River was determined based on the 12/38 operating rule i.e. extracting 12 ML/day from the river whenever the flow is greater than 38 ML/day. The daily extraction was summed to provide a potential monthly transfer value.
- A monthly water balance was developed for Suma Park Reservoir. This was developed using the recorded end of month storage data and recorded monthly water consumption. The average monthly storage volume was used to determine a surface area so that evaporation losses and direct rainfall additions to the storage could be calculated. Using this data, a monthly inflow series was determined using a back calculation method.
- Monthly water consumption data was analysed to determine how each level of water restriction applied over the period impacted on the amount of water consumed. This was done so that the potential higher water consumption could be accounted for with the Macquarie River pipeline option as storages would not fall to the historic levels.
- A second monthly water balance model was established for Suma Park Reservoir that used the inflow series derived from the actual data and added the transfer of water from the Macquarie River whenever the volume in Suma Park reservoir was less than 90%. The following calculations were undertaken for each month of the model:
 - the storage at the start of the month was checked to see if it was less than 90%. If it was the volume available from the Macquarie River was transferred to Suma Park Reservoir.
 - the combined storage at the start of the month was used to define the level of water restriction that would be in place and the corresponding monthly water demand applied. If this monthly demand was less than the actual monthly demand, the actual monthly demand value was used.
 - the storage in Suma Park Reservoir at the start of the month was used to determine the surface area to calculate evaporation losses and direct rainfall additions.
 - the actual Spring Creek Reservoir storage was added to the calculated Suma Park Reservoir storage to determine the combined storage volume at the end of each month, as the combined storage volume is used to determine the water restriction level.

It is noted that during this period the storage in Spring Creek Reservoir was manipulated to facilitate dam safety work. The assessment assumed that this operation remained unchanged.

Macquarie River Flow Data

The recorded daily river flow data for the period January 2000 to December 2010 was obtained for the Bruinbun and Sofala gauges and added to provide an estimate of Macquarie River flow at the proposed offtake point. This data is shown as duration curves in **Figure 61**.

There were 165 days over this period where no river flow data were available at either or both of the gauging stations (4.1% of days). Missing data was assigned a null value and not used in the analysis.

The flow duration curve derived from the addition of daily flow at Bruinbun and Sofala shows that the estimated flow in the river was greater than 38 ML/day for approximately 81% of the time over this period.

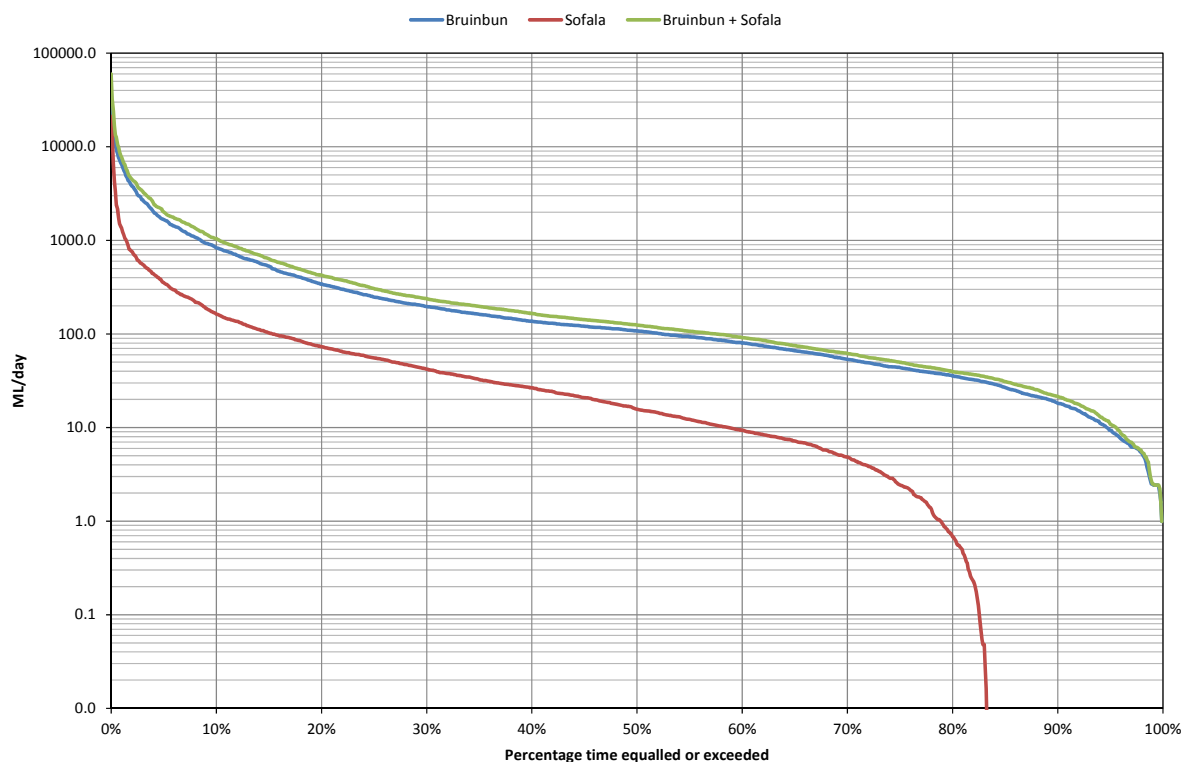


Figure 61: Daily Macquarie River flow data – January 2000 to December 2010

Combined Storage

Figure 62 shows the actual recorded combined storage and the modelled combined storage with the addition of inflows from the Macquarie River pipeline. This shows that with the addition of the Macquarie pipeline transfer, the combined storage level would not have fallen much below 50% and water restrictions would have remained at Level 2 or less.

The lowest actual combined storage recorded during this period was 23% in May 2010 (approximately 5,000 ML in storage). With the addition of water from the proposed Macquarie River pipeline, the combined storage at the same time is modelled to be 63% (13,700 ML in storage). The minimum combined storage with the modelled input from the Macquarie River pipeline is 10,700 ML (49%) in June 2008.

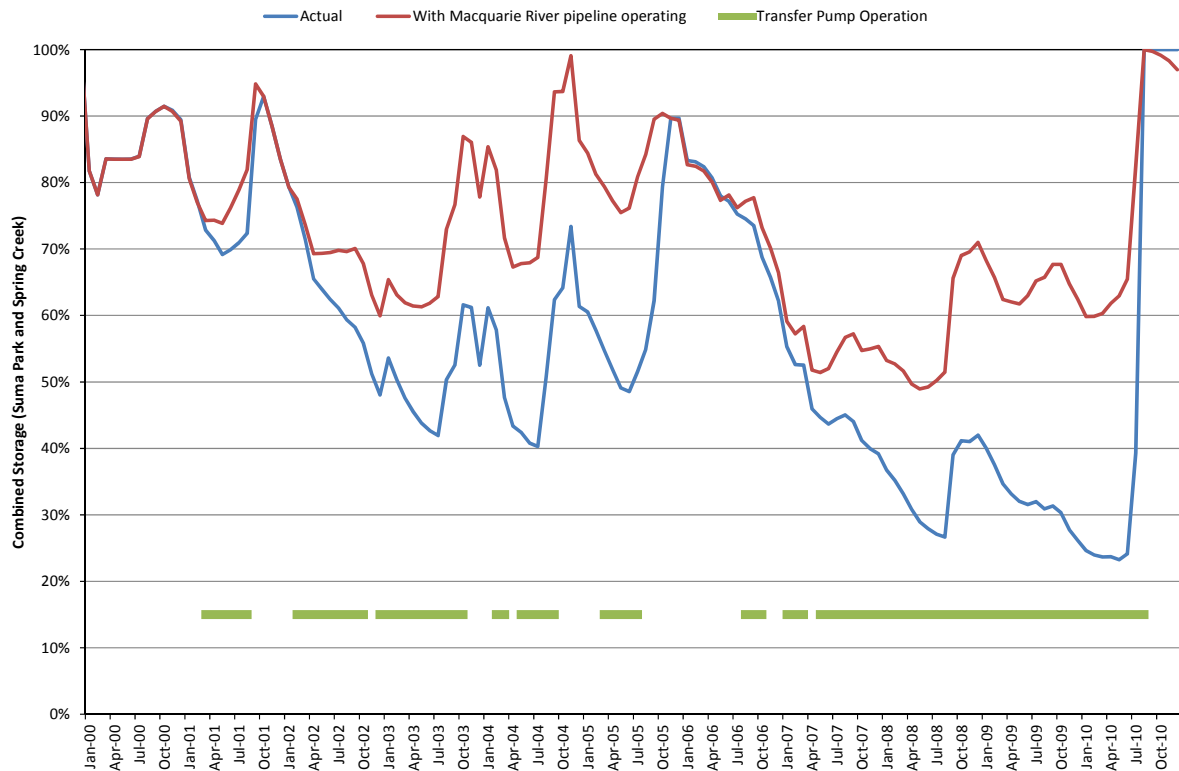


Figure 62: Combined storage behaviour: 2000 to 2010 analysis

Table 4.15 summarises the actual water consumption and the modelled water consumption that could have been supplied if the Macquarie River to Orange pipeline was operating. This demonstrates that increased annual water consumption could have been provided as the level and period of water restrictions would have been less with the addition of water from the Macquarie River.

Table 4.15 – Comparison of actual and modelled annual water consumption – 2000 to 2010 analysis

Year	Actual Consumption ML	Modelled Consumption ML	Change ML
2000	6326	6367	+ 40
2001	7063	7063	0
2002	7124	7124	0
2003	5239	5616	+ 377
2004	4973	5547	+ 574
2005	5138	5680	+ 542
2006	5941	6053	+ 112
2007	4896	5210	+ 314
2008	4389	5082	+ 692
2009	4091	5043	+ 952
2010	3765	5107	+ 1342

Table 4.16 shows the modelled annual river flow and volume extracted for each year of the assessment. This shows that the annual extraction ranged from 0.6% to 8.4% of the river flow, with an average of 1.2% over the period.

It is noted that the maximum annual extraction volume as a percentage of the annual river flow derived from this assessment is greater than calculated for the long term modelling which shows a peak of 6.0% (refer to **Section 4.3.2**). As described in the methodology for this assessment, it is based on the estimated river flow using the addition of the two upstream gauges. There is a further 1,826.5 km² of catchment area downstream of these two gauges (this represents 25% of the total catchment upstream of the proposed offtake point) and inflow from this catchment would add to the annual flow volume at the proposed offtake point.

If the Scenario B flow series is used to estimate the annual flow volume at the proposed offtake point, the maximum annual extraction is 4.2% as this modelled flow series includes the input from the catchment area downstream of the two gauges. This annual extraction is consistent with the long term modelling results.

Table 4.16 – River flow and extraction – 2000 to 2010 analysis

Year	Annual Macquarie River Flow ML	Annual Extraction ML	Volume Extracted as Percentage of Annual River Flow
2000	535818	0	0.0%
2001	119474	2208	1.8%
2002	39531	2784	7.0%
2003	88200	3480	3.9%
2004	70665	1716	2.4%
2005	219387	1320	0.6%
2006	51803	1164	2.2%
2007	118157	3036	2.6%
2008	92543	3612	3.9%
2009	33225	2784	8.4%
2010	767339	2508	0.3%
Totals	2136143	24612	1.2%

4.5 SENSITIVITY ANALYSIS

It has been suggested through community consultation that the flow data for the Macquarie River at Bruinbun is inaccurate in the low flow range. A community member who regularly crosses the river has observed days when there is no flow at Long Point despite the Bruinbun gauge indicating a flow of 20 or 30 ML/day. It is possible that this may occur if low flows at Bruinbun do not reach the Long Point area during dry periods, although this was not supported by the river flow data presented in **Section 3.2.1**.

The hydrology assessment has already factored in the possibility of less river flow than indicated by the historical data by adopting the Scenario B flow series. However if the low flow part of the flow duration curve is doubtful, the Scenario B flow series may be over estimating the pumping opportunity.

Therefore, a sensitivity analysis was undertaken to examine the impact of less flow, or more days of zero flow at the proposed offtake point. This was done by subtracting a set daily flow volume (20 ML/day and 30 ML/day) from the Scenario B flow series. The flow duration curves for the sensitivity analysis are shown in **Figure 63**. These flow duration curves show that by subtracting the set daily flow, the proportion of time when there is little or no flow in the river increases. The

Scenario B flow series indicates there is likely to be flow above 0.1 ML/day about 99% of the time, that is, little or no flow around 1% of the time. This is consistent with the historical Bruinbun stream flow data. Subtracting 20 ML/day from the Scenario B flow series, results in the river having little or no flow around 19% of the time (around 70 days per year on average). By subtracting 30 ML/day, the river is likely to have little or no flow around 25% of the time (around 91 days per year on average).

It is considered that subtracting 30 ML/day is an extremely conservative assumption as it suggests little or no flow in the Macquarie River for around three months each year at the proposed offtake point. Despite this conservativeness, the sensitivity analysis adopted this reduced flow series for the analysis of the long term average extraction data and the estimated secure yield.

A similar approach was adopted for the 2000 to 2010 analysis with 30 ML/day being subtracted from the estimated river flows derived from the addition of daily Bruinbun and Sofala river data.

It is noted that by reducing the flow series by subtracting 30 ML/day, the 80th percentile flow is less than 0.1 ML/day. The sensitivity analysis was based on maintaining the proposed 12/38 operating rule which means that the flow trigger of 38 ML/day is around the 59th percentile flow. This reduces the pumping opportunity.

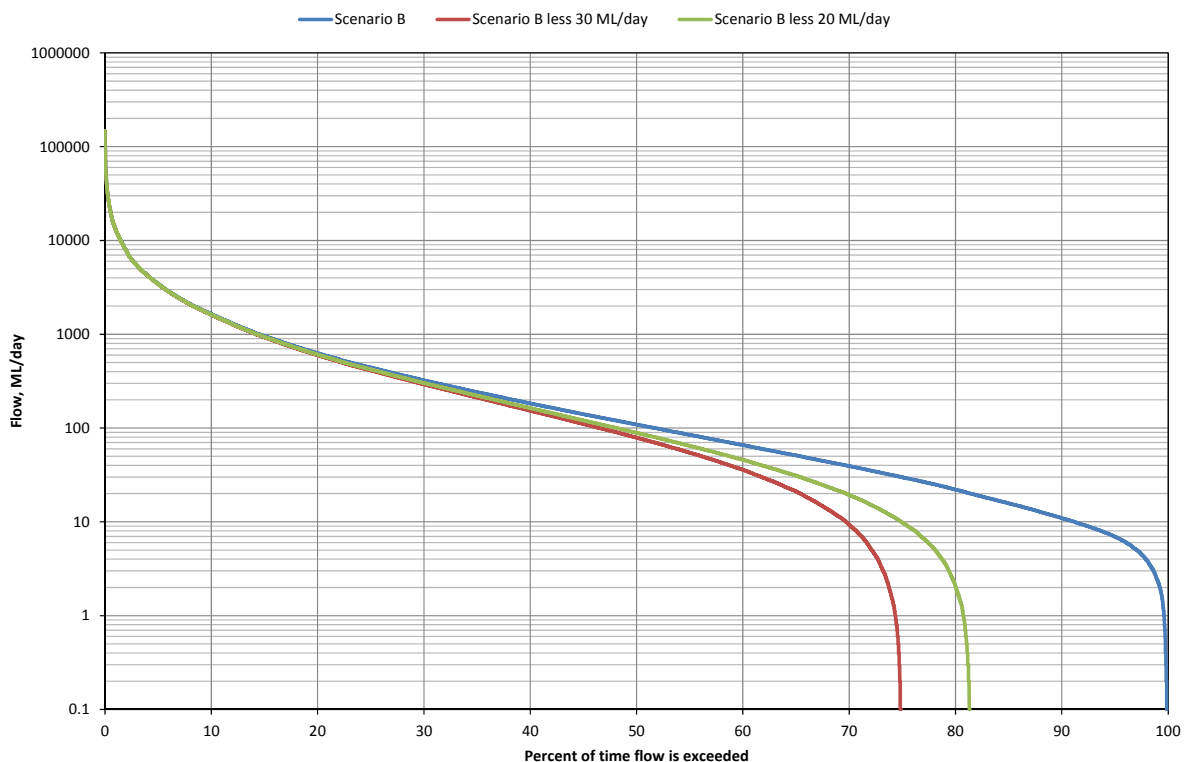


Figure 63: Flow duration curves for sensitivity analysis

4.5.1 LONG TERM AVERAGES

Water balance modelling was used to determine the long term average operating parameters for the project based on the 12/38 rule using the river flow series reduced by 30 ML/day. Model results show:

- pumping occurs approximately 30% of the time, averaging 111 pump days per year, ranging from zero to 271;
- of the 118 years modelled some transfer would have occurred in 116 of the years;
- the average long term extraction from the river is 0.44% of the annual flow, ranging from zero to 5.8% for individual years;
- the maximum extraction from the river in any one day is 31.5% (i.e. 12 ML/day extracted during a river flow of 38 ML/day);

- the average extraction on pumping days is 1.3% of flows in the river; and
- the average annual extraction is approximately 1,332 ML/year, ranging from zero to 3,252 ML/year.

The modelled flow duration curves are shown in **Figure 64**. There is no pumping in the low flow range (i.e. flows less than the 80th percentile flow).

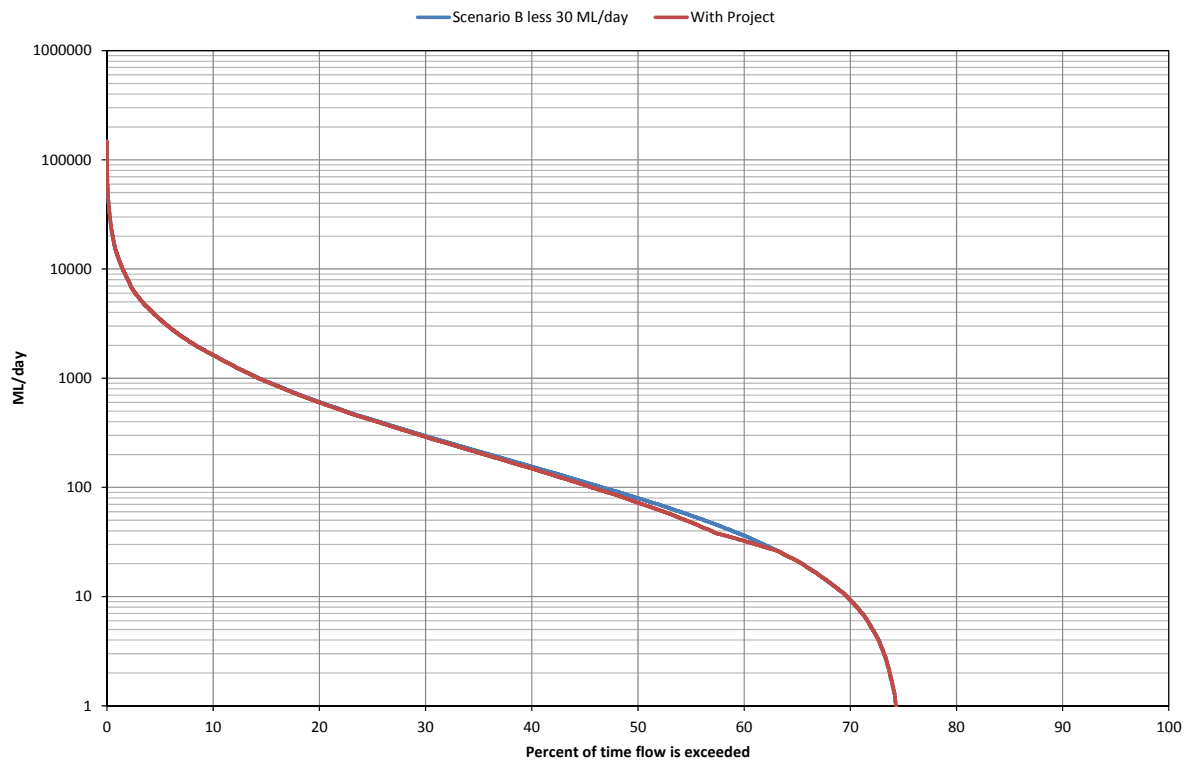


Figure 64: Macquarie River FDCs for 12/38 rule with reduced river flow

4.5.2 ESTIMATED SECURE YIELD

The estimated secure yield based on the reduced flow series are:

- Flow reduced by 20 ML/day = 2,300 ML/year
- Flow reduced by 30 ML/day = 2,200 ML/year

Using the flow series reduced by 30 ML/day reduces the secure yield to 2,200 ML/year. This would provide a total secure yield (coupled with the existing system) of 6,950 ML/year which meets the forecast demand until (see **Figure 65**):

- 2060 for the medium population growth
- 2044 for the high population growth (about 9 years less than Scenario B)

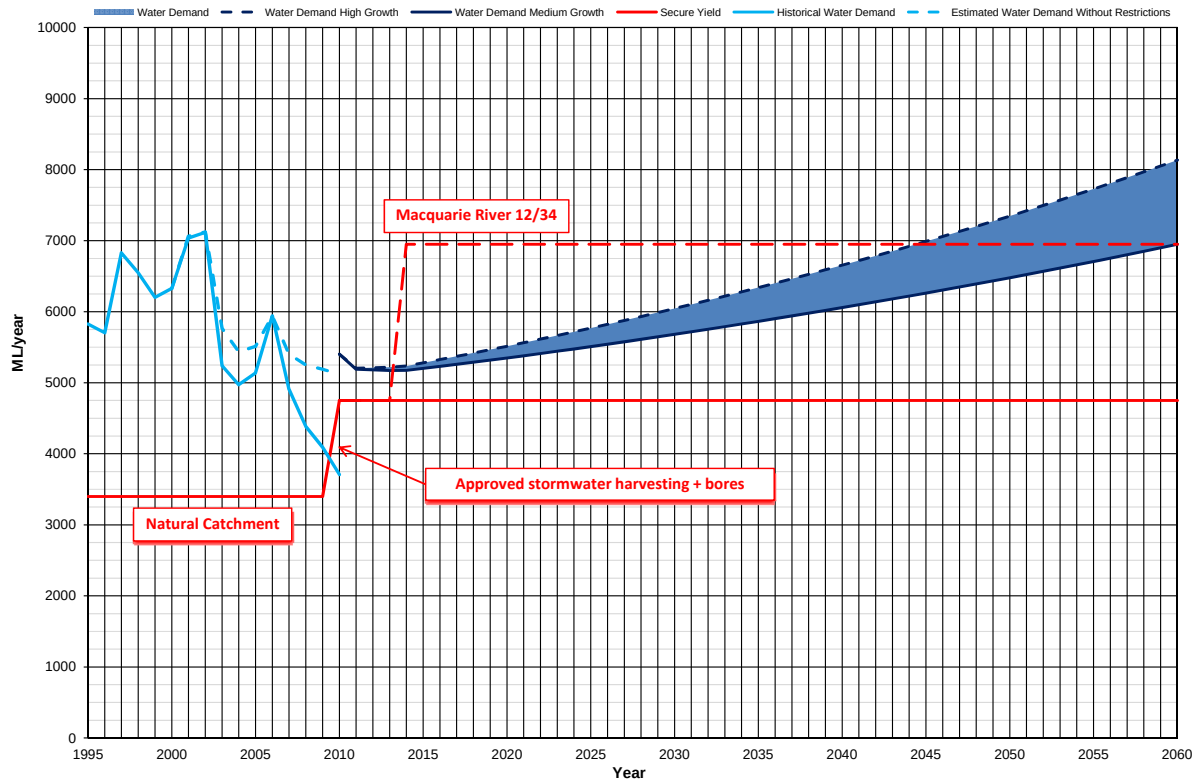


Figure 65: Demand vs secure yield (no climate change) – reduced river flow series

4.5.3 2000 TO 2010 ANALYSIS

The river flow series used in the 2000 to 2010 analysis (based on the addition of Bruinbun and Sofala data) was reduced by 30 ML/day. The resulting flow duration curve is shown as **Figure 66** and again shows a dramatic reduction in the low flow range.

Results of the 2000 to 2010 analysis are shown in **Figure 67**. The combined storage fell to a minimum of 45% compared to around 49% for the flow series. This would have resulted in Level 3 water restrictions being applied for a short period.

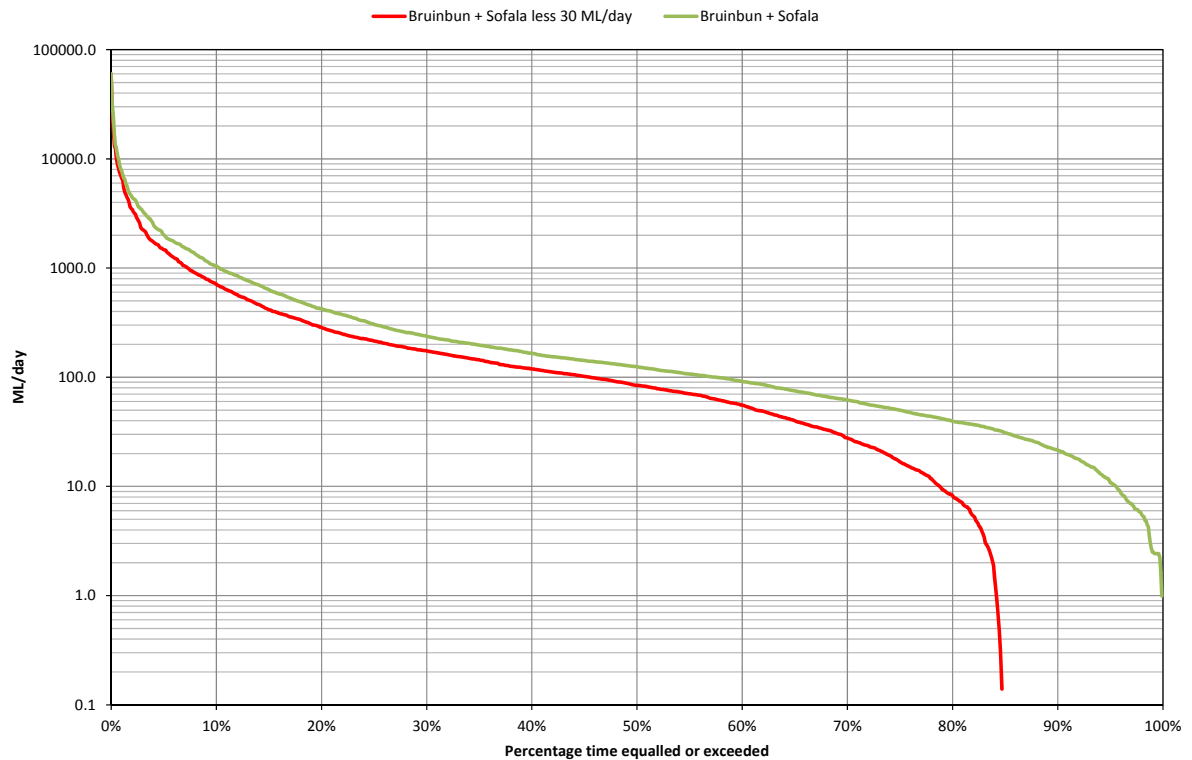


Figure 66: Daily Macquarie River flow data – January 2000 to December 2010 less 30 ML/day

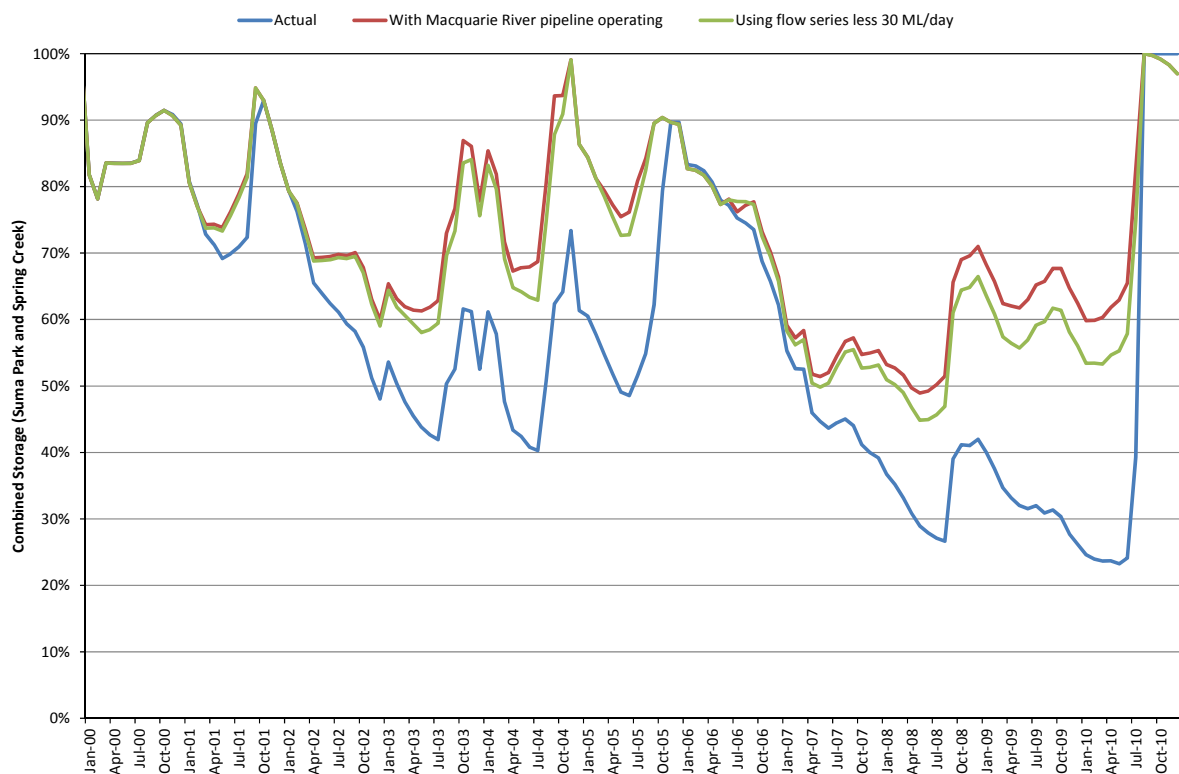


Figure 67: 2000 to 2010 analysis – reduced river flow series

Table 4.17 summarises the actual water consumption and the modelled water consumption that could have been supplied if the Macquarie River to Orange pipeline was operating with the reduced river flow series. The project provided an extra 4,636 ML to the community over this period compared to 4,945 ML with the Scenario B flow series.

Table 4.17 – Actual and modelled annual water consumption – 2000 to 2010 analysis, reduced river flow

Year	Actual Consumption ML	Modelled Consumption ML	Change ML
2000	6326	6367	+ 40
2001	7063	7063	0
2002	7124	7124	0
2003	5239	5616	+ 377
2004	4973	5547	+ 574
2005	5138	5680	+ 542
2006	5941	6053	+ 112
2007	4896	5210	+ 314
2008	4389	5005	+ 616
2009	4091	4924	+ 833
2010	3765	4993	+ 1228

4.5.4 SENSITIVITY ANALYSIS CONCLUSION

The sensitivity analysis presented above is based on a very conservative stream flow series that assumes there is little or no flow in the Macquarie River about 25% of the time (around 91 days per year on average). Even under these assumptions, analysis of the system shows that:

- the project could deliver a substantial secure yield benefit of around 2,200 ML/year which would provide a minimum of around 32 years water security under a high population growth
- the project could have benefited the community through the recent drought period with the combined storage falling to around 45% (compared to the 23% experienced).

It is concluded from the sensitivity analysis that the proposed Macquarie River to Orange pipeline is a robust water supply option that is not significantly impacted by assumptions relating to low river flow.

4.6 DOWNSTREAM HYDROLOGY IMPACTS

4.6.1 UNREGULATED WATER SOURCES

The unregulated water sources extend downstream from the proposed offtake structure to Burrendong Dam. There are no water access licences along this section of the Macquarie River. As such, the reduction in river flows resulting from the operation of the project would not impact on any existing water access licences.

Basic stock and domestic rights along this section of the Macquarie River would be protected by not extracting water during low flows. Assessment of the project demonstrates that there is no change in the flow regime for low flows (those flows equalled or exceeded 80 percent of the time). If the river flow series is greater than estimated in this assessment (i.e. equivalent to the current NOW modelling, or Scenario A) the proposed 38 ML/day flow trigger would be equivalent to the 93rd percentile flow. Therefore pumping would not occur below the recommended 95th percentile flow cease to pump threshold (Government of New South Wales, 2002) and this would protect the very low flows and the supply to basic right pumpers during dry periods.

It is noted that the Draft Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources (NSW Office of Water, 2011) sets a visible flow criteria as a cease to pump threshold for the taking of water (Clause 50(2)). Therefore the project is adopting a cease to pump threshold that is well above the provisions of the draft plan that would ensure low flows are not impacted in the unregulated section of the Macquarie River.

The proposed pump operation would also not impact on river flow for five hours each day to avoid operating in the peak power tariff periods. The benefit of this is that for 20% of the day the river flow is unaffected by the project. This would provide pulses down the river system that would return pools and riffles to the same state as if the pumps were not operating.

4.6.2 REGULATED WATER SOURCES

4.6.2.1 Background

Flows in the Macquarie River are highly regulated with Burrendong Dam regulating 91% of inflows (CSIRO, 2008). Management of the regulated water sources is defined in the Water Sharing Plan for the Macquarie and Cudgegong Regulated Rivers Water Source 2003 (Government of NSW, 2006) hereon referred to as the Macquarie-Cudgegong WSP.

The Macquarie-Cudgegong WSP provides the framework for water allocation in the regulated rivers of the Macquarie Valley. Under this water sharing plan, the total share component of access licences plus the environmental water allowance is 899,453 ML consisting of (DECCW, 2010 and Government of NSW, 2006):

- 14,265 ML for domestic and stock access licences
- 22,681 ML for local water utility access licences
- 19,419 ML for regulated river (high security) access licences
- 632,428 ML for regulated river (general security) access licences
- 50,000 ML for regulated river (supplementary water) access licences
- 160,000 ML for the environment.

The total regulated environmental share at June 2010 is 262,148 ML consisting of (DECCW, 2010):

- 160,000 ML provided in the Macquarie-Cudgegong WSP
- 46,275 ML of general security entitlement purchased by the NSW Government
- 55,873 ML of general security entitlement held by the Commonwealth Environmental Water Holder.

In addition to the above 3,330 ML of supplementary share has been purchased and registered to the holdings of the NSW and Australian governments (DECCW, 2010).

The 160,000 ML (160 GL/year) of environmental water provided for in the Macquarie-Cudgegong WSP is split into two sub-allowances (Government of NSW, 2006):

- Sub-allowance 1 (translucent) which receives 96 GL/year. This part to be released, subject to plan conditions, during the periods 1 June to 30 November and 15 March to 31 May (inclusive) each year
- Sub-allowance 2 (active) which receives 64 GL/year. This part to be released when needed to enhance opportunities for native fish recruitment and dispersal in the Macquarie River and Macquarie Marshes to ensure completion of colonial water bird breeding and alleviate severe, prolonged drought conditions in the Macquarie Marshes

The Macquarie-Cudgegong WSP sets a long term extraction limit of 391,900 ML/year that ensures that approximately 73% of the long term average annual inflow to the system (estimated to be 1,448,000 ML/year) is preserved for the maintenance of basic ecosystem health (Government of NSW, 2006).

The amount of water available each year from regulated flows for the irrigation industry and the environment is determined by the allocation of shares to general security access licences. The process of allocating water for extraction and the environment is called the available water determination (DECCW, 2010). It is calculated by adding the volume of water stored in Burrendong and Windamere dams and the likely future minimum inflows. Water is then allocated to stock and domestic, town water and high security shares, delivery and storage losses, and any water allocations remaining from previous available water determinations. The remaining water resource is allocated to the general security shares and the environmental water allowance.

4.6.2.2 Assessment

The project would reduce the inflow to Burrendong Dam by an average of 1,616 ML/year. The assessment of this reduced inflow and how it may impact on the operation of the Macquarie-Cudgegong WSP is complex due to the rules relating to allocations and releases. It was therefore determined that the best approach to assess the potential impacts of the project on the downstream regulated system was to model the extractions using NSW Office of Water's water planning model (IQQM) that forms the basis of the Macquarie-Cudgegong WSP. This modelling was undertaken by NSW Office of Water's Water Resource Management and Modelling Unit².

The project's daily river extractions determined from the water balance modelling for the period 1890 to 2007 were provided to NSW Office of Water's Water Resource Management and Modelling Unit. These were inserted into the IQQM model as an extraction upstream of Burrendong Dam. Daily and annual output data was obtained for the base case (without extraction) and with the proposed extraction for the following:

- inflow to Burrendong Dam
- Burrendong Dam storage volume
- general security diversions downstream of Burrendong Dam
- high security diversions downstream of Burrendong Dam
- July announced available water allocations
- Macquarie River flow at Marebone Weir
- irrigation diversion downstream of Marebone Weir

Post processing of the IQQM output data was undertaken to assess the impact of the project.

Of the above, the Macquarie River flow at Marebone Weir less the downstream irrigation diversions is considered to be the best indicator of flows to the Macquarie Marshes (refer to **Figure 68**). The model output at this location has taken into account all operating rules with regards to general security allocations, environmental flow releases (timing and volume) and the effect of carryover allocations and the water balance modelling of storage and river gains/losses. As the IQQM assessment compares the base case to the with development case under the same operating rules, it can be concluded that the modelled change in flow downstream of Marebone Weir results from the proposed extraction of water from the Macquarie River upstream of Burrendong Dam.

The following dry periods were examined in the model results:

- 1895/96 to 1902/03 (Federation Drought period)
- 1937/38 to 1941/42
- 2001/02 to 2006/07

² The IQQM assessment was undertaken for the project when the 12/34 operating rule was being assessed (refer to Footnote 1 on page 45). Under the 12/34 rule, the long term average annual extraction was determined to be 1,665 ML/year. As this is more than with the proposed 12/38 operating rule, it was considered that the 12/34 IQQM assessment would provide a conservative assessment of the project. Furthermore, the change in average annual extraction of 49 ML/year is well within the error range of the models used. Therefore the IQQM assessment was not updated for the 12/38 operating rule. All results presented and discussed in this section are based on the higher average annual extraction derived for the 12/34 operating rule.

These periods were identified from the base case run as being relatively low flow periods for the Macquarie River at Marebone Weir.

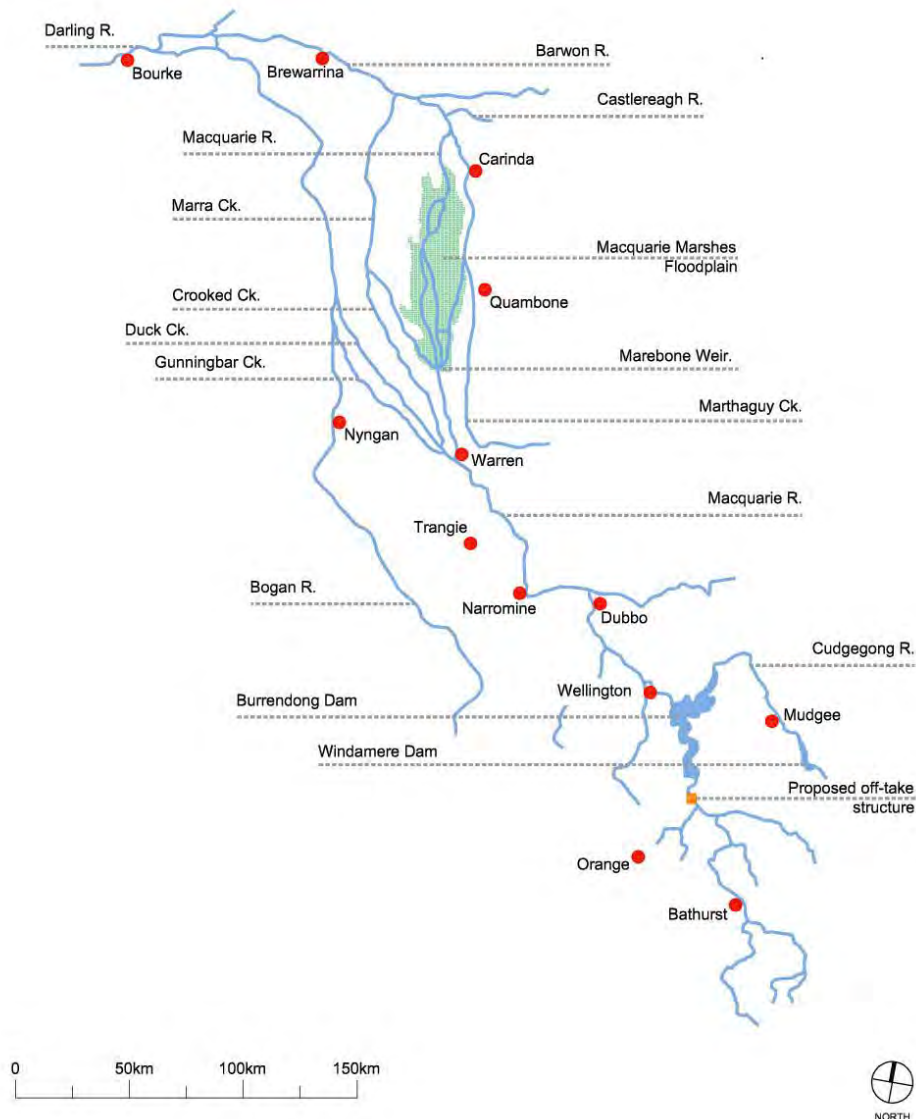


Figure 68: Location of Marebone Weir above the Macquarie Marshes

Inflow to Burrendong Dam

Table 4.18 summarises annual inflow statistics for Burrendong Dam. The average annual inflow to the dam decreases by 1.61 GL/year, which is consistent with the water balance model results that show an average annual extraction 1.665 GL/year². The slight difference is due to the influence of operational rules that alter the operation of Windamere Dam releases based on water orders from Burrendong Dam.

The reduction in average annual inflow represents 0.16% of the long term average annual inflow to the system. The water balance modelling shows that the project results in an increase in the average annual flow in Summer Hill Creek in the order of 1.34 GL/year. With this additional flow added to the Macquarie River, the average net extraction would be 0.27 GL/year, or 0.03% of the long term average annual inflow to Burrendong Dam.

Table 4.18 – IQQM results – Burrendong Dam inflow

Statistic	Base Case	With Project	Change
Minimum, GL/year	105.8	102.1	-3.7
Average, GL/year	1014.1	1012.5	-1.6
Maximum, GL/year	4510.5	4509.6	-0.9
Median, GL/year	789.8	788.1	-1.7

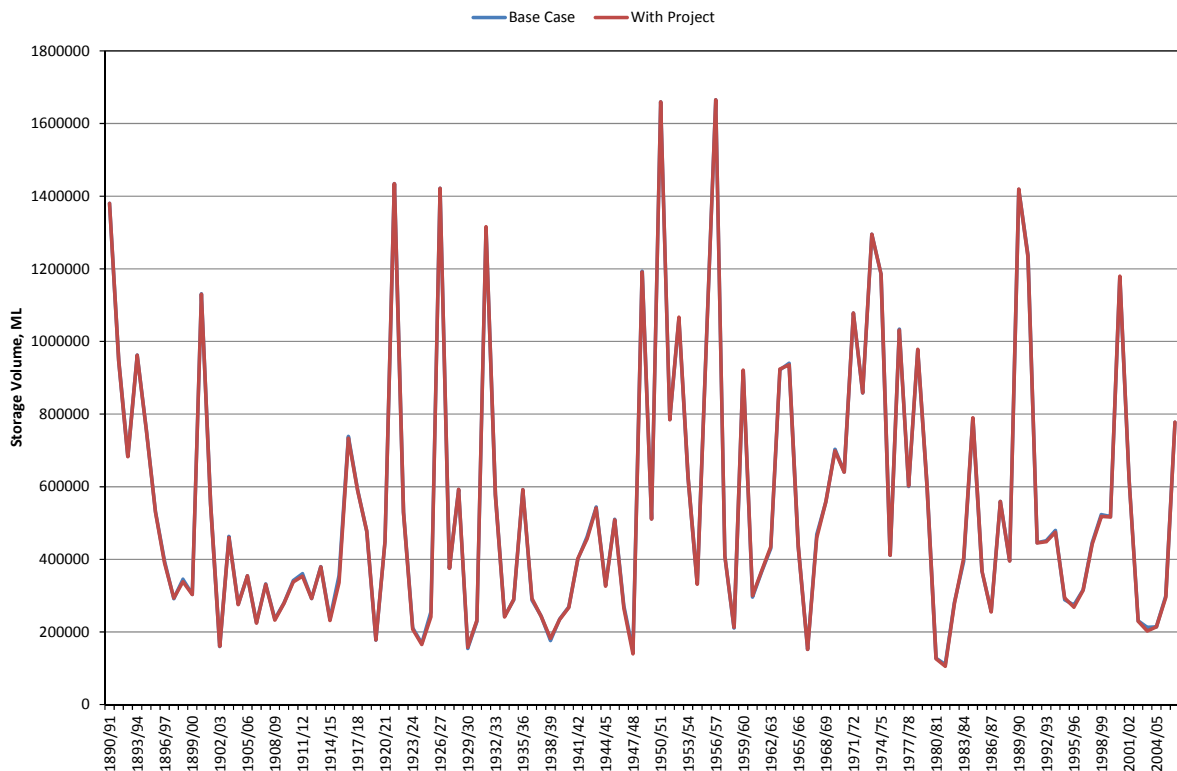
Total inflow over the three nominated dry periods is summarised in **Table 4.19**. The reduced inflow caused by the project represents only a small proportion of the total inflow volume during these periods.

Table 4.19 – IQQM results – Burrendong Dam inflow during dry periods

Climate Period	Base Case GL	With Project GL	Change over period GL	Percent Change over period
1895/96-1902/03 (8 years)	5704.8	5684.3	-20.4	-0.36%
1937/38-1941/42 (5 years)	1855.3	1842.9	-12.4	-0.67%
2001/02-2006/07 (6 years)	3197.9	3187.5	-10.4	-0.32%

Burrendong Storage Volume

Figure 69 shows the modelled Burrendong storage volume at 1 July each year. There is very minimal change in the storage volume between the two modelled cases (therefore the two lines are generally the same).


Figure 69: Modelled Burrendong Dam storage behaviour

General Security Diversions Downstream of Burrendong

Modelled general security diversions downstream of Burrendong Dam are shown in **Figure 70**. The average annual general security diversion for the base case is 355.5 GL/year. This reduces to an average of 354.9 GL/year with the project; a reduction of 0.6 GL/year or 0.17%.

The Macquarie Marshes hold a total general security entitlement of 262.15 GL/year which is 41% of the total general security entitlement downstream of Burrendong Dam (632.438 GL/year). Therefore the average annual reduction in general security entitlement for the Macquarie Marshes is around 0.25 GL/year. This represents a very minimal long term change for the system.

The change in general security diversions during the three dry periods is summarised in **Table 4.20**. Again the modelled changes are very minimal over the dry periods.

Table 4.20 – IQQM results – General security diversions downstream of Burrendong Dam during dry periods

Climate Period	Base Case GL	With Project GL	Total Change GL	Total Percent Change	Macquarie Marshes Share GL
1895/96-1902/03 (8 years)	2245.5	2232.7	-12.8	-0.57%	-5.2
1937/38-1941/42 (5 years)	623.7	626.8	+3.1	+0.49%	+1.3
2001/02-2006/07 (6 years)	1539.9	1537.0	-2.9	-0.19%	-1.2

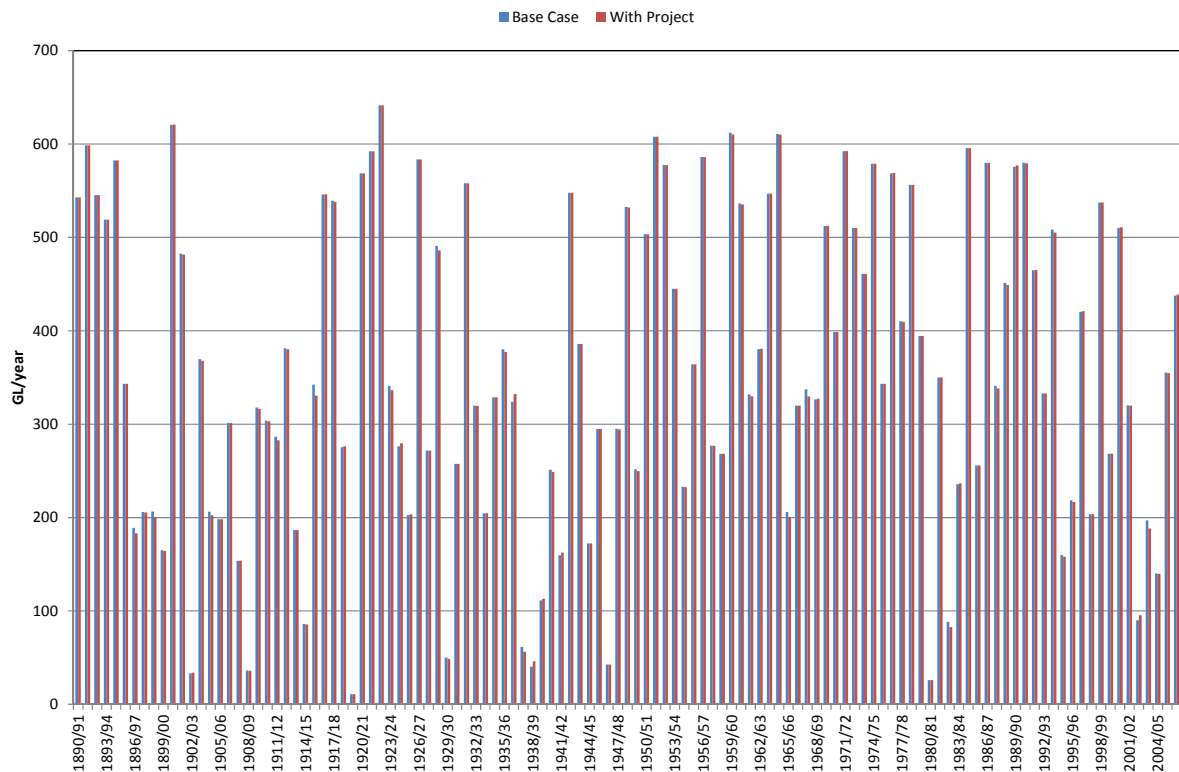


Figure 70: Modelled general security diversions downstream of Burrendong Dam

High Security Diversions Downstream of Burrendong

The modelled average annual high security diversion downstream of Burrendong Dam for the base case is 21.8 GL/year. The IQQM modelling indicated there would be no change to the high security diversion downstream of Burrendong Dam with the project.

Announced Available Water Allocations

The IQQM model determines a daily announced available water allocation based on the methodology described above and the Macquarie-Cudgegong WSP rules. The average daily announced available water allocation for the base case is 52.6%. This reduces slightly with the project to 52.5%.

Figure 71 shows the change in July announced available water allocations³ as a result of the project. There are 23 years (out of the 117 years modelled) where the July announced available water allocation is reduced. The average reduction is 1.1%.

There are six years where the July announced available water allocation is increased. The average increase in these years is 1.2%.

There are 88 years where there is no change in the July announced available water allocation. The long term average July announced available water allocation reduces from 32.3% to 32.1% with the project. This represents a very minimal long term change for the system.

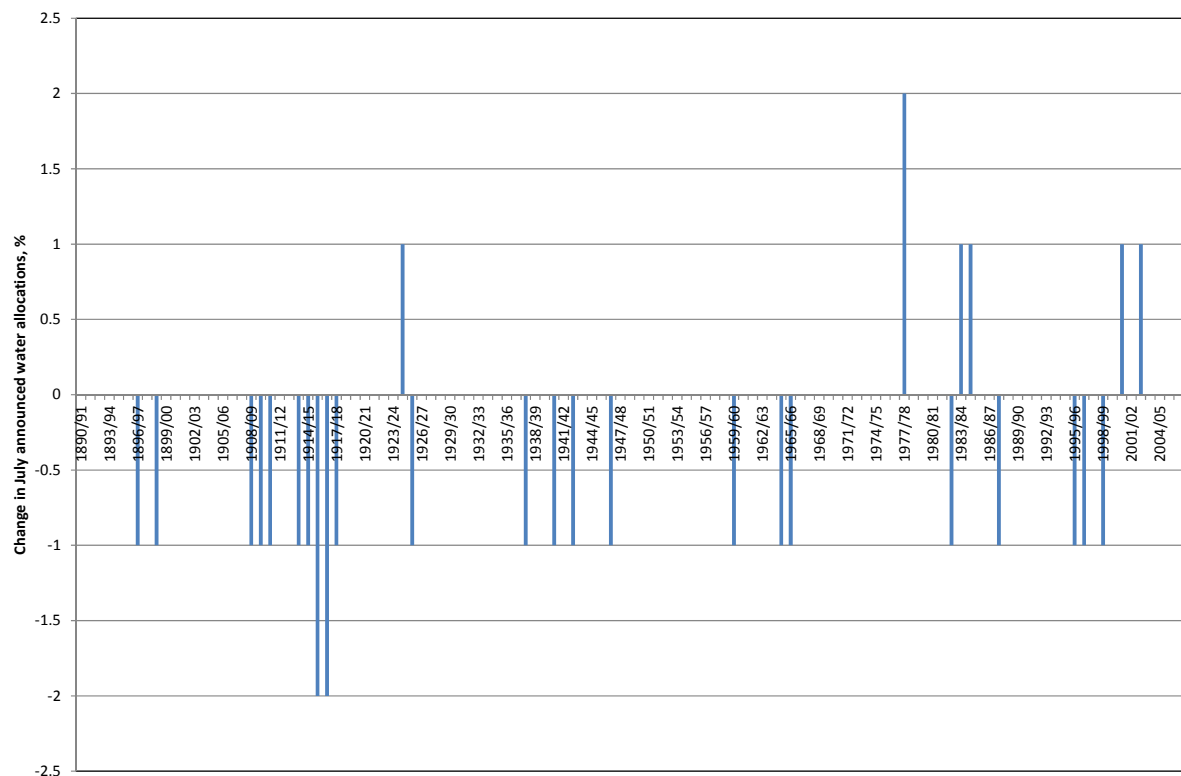


Figure 71: Change in July announced available water allocations

Macquarie River flow downstream of Marebone Weir

Table 4.21 summarises annual flow statistics for the Macquarie River downstream of Marebone Weir. These figures exclude the downstream irrigation diversions and therefore represent flow to the Macquarie Marshes. **Figure 72** shows the modelled annual flow downstream of Marebone Weir less the downstream irrigation diversions.

³ 8 July announced allocations were used for this comparison to remove the influence of carry over

The average annual flow decreases by 0.5 GL/year, which is consistent with the results for the reduction in general security allocations below Burrendong Dam. The reduction in average annual flow represents 0.12% of the long term average annual flow in the Macquarie River at Marebone Weir.

This result shows that the average reduction in inflow to Burrendong Dam of 1.61 GL/year does not equate to the same reduction in flows to the Macquarie Marshes due to the influence of flow regulation and operation of the Macquarie-Cudgegong WSP.

Table 4.21 – IQQM results – Macquarie River at Marebone Weir

Statistic	Base Case	With Project	Change
Minimum, GL/year	33.9	33.9	0.0
Average, GL/year	426.5	426.1	-0.5
Maximum, GL/year	1582.4	1582.4	0.0
Median, GL/year	302.2	300.1	-2.1

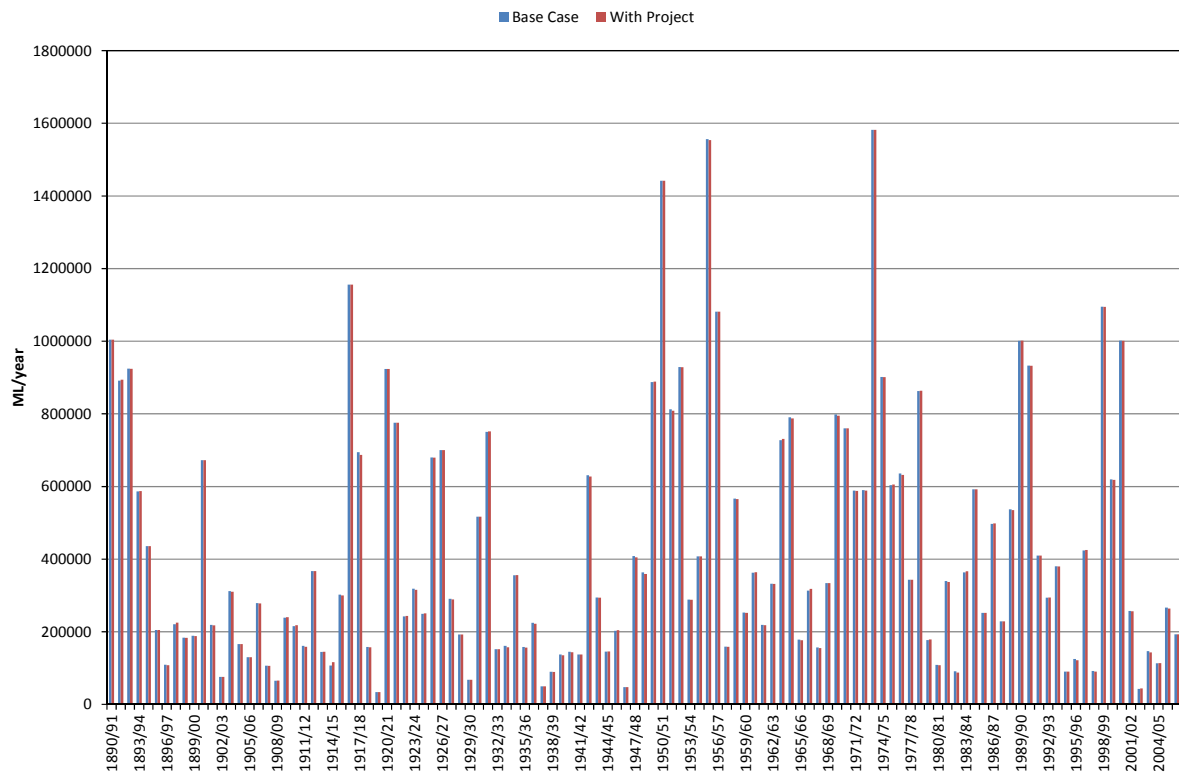


Figure 72: IQQM results – modelled annual Macquarie River downstream of Marebone Weir

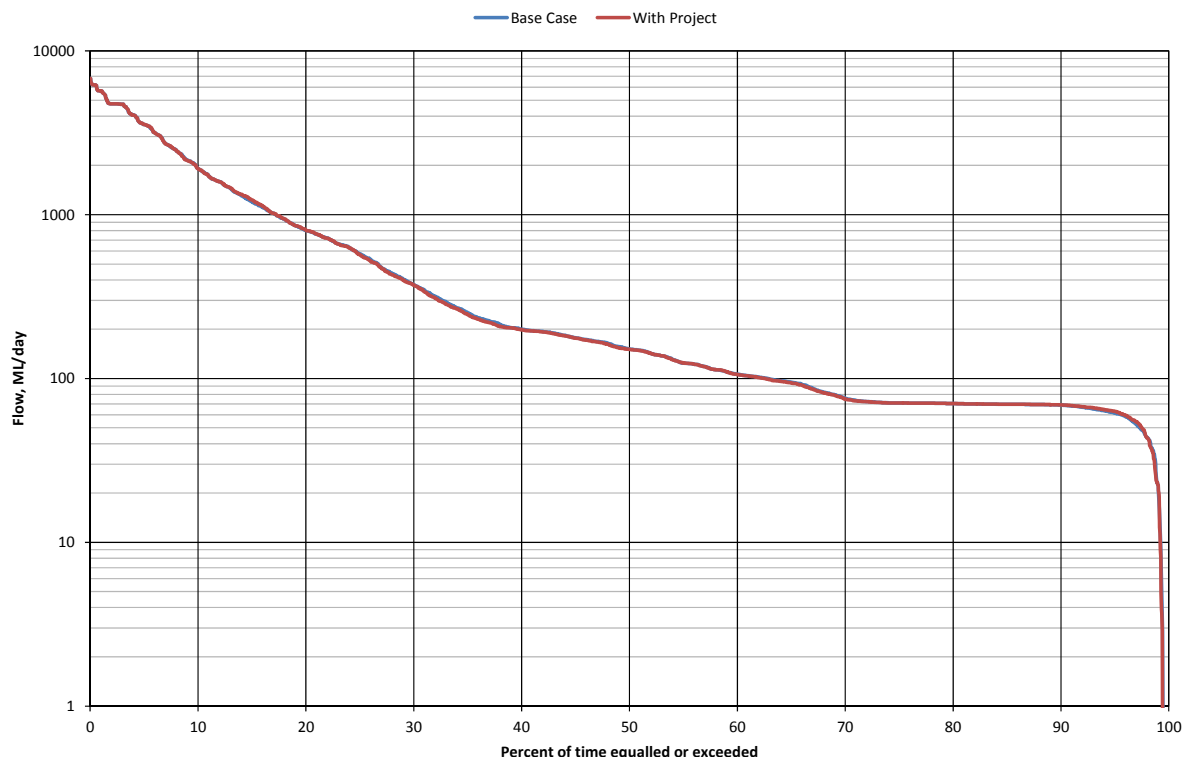
Total inflow over the three nominated dry periods is summarised in **Table 4.22**. The reduced inflow caused by the project represents only a small proportion of the total inflow volume during these periods.

Table 4.22 – IQQM results – Macquarie River downstream of Marebone Weir during dry periods

Climate Period	Base Case GL	With Project GL	Change over period GL	Percent Change over period
1895/96-1902/03 (8 years)	1875.4	1874.0	-1.4	-0.07%
1937/38-1941/42 (5 years)	559.1	554.5	-4.7	-0.83%
2001/02-2006/07 (6 years)	1019.5	1014.1	-5.3	-0.52%

The flow duration curves developed from the modelled daily river flow data at Marebone Weir for the three dry periods are provided as **Figure 73** to **Figure 75**. The main components of size, frequency, duration and timing are retained in the flow regime with the project. The slight reduction in volume is reflected by the difference between the two lines. The majority of the change occurs in the moderate to high flow classes (70th to 30th percentile flow) with no change in the low flows.

As explained in the water balance modelling section (**Section 2.3.4**) the modelling assumes that the climate experienced from 1890 to 2007 is repeated for the next 118 years. Further, the Orange water demand used in the modelling starts at a base of 5,400 ML/year in year one (which is represented by the 1890 climate) and is assumed to grow at 0.8% per annum throughout the modelling. Therefore the annual water demand has increased significantly at the end of the 118 year modelling sequence. As such, the results presented for the “2001/02 to 2006/07 dry period” are very conservative.


Figure 73: Marebone Weir (excluding downstream irrigation diversions) - 1895/96-1902/03

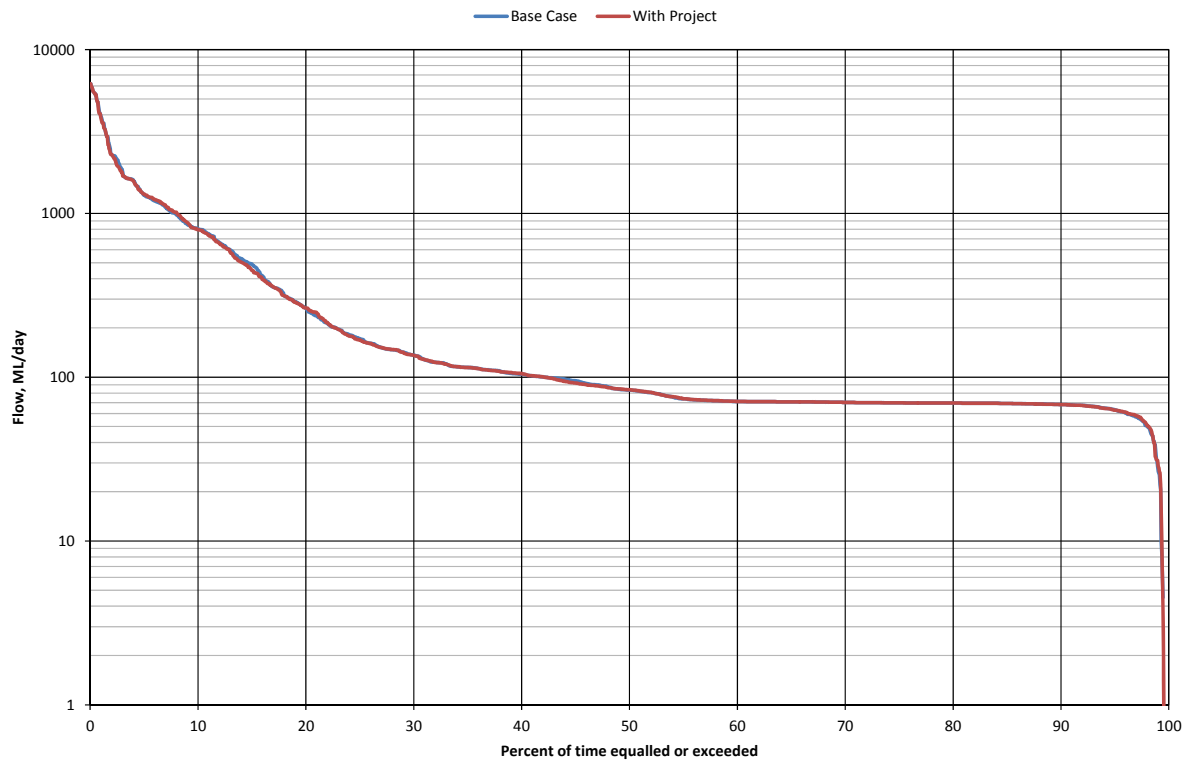


Figure 74: Marebone Weir (excluding downstream irrigation diversions) - 1937/38-1941/42

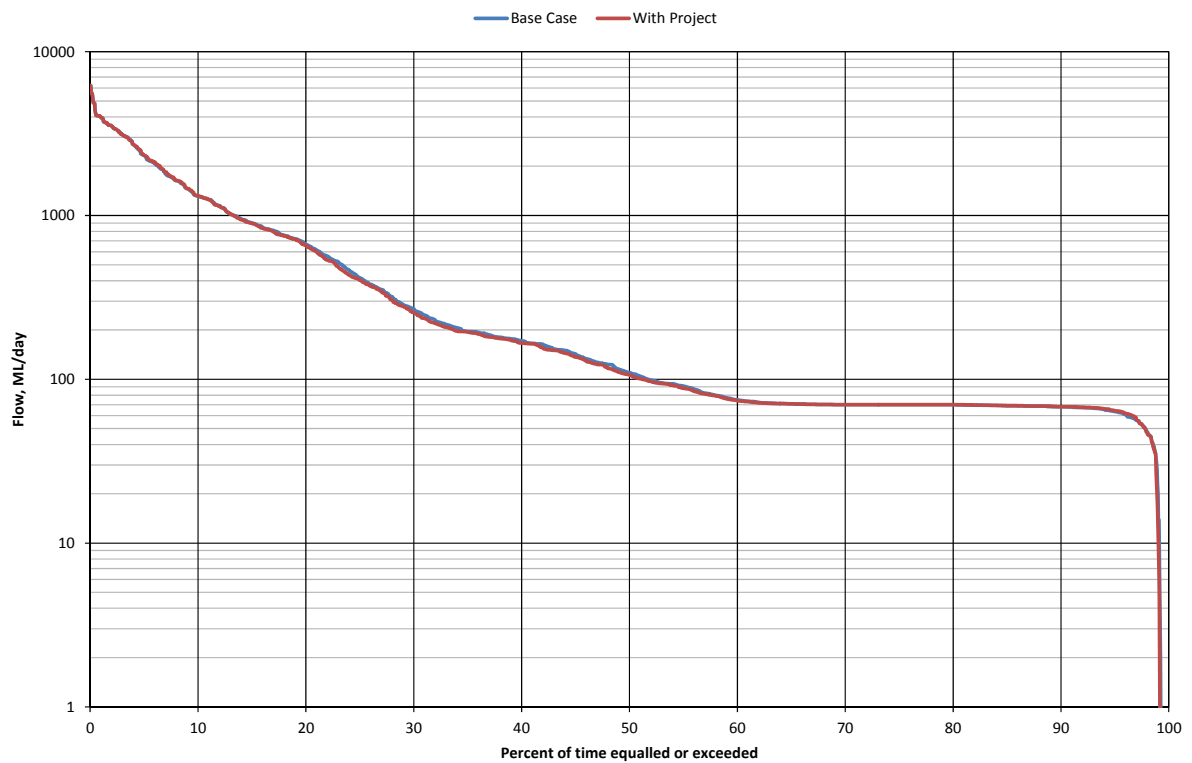


Figure 75: Marebone Weir (excluding downstream irrigation diversions) - 2001/02-2006/07

Flow to Macquarie Marshes in Maximum Extraction Year

Assessing the potential changes on flows to the Macquarie Marshes is complex as modelling needs to take into consideration the rules associated with operation of the Water Sharing Plan for the Macquarie and Cudgegong Regulated Rivers Water Source 2003 (Government of NSW, 2006) – this plan applies to the Macquarie River downstream of Burrendong Dam and the Cudgegong River downstream of Windamere Dam.

Therefore NSW Office of Water's IQQM was used as described above with the daily extraction for the pipeline project input to the model as an extraction upstream of Burrendong Dam.

The modelled maximum annual extraction for the project is 3,876 ML/year² which occurred in "1896". The IQQM works in water years (same as financial years) and the extraction for the 1896/97 water year was checked and also found to be 3,876 ML/year.

The modelled inflow to Burrendong Dam with and without the project for the few years either side of 1896/97 are shown in **Table 4.23**. This shows that despite 1896/97 being the largest extraction year for the project, it does not equate to the same change for Burrendong Dam inflow. It would appear that in the previous year some water was held back in Windamere Dam as the extraction in 1895/96 was only 1,992 ML. A portion of this water was then released in 1896/97 which reduces the impact of the project.

Table 4.23 – Modelled Burrendong Dam inflow and general security diversions – 1893 to 1899

Water Year	Burrendong Dam Inflow, ML/year			General Security Diversions, ML/year		
	Without Project	With Project	Change	Without Project	With Project	Change
1893/94	926823	926403	-420	519024	519032	+8
1894/95	824604	824232	-372	582333	582328	-5
1895/96	571146	567594	-3552	343357	343338	-18
1896/97	399901	397317	-2583	188861	183201	-5660
1897/98	421021	417961	-3061	205800	205520	-280
1898/99	427097	424350	-2747	206487	200261	-6226

In the three years before the start of the 1896 water year, inflows to Burrendong Dam are less with the project, but the general security diversion remained essentially the same. There was 3,140 ML less in Burrendong Dam storage at the start of the 1896 water year, and it would appear that this lead to a reduction in the general security diversions for that year. These were reduced by 5,660 ML which is greater than the project extraction for that year. Likewise in 1898/99 when the pipeline extraction was only 2,952 ML, the general security diversions downstream of Burrendong Dam were 6,226 ML less.

The modelled reduction in water for the marshes in these two years was:

- 1896/97 -1,766 ML
- 1898/99 -691 ML

The assessment of water for the marshes was assessed in the IQQM analysis as the flow at Marebone Weir less the downstream general security diversions. This data was reviewed and it was found that the largest change occurred in the 1917/18 water year when the water available for the marshes reduced by 7,035 ML. It is interesting to note that in this year the pipeline only extracted 780 ML, but the inflow to Burrendong Dam was 9,351 ML less; most likely due to changes in releases from Windamere Dam. Also the reduction in general security diversions in that year was only 1,164 ML.

The largest increase in annual flow to the marshes was calculated in the 1914/15 water year when an additional 9,467 ML was available. This occurred in a year when the pipeline project extracted 3,072 ML.

These results demonstrate that translating the maximum extraction year through to the Macquarie Marshes is complex as there are numerous rules relating to carry over, sharing general security water and assumptions relating to cropping areas and water orders. This supports the concept that it is better to look at long term changes rather than specific years. Despite this, data for the 1896/97 water year was analysed to provide some further detail if the maximum extraction year is to be considered. This data is presented in **Table 4.24**.

Table 4.24 – Water for Macquarie Marshes – 1896/97 modelled water year

Measure	Base Case	With Project	Change
Annual, ML/year	109,581	107,815	-1,766
Maximum daily flow, ML/day	3,429	3,427	-2
Average daily flow, ML/day	300	295	-5
Minimum daily flow, ML/day	3.8	3.9	+0.1
Monthly flows, ML/month			
July	24,017	23,855	-162
August	16,672	16,560	-112
September	5,913	5,892	-21
October	3,024	3,023	-1
November	9,429	9,431	+3
December	6,989	6,921	-68
January	10,870	10,866	-4
February	3,666	3,437	-229
March	2,290	2,194	-97
April	2,126	2,122	-3
May	2,088	2,089	0
June	22,497	21,424	-1,073

4.6.2.3 Conclusion

The IQQM analysis comparing the base case and the influence of extraction from the Macquarie River upstream of Burrendong Dam shows that the project has minor impacts on streamflow and use through the regulated system. Flow regulation through Burrendong Dam and operation in accordance with the Macquarie-Cudgegong WSP buffers the direct impact of the proposed extraction such that the reduction in streamflow in the Macquarie River at Marebone Weir represents only 0.12% of the long term average annual flow or up to about 0.80% during drier periods. These changes are sufficiently small that they are within the uncertainty of the model itself.

It is noted that this assessment does not include the increased flow from the Summer Hill Creek/Lewis Pond Creek system. This additional flow is estimated to decrease the average annual extraction by approximately 1,300 ML/year (1.3 GL/year). Furthermore it is based on the assessment of the previous 12/34 operating rule. It therefore presents a worst case assessment of the project and its impact. The actual long term changes would be less than assessed.

It is concluded that the changes in streamflow as a result of the project would not detrimentally impact on the ability to operate the regulated system in accordance with the Macquarie-Cudgegong WSP and the impact on downstream water users and flow regimes at the Macquarie Marshes is likely to be negligible.

4.7 WATER MANAGEMENT OBJECTIVES

Assessment of the project against the NSW river flow objectives is provided in **Table 4.25**. It is concluded from this assessment that the project is consistent with these objectives.

Table 4.25 – NSW river flow objectives

No.	Objective ⁽¹⁾	Comment
Objective 1	Protect natural water levels in pools of creeks and rivers and wetlands during periods of no flow	The adopted cease to pump flow of 38 ML/day means that pumping would not occur from Gardiners Hole in periods of no flow. This would protect water levels and pools along the Macquarie River. Low flow in Summer Hill Creek is estimated to increase with the project over the long term.
Objective 2	Protect natural low flows	The adoption of a cease to pump threshold prevents the project from impacting on low flows. This would protect basic stock and domestic rights and preserve environmental flows in the river system.
Objective 3	Protect or restore a proportion of moderate flows, “freshest” and high flows	The project slightly reduces flows across the 10 th to 80 th percentile flow range which represents the volume extracted by the project. The proportion of flow extracted in the moderate to high flow range is less due to the increased river flows. Main components of size, frequency, duration and timing are retained in the flow regime with the project.
Objective 4	Maintain or restore the natural inundation patterns and distribution of floodwaters supporting natural wetland and floodplain ecosystems	No significant areas in the unregulated section of the Macquarie River downstream to Burrendong Dam, below which 91% of flow is regulated. Assessment shows the project would not impact on the ability to operate the regulated system in accordance with the Macquarie-Cudgegong WSP which includes environmental flow allocations to the Macquarie Marshes.
Objective 5	Mimic the natural frequency, duration and seasonal nature of drying periods in naturally temporary waterways	The Macquarie River at the proposed offtake point is not classified as a naturally temporary waterway. Streamflow records for the upstream Bruinbun gauge show some streamflow occurring 99% of the time.
Objective 6	Maintain or mimic natural flow variability in all rivers	The project slightly reduces flows across the 10 th to 80 th percentile flow range which represents the volume extracted by the project. Analysis demonstrates that all components of the flow regime (floods, high, medium and low flows) are retained and show similar variability and magnitude.
Objective 7	Maintain rates of rise and fall of river heights within natural bounds	The project does not have the capability of dramatically changing the river height due to the limited daily extraction. Once pumping has commenced, the relative rise and fall of the river would not be altered.
Objective 8	Maintain groundwaters within natural levels, and variability, critical to surface flows or ecosystems	The project will not have any direct impact on groundwater levels. The change in river levels downstream of the extraction are very minor and are not expected to alter the patterns of groundwater recharge from the river.
Objective 9	Minimise the impact of in-stream structures	The river pump station has been designed to minimise its impact. This is described in Chapter 6 of the Environmental Assessment.
Objective 10	Minimise downstream water quality impacts of storage releases	Not applicable to the project
Objective 11	Ensure river flow management provides for contingencies	The proposed daily extraction management will provide a high level of system monitoring with the ability to adjust operations if required.
Objective 12	Maintain or rehabilitate estuarine processes and habitats	Not applicable to the project

Source: (1) Government of NSW, 2002

4.8 MANAGEMENT COMMITMENTS

The following sections provide an outline of the management commitments relating to the project.

4.8.1 WATER ENTITLEMENT

Orange City Council has an existing surface water entitlement under the Water Act, 1912 to extract up to 7,800 ML/year from the Macquarie system for the purpose of town water supply (Licence 80SL046857). The full town water entitlement was included Draft Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources (Clause 23(x)) (NSW Office of Water, 2011).

Orange City Council also holds an option for the purchase of a 640 ML/year unregulated water access licence that would be transferred from an upstream location on the Macquarie River to the proposed offtake point if the project obtains approval. There is no opportunity under the draft water sharing plan to convert this volumetric allocation into a town water supply entitlement. Therefore, as an unregulated access licence, extraction would be dictated by the cease to pump rules defined in the Draft Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources (NSW Office of Water, 2011). At present this states that water must not be taken if there is no visible flow in the water source (Clause 50(2)) or from a natural pool, lagoon or lake when that source is at less than 100% capacity after visible flow has ceased (Clause 50(4)). However, this only applies for existing licences that remain in-situ.

Modelling of the project indicates the average annual extraction is 1,616 ML/year ranging from zero to 3,804 ML/year. As the long term average extraction and potential annual peak exceed the volumetric allocation of the unregulated licence, Council proposes a temporary transfer of a portion of its town water supply access entitlement from Summer Hill Creek to the Macquarie River. Such a transfer is permitted under the Draft Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources (NSW Office of Water, 2011) and would happen on a year to year basis. The nominated transfer volume would revert back to Summer Hill Creek at the end of each 12 month period. Transfer of Macquarie River entitlement back to Summer Hill Creek is not permitted.

Use of the transferred portion would be subject to conditions attached to the works approval granted for the project. That is, if a works approval is granted for the project and adopts the proposed 38 ML/day commence to pump trigger, regardless that the transfer is a town water supply entitlement that is not subject to the access rules under the draft water sharing plan, extraction would be subject to the works approval conditions.

In addition to the temporary transfer, Council would continue to purchase water access licences as they become available in accordance with the trading provisions of the Draft Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources (NSW Office of Water, 2011). Once purchased and nominated to the offtake point, any additional water access licences would attract the same conditions as the works approval.

In summary, Orange City Council's preferred option for securing a water entitlement under the Water Act, 1912 is (subject to the project obtaining development consent):

- Make an application for the permanent transfer of the 640 ML unregulated licence at the same time as lodging an application under Part 2 of the Water Act, 1912 for works approval.
- Once operational, make annual temporary transfers of a nominated portion of the existing water entitlement from Summer Hill Creek to the Macquarie River. These temporary transfers would be made under the provisions of the Water Management Act, 2000, as the draft water sharing plan is likely to be in force by the time the scheme becomes operational.
- Continue to purchase water access licences as they become available in accordance with the trading provisions of the Draft Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources (NSW Office of Water, 2011).

4.8.2 DAILY EXTRACTION MANAGEMENT

Orange City Council would implement daily extraction management as recommended by the Government of New South Wales (2002).

Management Option 3b, with the exception of daily flow class announcements, would be implemented for the project. Management Option 3b represents the highest level of daily extraction management, and although it is not required under the Draft Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources (NSW Office of Water, 2011) adoption of this level of daily extraction management forms a responsible management basis for the project.

The committed management actions to comply with this level of daily extraction management are:

- daily reading and logging of the upstream river gauge (Station 421192)
- logging of all flow meters and pump run time
- annual reporting for the project operation.

4.8.3 DECISION SUPPORT TOOL

Assessment of the project as presented in this report is based on the defined 12/38 operating rule. The long term extraction volumes are also based on the assumption of continued water demand growth for the next 118 years. This provides a conservative basis for the assessment and in effect presents a worst case scenario.

If the project obtains approval, Orange City Council would then have a variety of water supply options, each with different performance characteristics. Council therefore proposes to develop a decision support tool that would make use of operational and model data and consider elements such as seasonal variation and long term climate indicators (such as the southern oscillation index) to optimise the use of the various sources. It is considered that this tool would help reduce the required extraction from the Macquarie River such that the long term average annual extraction would be less than used in this impact assessment.

Conclusion

5.1 CONCLUSIONS

The report presents an analysis and assessment of the proposal to transfer water from the Macquarie River to Orange to supplement the city's water supplies. Main conclusions drawn from the study are:

- The Macquarie River provides a viable water source that could help contribute to the water security for Orange.
- The average annual extraction from the Macquarie River under the proposed 12/38 operating rule is 1,616 ML/year which represents 0.52% of the average annual river flow.
- The project can substantially increase the city's secure yield and provide water security for the next 39 to 58 years (without the potential impacts of climate change) based on high and medium population growth projections respectively.
- Under the potential impacts of climate change, the project can provide water security for the next 26 to 37 years based on high and medium population growth projections respectively.
- Sensitivity analysis demonstrates that the project is a robust water supply option that is not significantly impacted by assumptions relating to low river flow.
- Orange City Council has a water supply entitlement that provides access to 7,800 ML/year of water for town water supply purposes from the Macquarie system. The existing water supply system cannot deliver this supply with security. The addition of the Macquarie River pipeline provides a diversified system that could help contribute to the water security for Orange. Adding independent water sources to the system increases security.
- Adding the project to the water supply system helps augment and diversify water sources which makes the entire water supply system more resilient to the potential impacts of climate change.
- The project can be operated consistent with the NSW River Flow Objectives, with particular emphasis on protecting low river flows, by adopting a proposed cease to pump threshold that is higher than required by the Draft Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources.
- The project has negligible impact on system flows downstream of Burrendong Dam and would not impact on the ability to operate the regulated system in accordance with the Macquarie-Cudgegong water sharing plan. The impact on downstream water users including the Macquarie Marshes is likely to be negligible.
- Orange City Council can ensure it has proper access entitlement to the water through the transfer of an unregulated licence from an upstream location on the Macquarie River to the proposed offtake point and temporary transfer of a portion of its existing water access licence from Summer Hill Creek to the Macquarie River on a year to year basis.

5.2 MANAGEMENT COMMITMENTS

Orange City Council proposes that the following management commitments would be implemented for the project:

- Temporary transfer of a portion of the existing 7,800 ML/year water access licence from Summer Hill Creek to the Macquarie River to ensure it holds proper access rights for the water.
- Continue to actively seek and purchase water access licences as they become available in accordance with the trading provisions of the Draft Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources (NSW Office of Water, 2011).
- Implementation of daily extraction management as recommended by the Government of New South Wales (2002) including daily reading and logging of the upstream river gauge, logging of all flow meters and pump run time and annual reporting for the project operation.
- Development of a decision support tool that would make use of operational and model data and consider elements such as seasonal variation and long term climate indicators (such as the southern oscillation index) to optimise the use of the various water supply sources available to Council.

References

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- Central West Catchment Management Authority (2011) *Central west catchment action plan 2011-2021*. State of New South Wales.
-
- Cloke P (undated) *Notes on secure yield*. Unpublished paper.
-
- CSIRO (2008) *Water availability in the Macquarie-Castlereagh. A report to the Australian Government from the CSIRO Murray-Darling basin sustainable yields project*. CSIRO, Australia.
-
- DECCW (2010) *Macquarie Marshes adaptive environmental management plan*. Department of Environment, Climate Change and Water NSW. <http://www.wetlandrecovery.nsw.gov.au/download/10224MacquarieMarshAEMP.pdf>. Accessed 23 March 2012.
-
- Geolyse Pty Ltd (2012a) *Technical note 2: Orange water resources*. Report prepared for Orange City Council.
-
- Geolyse Pty Ltd (2012b) *Technical note 3: Potable water demand and effluent production*. Report prepared for Orange City Council.
-
- Government of NSW (2006) *Water sharing plan for the Macquarie and Cudgegong regulated rivers water source 2003*. <http://www.legislation.nsw.gov.au/viewtop/inforce/subordleg+177+2003+FIRST+0+N/>. Accessed 26 March 2012.
-
- Government of NSW (2002) *Advice to water management committees. No. 6 daily extraction management in unregulated rivers (2002 version)*. NSW Government.
-
- MWH (2009) *Centroc water security study*.
-
- MWH (2010) *Emergency water supply further feasibility assessment*. Report prepared for Orange City Council.
-
- MWH (2011) *Emergency water supply concept report*. Report prepared for Orange City Council.
-
- NSW Office of Water (2011) *Draft Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources*
-
- Samra S and Cloke P (2010) *NSW Response for addressing the impact of climate change on the water supply security of country towns*. Proceedings of Practical Responses to Climate Change, National Conference 2010, 29 September - 1 October 2010, Melbourne, Institution of Engineers, Australia.
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Appendix A

SECURE YIELD RESULTS

ORANGE WATER SUPPLY

Preliminary Results

Program: ORANGE9E.BAS

TABLE 9E-2B

Operating Rule 5/10/10% applied – Restriction duration 5%, Frequency of Restriction 1 in 10 years and demand reduced by 10%

Run No.	Supply from External Sources							Suma Park Dam Storage. Volume (ML)	Secure Yield (ML/a)	Restriction			Critical Drought	
	BSC100/PC100	Bores 75	MR12/34	Bores 300	BSC2	IPR	Lake Rowlands Dam			Applied at storage	Duration	1 in x year	From	To
11-5	✓	✓	12/34	-	-	-	-	17290	7400	45	2.39	19.50	31/10/1894	20/03/1900
11-6	✓	✓	12/34	-	-	-	-	18970	7550	50	3.10	19.50	31/10/1894	27/02/1900
3-1	✓	✓	-	-	-	-	-	17290	4600	50	2.25	39.0	6/11/1894	20/03/1900

Suma Park Dam Storage

Run number	Suma Park Dam Storage volume (ML)
11-5	17290
11-6	18970
3-1	17290

General run condition is to use Suma Park Dam first (Maximum 38 ML/d) until 25% full then Spring Creek Dam until 25% full then Gosling Creek Dam.

Environmental release condition from Suma Park Dam:

Is either 1 ML/d or equal to inflow if inflow is less than 1 ML/d

Demand Pattern: % of Annual Demand

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
11.75	9.96	10.26	8.53	7.25	6.35	6.36	6.51	6.56	7.68	8.24	10.55

Daily demand is equal to the monthly demand divided by the number of days in the month

Storage in dam:	Full storage ML	Dead storage ML	Leakage ML/d	Streamflow Transposition Factor
Gosling Creek Dam	587	57	0	0.1285
Spring Creek Dam	4500	137	0	0.3520
Suma Park Dam	Various	205	0.263	1.0

Streamflow Sequences: Based on streamflow generated by the Department of Finances and Services and data series provided by Geolyse

SUMASFS8.Txt - Generated by AWBM model with data based on averaged rainfall and evaporation data over the catchment of Suma Park Dam from 01/01/1890 to 31/10/2007

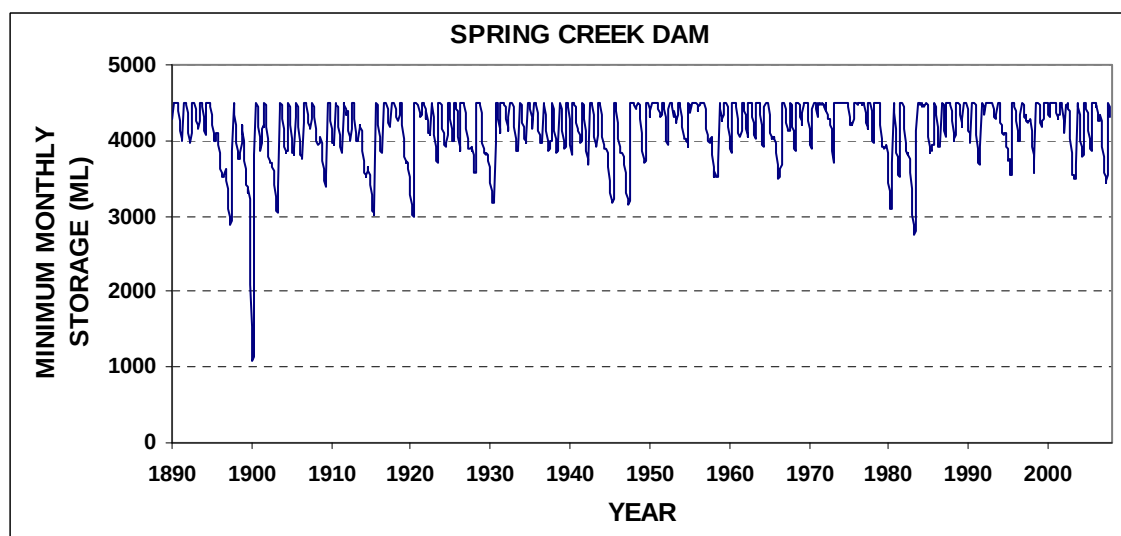
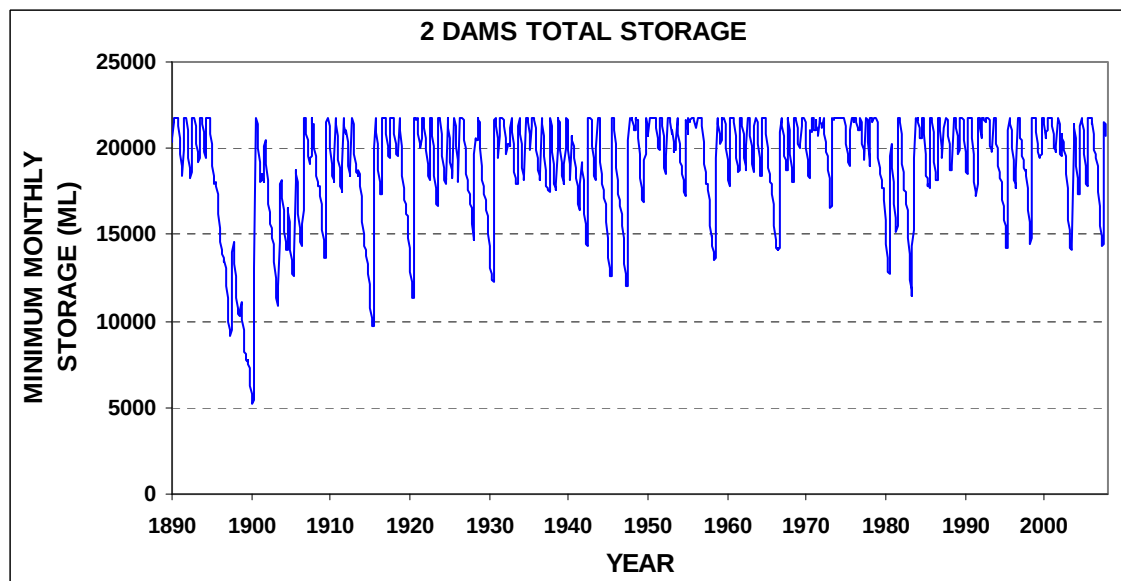
Extra water to Suma Park Dam:

- (1) BSC100/PC100 - Storm water harvesting is based on Consultant's data file "Secure yield input data_System Assessment_June2011.xlsx".
Use daily data from Run11_5 Blackmans Swamp Creek and Ploughmans Creek stormwater harvesting with no restrictions (PS3) as input (Max transfer of 8.64 ML/d) to Suma Park Dam ONLY when Suma Park Dam is less than 100%.
BSC100/PC100 and BSC2 are mutually exclusive, only either one is engaged but NOT both.
- (2) Bores75
Add a daily inflow of 0.2 ML/day to Suma Park Dam ONLY when Suma Park Dam is less than 100%.
- (3) MR12/34 - Macquarie River extraction is based on Consultant's data file "Macquarie Rv at offtake.xlsx" provided 22/2/2012.
Add 12 ML/day to Suma Park Dam when volume in Suma Park Dam is < 90% full and flow in the Macquarie River is > 34 ML/day

ORANGE WATER SUPPLY

Storage Behaviour Plots for:

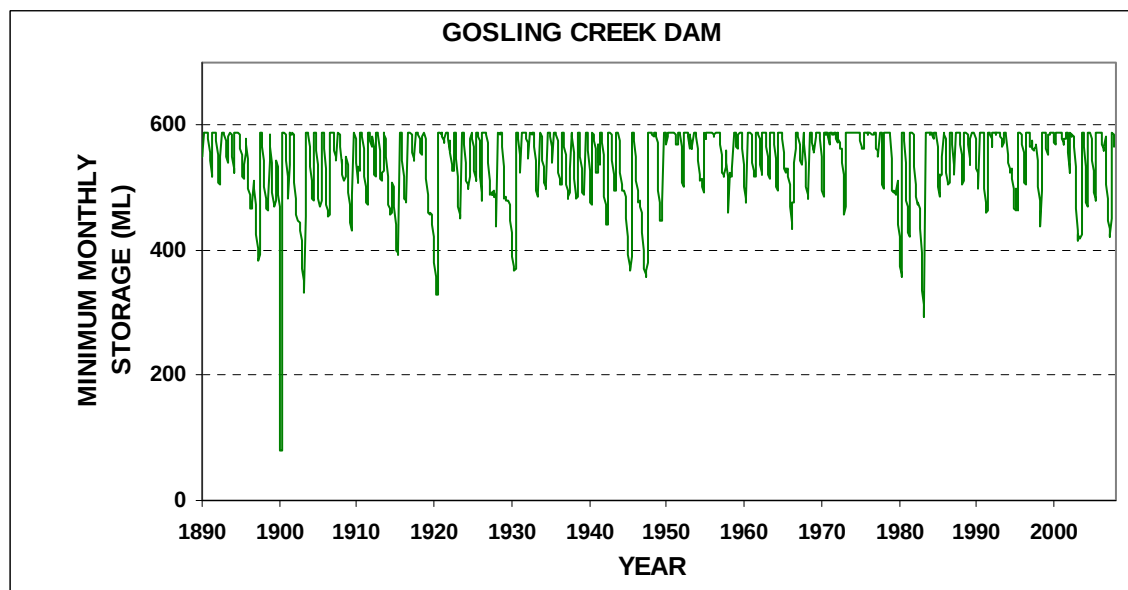
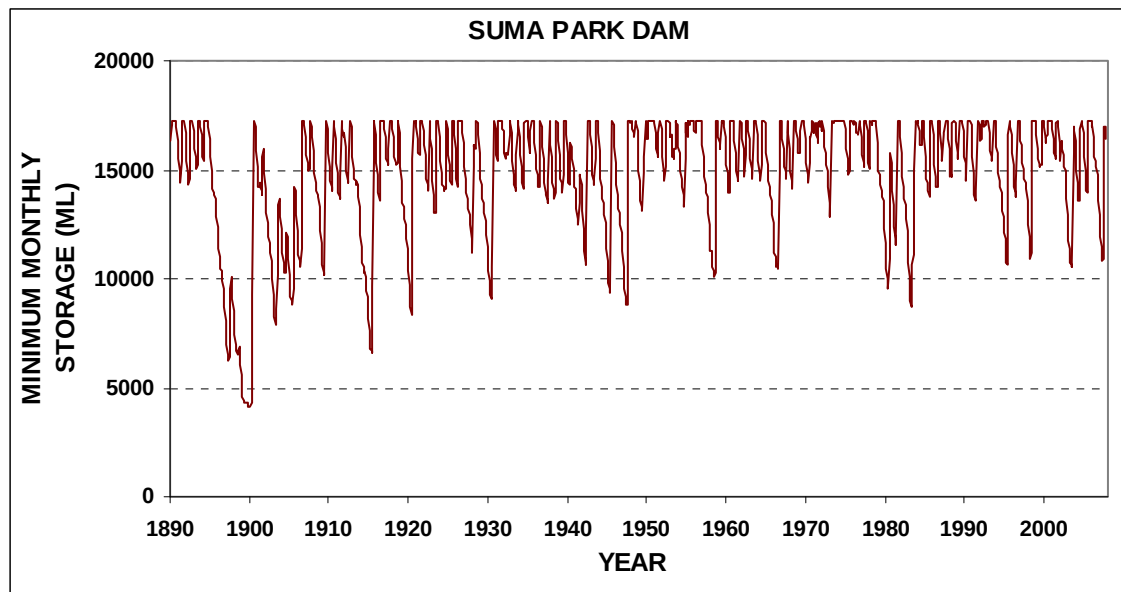
Run9B3-1 Secure Yield = 4600 ML/a



ORANGE WATER SUPPLY

Storage Behaviour Plots for:

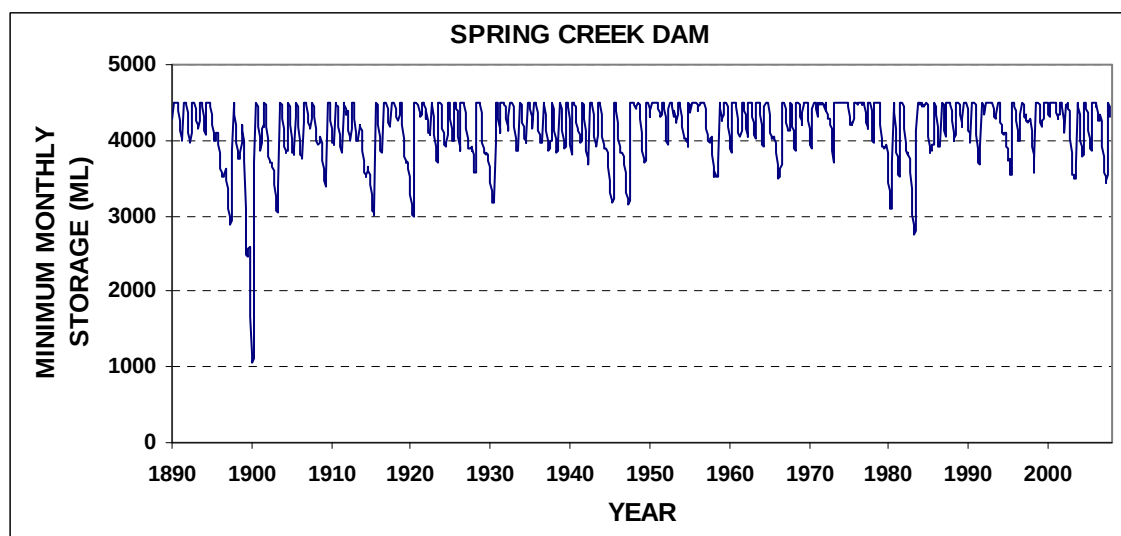
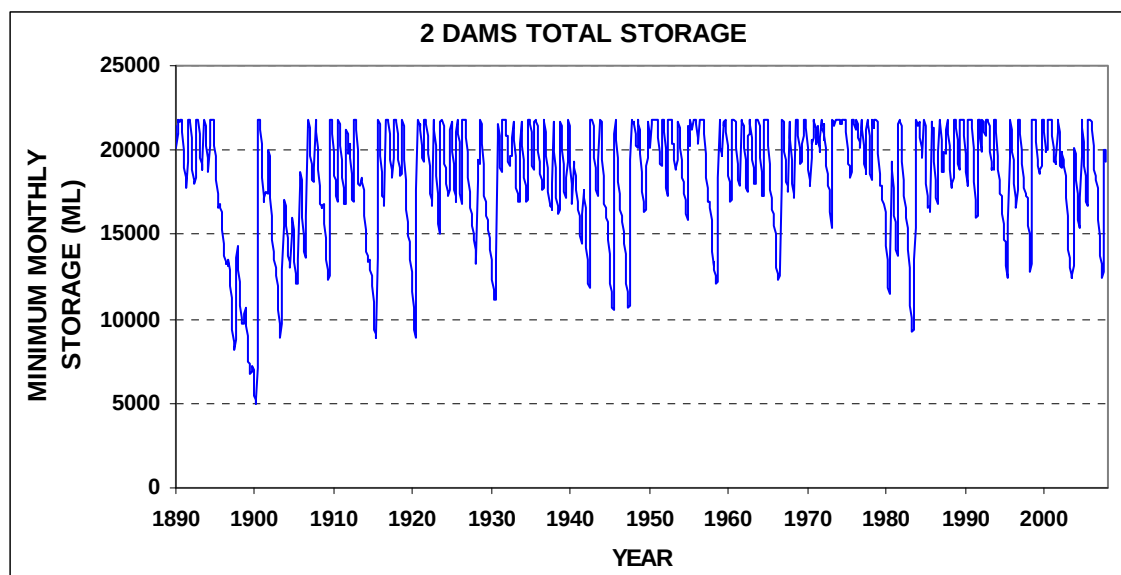
Run9B3-1 Secure Yield = 4600 ML/a



ORANGE WATER SUPPLY

Storage Behaviour Plots for:

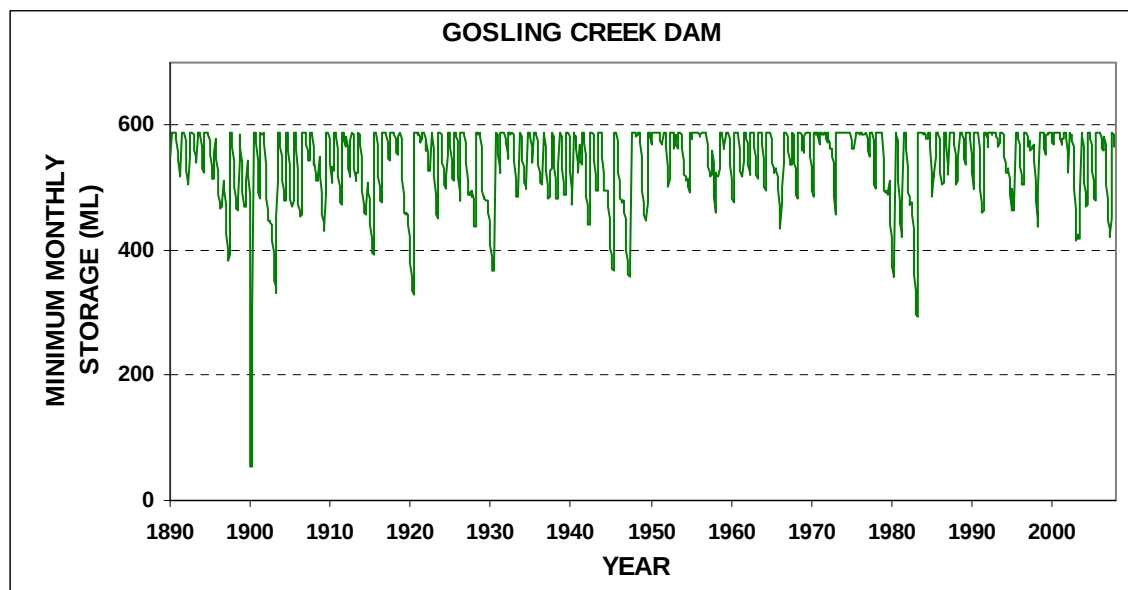
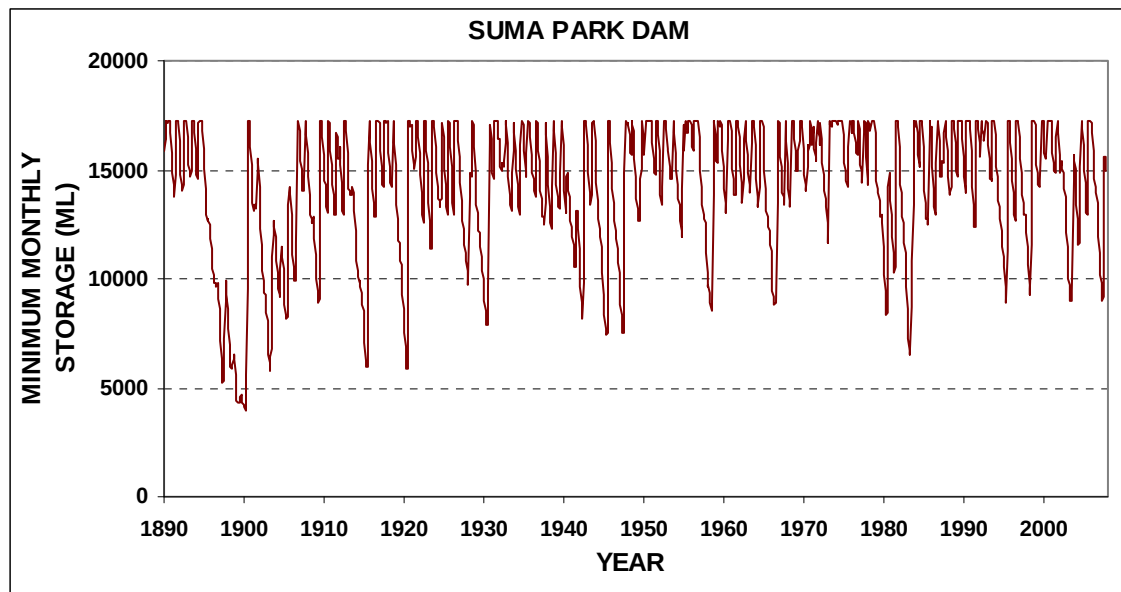
Run9E11-5 Secure Yield = 7400 ML/a



ORANGE WATER SUPPLY

Storage Behaviour Plots for:

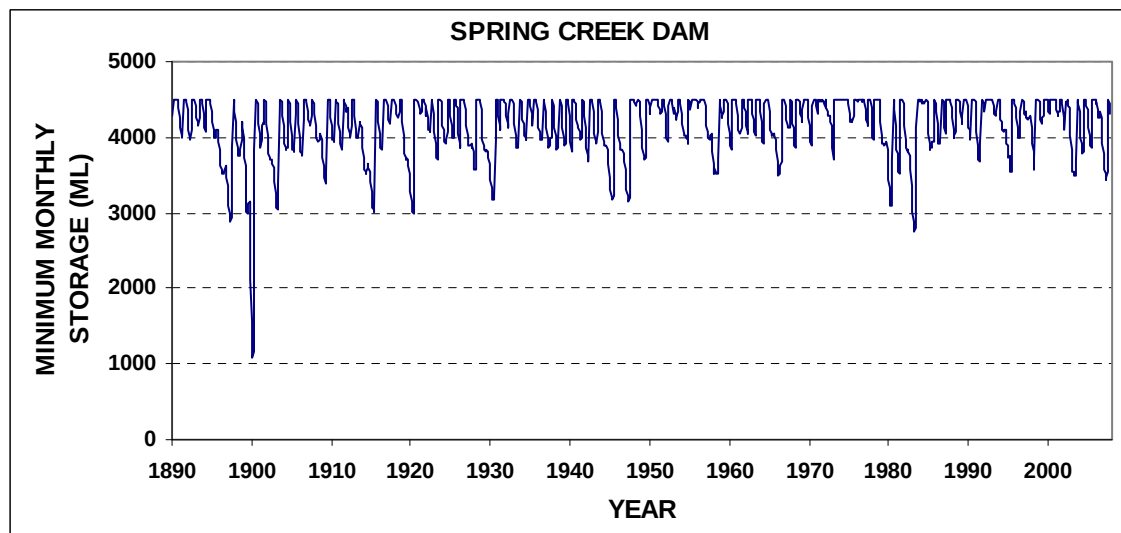
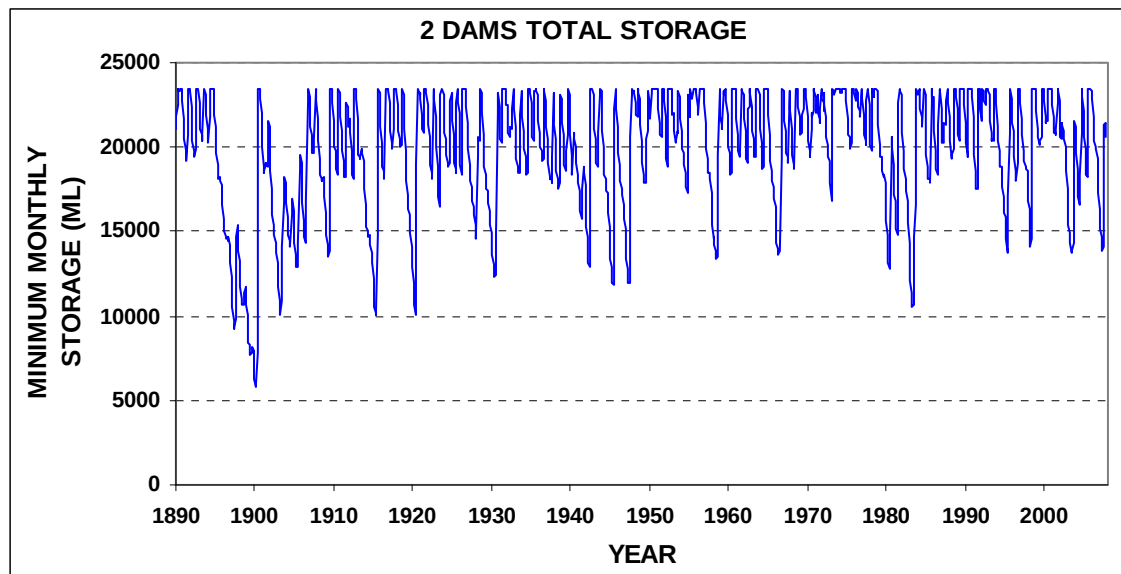
Run9E11-5 Secure Yield = 7400 ML/a



ORANGE WATER SUPPLY

Storage Behaviour Plots for:

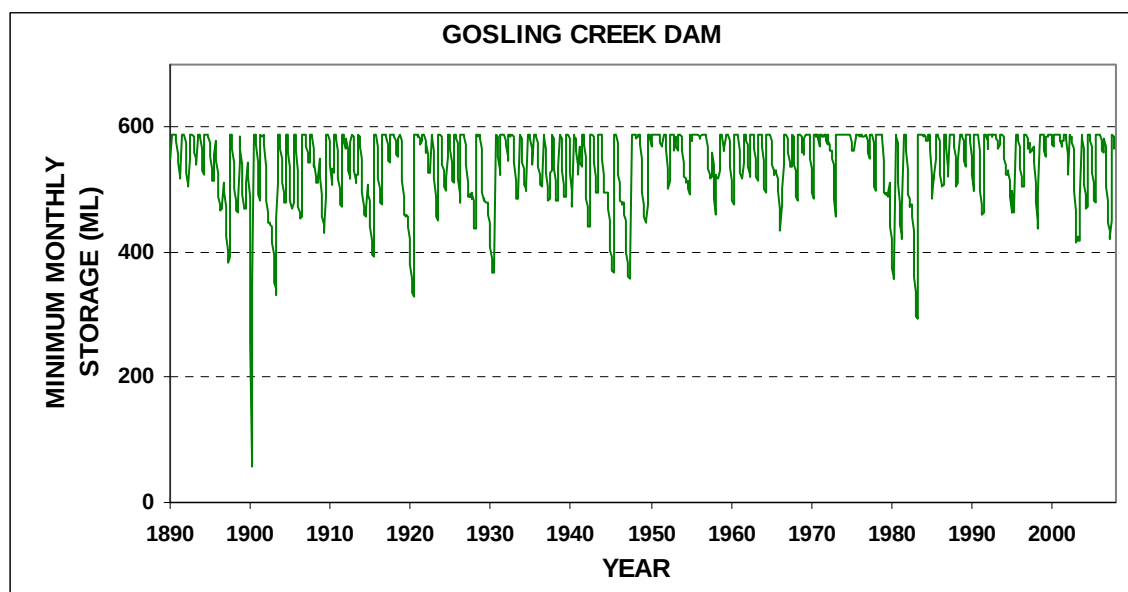
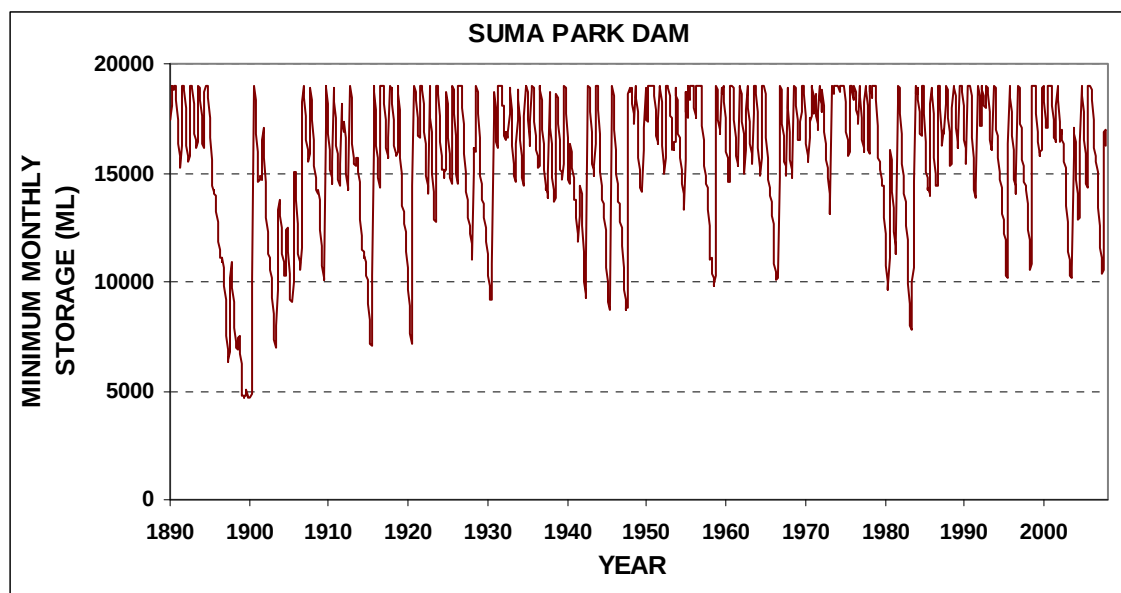
Run9E11-6 Secure Yield = 7550 ML/a



ORANGE WATER SUPPLY

Storage Behaviour Plots for:

Run9E11-6 Secure Yield = 7550 ML/a



Appendix B

CLIMATE CHANGE SECURE YIELD



MEMORANDUM

TO	Martin Haege Environmental Engineer, Geolyse Pty Ltd
CC	
FROM	Peter Cloke, Principal Hydrologist
DATE	21 May 2012
SUBJECT	Orange Water Supply System Modelling Comments

I refer to your request of 29 April 2012 to undertake Orange Water Supply Headworks system modelling using the provided Macquarie River flow data at the proposed pipeline intake. Please find herein the model results and a summary of their basis.

Background

While secure yield allows for meeting demand with restrictions through a much worse drought than has occurred since about 1890, consideration needs to be given to possible changes from Climate Change.

For this study additional consideration was given by using the approach proposed in NSW Office of Water's (NOW) Draft Proposed Policy for assessing the impact of climate change on non-metropolitan water supplies as given in (Samra and Cloke, 2010) and provided as an attachment.

NSW Water Solutions undertook the system modelling however the results are dependent on modelled data provided by others and as such NSW Water Solutions do not accept any responsibility arising from any errors in the provided data.

Data

The required Climate Change data to follow the proposed approach were provided by NOW.

Daily values of rainfall and evapotranspiration were obtained from NOW's 2008 data sets (Vaze et al, 2008) (Ref 1) for the 15 global climate models (GCMs) and the corresponding historic data for the nominated catchment grid points. The climate change data are for projected ~2030 and were obtained by Vaze et al (Ref 1) by scaling the historical 1895-2006 daily rainfall and evapotranspiration data using the methods detailed in Chiew et al, 2008 (Ref 2). The climate change data are based on the Year 2030 A1B warming scenario, a mid-range emissions scenario.

Modelling

The modelling essentially involved two steps:

- The daily data from the 15 GCMs and the corresponding historic base data were input into the previously calibrated rainfall runoff models to produce 16 series of inflows to Orange's water supply dams, flows from the stormwater harvesting systems and Macquarie River flows at the proposed pipeline intake. The inflows to the Orange water supply dams were developed by NSW Water Solutions, the

Macquarie River flows were developed by Kozarovski and Partners and the stormwater harvesting flows were developed by Geolyse Pty Ltd.

- The 16 series of daily inflows, (and daily rainfalls and daily evaporation) were input into the headworks storage behaviour model to determine 16 corresponding secure yield estimates. *(The required daily evaporation was obtained from relations developed between historic evapotranspiration and historic evaporation and then applied to the climate change evapotranspiration daily values).*

It is noted the effective modelling period was 1896 to 2006 as the first year of data were used for model initialisation.

Results

The full results from the secure yield modelling of the 16 inflow series are provided as attachments. The conditions for the cases examined were:

- *Environmental flow release rule 1 (1 ML/d or equal to inflow if < 1 ML/d)*
- *BSC100/PC100*
- *Bores 75*
- *MR12/34- add 12ML/d to Suma Park if storage <90% and river flow > 34 ML/d*

Table 1 summarises the key results for determining the factors to apply to the traditional secure yield estimates to allow for Climate Change.

Table 1: Climate Change Factors

Case	Secure Yield Estimates ML/a				Relevant Case in terms of NOW Draft Policy	Adopted Factor to be Applied for Climate Change
	Historic from Climate Change data Base	Median from GCMs (5/10/10)	Lowest from GCMs (5/10/10)	Lowest from GCMs rerun with (5/10/25)		
	A	B	C	D		
Suma Park Storage ML						
17,290	8650	8400	7300	8150	D/A	0.942
18,970	9050	8600	7500	8350	D/A	0.923

It is noted that the secure yields in column A are higher than the original historic secure yields due to the reduced availability (1896-2006) of the climate change data. The climate change data misses part of the critical drought (1894-1900) that is included in the historic data (1890-2007) used to determine the secure yield based on past climate conditions.

References

1. Vaze, J., Post D., Chiew F., Perraud J-M. and Kirono D. (2008), "Future climate and runoff projections (~2030) for New South Wales and Australian Capital Territory, NSW Department of Water and Energy, Sydney.
2. Chiew F., Teng J., Kirono D., Frost A.J., Bathols J.M., Vaze J., Viney N.R., Young W.J., Hennessy K.J., and Cai W.J., (2008), "Climate data for hydrologic scenario modelling across the Murray-Darling Basin", A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project. CSIRO, Sydney.

SUMMARYZ1.TXT

***** Summary Output Table for Orange water Supply - Impact Study
 * ORANGEIZ * Daily Simulation for RunZC: 13:53:25 05-07-2012
 ***** Total Dam Capacity = 21790 ML

Stream- flow Set No.	Secure Yield (ML/a)	Apply Restrictions At Storage =(<%)of (ML) Full	Restriction Yield (ML/a)	Yield (%) of max.	Restrictions Duration % of Time	Once In (X)Years	Critical Drought from	to
1	9450	10895	50	8505	90	1.86	27/10/1912	14/05/1915
2	8800	10895	50	7920	90	1.81	27/10/1912	14/05/1915
3	7300	10895	50	6570	90	2.58	01/01/1896	20/03/1900
4	8200	10895	50	7380	90	2.19	01/01/1896	20/03/1900
5	8400	10895	50	7560	90	1.73	01/01/1896	20/03/1900
6	7950	10895	50	7155	90	2.12	01/01/1896	20/03/1900
7	8450	10895	50	7605	90	2.62	01/01/1896	20/03/1900
8	7750	10895	50	6975	90	2.60	01/01/1896	20/03/1900
9	7700	10895	50	6930	90	2.81	01/01/1896	20/03/1900
10	9350	10895	50	8415	90	2.10	15/10/1912	14/05/1915
11	9050	10895	50	8145	90	2.88	01/01/1896	20/03/1900
12	8000	10895	50	7200	90	2.58	01/01/1896	20/03/1900
13	8250	10895	50	7425	90	2.46	01/01/1896	20/03/1900
14	8750	10895	50	7875	90	3.02	01/01/1896	20/03/1900
15	9000	10895	50	8100	90	2.20	27/10/1912	14/05/1915
16	8650	10895	50	7785	90	2.08	27/10/1912	14/05/1915

streamflow set 16 is Historical data

Summary of ranked Secure Yield

Ranked Order	Comment	Streamflow Set	Secure Yield
0	Historical	16	8650
1		1	9450
2	2nd Highest	10	9350
3		11	9050
4		15	9000
5		2	8800
6		14	8750
7		7	8450
8	Median	5	8400
9		13	8250
10		4	8200
11		12	8000
12		6	7950

13		8	7750
14	2nd Lowest	9	7700
15	Lowest	3	7300

SUMMARYZ2.TXT

***** Summary Output Table for Orange water Supply - Impact Study
 * ORANGEIZ * Daily Simulation for RunZC: 14:19:19 05-07-2012
 ***** Total Dam Capacity = 23470 ML

Stream- flow Set No.	Secure Yield (ML/a)	Apply Restrictions At Storage =<(%)of		Restriction (ML/a)	Yield (%) of max.	Restrictions		Critical Drought	
		(ML)	Full			Duration % of Time	Once In (X)Years	from	to
1	9900	11735	50	8910	90	1.96	13.88	27/10/1912	14/05/1915
2	9200	11735	50	8280	90	1.89	12.33	16/10/1912	14/05/1915
3	7500	11735	50	6750	90	2.49	18.50	01/01/1896	20/03/1900
4	8550	11735	50	7695	90	2.57	13.88	01/01/1896	20/03/1900
5	8600	11735	50	7740	90	1.68	27.75	01/01/1896	20/03/1900
6	8150	11735	50	7335	90	2.03	18.50	01/01/1896	20/03/1900
7	8750	11735	50	7875	90	2.67	12.33	01/01/1896	20/03/1900
8	7950	11735	50	7155	90	2.57	15.86	01/01/1896	20/03/1900
9	7900	11735	50	7110	90	2.81	15.86	01/01/1896	20/03/1900
10	9800	11735	50	8820	90	2.30	13.88	15/10/1912	14/05/1915
11	9200	11735	50	8280	90	2.40	15.86	01/01/1896	20/03/1900
12	8250	11735	50	7425	90	2.62	18.50	01/01/1896	20/03/1900
13	8450	11735	50	7605	90	2.45	18.50	01/01/1896	20/03/1900
14	8950	11735	50	8055	90	2.52	13.88	01/01/1896	20/03/1900
15	9300	11735	50	8370	90	2.24	12.33	27/10/1912	07/06/1915
16	9050	11735	50	8145	90	2.42	12.33	14/10/1912	14/05/1915

streamflow set 16 is Historical data

Summary of ranked Secure Yield

Ranked Order	Comment	Streamflow Set	Secure Yield
0	Historical	16	9050
1		1	9900
2	2nd Highest	10	9800
3		15	9300
4		2	9200
5		11	9200
6		14	8950
7		7	8750
8	Median	5	8600
9		4	8550
10		13	8450
11		12	8250
12		6	8150

13		8	7950
14	2nd Lowest	9	7900
15	Lowest	3	7500

NSW RESPONSE FOR ADDRESSING THE IMPACT OF CLIMATE CHANGE ON THE WATER SUPPLY SECURITY OF COUNTRY TOWNS

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ABSTRACT

Under the NSW Government's *Best-Practice Management of Water Supply and Sewerage Guidelines*, local water utilities in non-metropolitan NSW are required to prepare and implement a comprehensive 30-year integrated water cycle management (IWCM) strategy. The IWCM strategy is prepared for the utility's water supply, sewerage and stormwater businesses, including the water supply headworks, and is effectively a 30-year rolling strategy, which must be reviewed and updated by each utility every 6 years.

For the past 25 years most urban water supply headworks in country NSW have been sized on a robust Security of Supply basis. This security of supply basis has been designed 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 water restrictions during a significantly more severe drought than had been experienced historically. The required water restrictions must not be too severe, not too frequent, nor of excessive duration. Recent analysis for the severe 2001-2007 drought has confirmed the continuing robustness of the NSW Security of Supply basis.

To understand the potential impact of climate change on the security of urban water supplies, results are presented from a pilot study for 11 non-metropolitan NSW water supplies utilising 112 years of downscaled daily hydrometeorological data from 15 global climate models for climate change projections for the year 2030 using the A1B medium warming emissions scenario. This analysis enabled determination of the impact of climate change on the Year 2030 secure yield for each water supply.

Future 30-year IWCM strategies in NSW will need to include assessment of the secure yield of the utility's water supply in accordance with the analysis reported for the pilot study. Implementation of these strategies, together with the required 6-yearly updates, will address future water security.

INTRODUCTION

The NSW Government is tackling the challenge of the impact of climate change on non-metropolitan urban water utilities in a multi-pronged approach through comprehensive best practice management requirements, as noted below.

The key element of the NSW response to climate change is that the utilities will be required to determine their urban water supply security along the lines of the analysis reported in this paper for the pilot study for 11 NSW water supplies. Reporting of such water supply security analysis will need to be documented in each utility's 30-year IWCM strategy.

Background

The NSW Government's *Best-Practice Management of Water Supply and Sewerage Guidelines* (Dept Water and Energy, 2007) is the key driver for reform of planning and management and performance improvement in non-metropolitan NSW. 106 NSW local water utilities provide piped water supply and sewerage services to the 1.8 million people in NSW country towns (97.9% water supply coverage). The 19 requirements of the guidelines include:

- Annual performance monitoring by each utility;
- Current 20 year strategic business plan and financial plan;
- Regulation of water supply, sewerage and trade waste (including pay-for-use water pricing, full cost recovery, commercial sewer usage, trade waste and developer charges, trade waste approvals for all dischargers and a sound trade waste regulation policy by each utility);
- Demand management;
- Drought management ; and

- Integrated Water Cycle Management (IWCN) - comprehensive 30 year strategy required for the utility's water supply, including headworks, sewerage, and where cost-effective, stormwater businesses. A full range of scenarios must be evaluated on a rigorous triple bottom line (TBL) basis, with extensive community involvement. The IWCN Strategy is effectively a 30-year rolling strategy, which must be reviewed and updated by each utility every 6 years.

The non-metropolitan NSW utilities have annual revenue of \$950 million and an asset base with a current replacement cost of almost \$20 billion (NSW Office of Water, 2010 (1) : vii). Overall, the utilities had met 82% of the requirements of the *Best-Practice Management Guidelines* by June 2009. The Best-Practice Management Guidelines, the IWCN Guidelines, the 7 IWCN Information Sheets and the annual NSW Water Supply and Sewerage Performance Monitoring Reports and Benchmarking Reports are available on the NSW Office of Water website (www.water.nsw.gov.au).

NSW Security of Supply Basis

45 local water utilities have surface water supplies with storage dams in non-metropolitan NSW. Such utility storages have in the main been sized on the NSW Security of Supply basis since the mid-1980s (NSW Public Works, 1986; Samra & French, 1988 and Cloke, 1995).

The purpose of the NSW Security of Supply basis is to determine the cost-effective storage volume and transfer capacities required to enable each water utility to operate its system with only moderate water restrictions in the event of occurrence of droughts of similar severity to those in the historical record, generally back to at least 1895. The utility would also be able to cope with significantly more severe droughts albeit with more severe water restrictions. Effectively, each water supply system would be able to cope with approximately a '1 in 1000 year drought' (Cloke & Samra, 2009 :13).

Under the NSW Security of Supply basis (commonly referred to as the '5/10/20 rule'), water supply headworks systems are 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); and
- 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.

This enables the utilities to operate their systems without restrictions until the volume of stored water approaches the trigger level determined by a) and b) above (typically about 50% to 60% of the storage capacity). If at this trigger level, the utility imposes drought water restrictions which reduce demand by 20%, the system would be able to cope with a repeat of the worst recorded drought, commencing at that time, without emptying the storage.

'Secure yield' is 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'¹.

The robustness of the NSW Security of Supply basis has been demonstrated by Cloke & Samra (2009 :7) who showed that for the 10 NSW urban water supplies studied, the very severe 2001 to 2007 drought resulted in a reduction in the secure yield of up to 7% for 7 of the water supplies and a reduction of about 15% for the other 3 supplies.

The first paragraph in footnote 2 below², which is a quote from page 3 of the *2008-09 NSW Water Supply and Sewerage Performance Monitoring Report* shows that for the 15 years from 1986, the frequency of drought water restrictions by the non-metropolitan NSW water utilities was consistent with the implied target of no restrictions in 90% of years in b) above.

The *2008-09 NSW Water Supply and Sewerage Benchmarking Report* shows each utility's drought water restrictions over each of the last 6 years (page 56).

¹ As noted at the top of page 3, this has been superseded by a '5/10/10 rule' since February 2009.

² 'For the 15 years from 1986 to 2000/01, on average, the NSW utilities did not apply any drought water restrictions for 87% of the years, which include the severe 1993 to 1994 drought. This is consistent with the implied target of no restrictions in 90% of years in the NSW Security of Supply basis (commonly referred to as the '5/10/10 rule').

For the 23 years from 1986 to 2008/09, on average, the NSW utilities did not apply any drought water restrictions for 75% of the years. However, this period includes both the above 1993 to 1994 drought and the very severe 2001 to 2008/09 drought.'

The 2008-09 Performance Monitoring Report (page 8) also shows 'there has been a 47% reduction in the volume of average annual residential water supplied per property in non-metropolitan NSW over the last 18 years (from 330 to 175kL per connected property)'. It is therefore considered that it will now be much more difficult to achieve a 20% reduction in consumption than it was 20 years ago as there has been a large reduction in outdoor water use. Accordingly, in February 2009 the NSW Office of Water agreed to basing future planning in non-metropolitan NSW on being able to achieve an average of only a 10% reduction in consumption through a repetition of the worst drought commencing with the storage already drawn down to satisfy the restriction duration and frequency criteria in a) and b) on page 2. Thus the NSW '5/10/20 rule' has been superseded by a '5/10/10 rule'.

Accordingly, a pilot study has been undertaken to examine the impacts climate changed hydrometeorological data has on water security for 11 surface water supplies and to develop a methodology suitable for application for this purpose by the other NSW water utilities.

PILOT STUDY

A Climate Change Steering Group has been formed to oversee a climate change pilot study for 11 urban NSW water supplies and development of NSW guidelines for local water utilities on assessing the impact of climate change on the secure yield of their water supplies. The Steering Group members are:

- Peter McLoughlin (National Water Commission)
- Jai Vaze (NSW Office of Water/CSIRO)
- Peter Cloke (NSW Public Works - commissioned to carry out the pilot study)
- Sascha Moege (Local Government and Shires Associations)
- Wayne Franklin (NSW Water Directorate)
- Sam Samra, Mike Partlin, Peter Ledwos (NSW Office of Water)

As indicated above, the purpose of the pilot study was to provide insights on the impacts of climate changed hydrometeorological data on the water security of the 11 water supplies in the pilot study and to then develop a suitable methodology and guidelines for application by the other NSW water utilities.

The pilot study (Samra & Cloke, 2010 :10) involved undertaking hydrological and system modelling to determine the impact of climate change on secure yield. The pilot study incorporates the scientific logic of the CSIRO's Murray Darling Basin Sustainable Yields Project (Chiew et al, 2008), which used daily historical data from 1895 to 2006 and applied the relevant global climate models (GCMs) to provide projected (~2030) climate changed data for each GCM for this period.

The pilot study uses daily values of rainfall and evapotranspiration from the NSW Office of Water's 2008 data sets³ (Vaze et al, 2008) for 15 GCMs. These future climate change series for ~2030 were obtained by Vaze et al by scaling the historical 1895-2006 daily rainfall and evapotranspiration data using the methods detailed in Chiew et al ,2008.. These data sets involve extension of the CSIRO data for the Murray Darling basin to cover all of NSW and are based on the Year 2030 A1B warming scenario⁴; a mid range emissions scenario.

The study essentially involved two modelling steps:

- Daily rainfall and evapotranspiration data were inputted into existing calibrated rainfall-runoff models to produce climate changed daily streamflows⁵
- The daily climate changed streamflows, rainfall and evapotranspiration were inputted into water supply system simulation models⁶ to determine climate changed secure yields.

The climate changed secure yields were compared with the secure yields for a repeat of the historical data set as noted on page 5.

³ This comprehensive data set provides projections of down scaled daily climate changed data for the Year 2030 for all of NSW. It is the best such data set available at present, and was therefore used for the pilot study. As noted on page 10 this data set now covers all of NSW, Victoria and the Murray Darling Basin, including Adelaide. As noted on page 10 improved and longer term projections of climate changed data are expected to be developed in the future and these should be applied by water utilities when they become available.

⁴ It is noted that there is little difference in the impacts of the various warming scenarios considered by the IPCC for the Year 2030. Such impacts diverge in longer term projections such as for the Year 2050 or 2070.

⁵ Use of a locally calibrated daily rainfall-runoff model for each water supply is essential. The analysis carried out in the pilot study demonstrated that use of generalised streamflow estimates available from the NSW Office of Water data sets is inappropriate for security of water supply analysis. In NSW, such a local daily rainfall-runoff model is routinely developed for any water supply secure yield study.

⁶ Similarly, a suitable system simulation model is routinely developed in NSW for any water supply secure yield study.

Table 1 lists the 15 GCMs that were used to produce the data sets

Table 1: The 15 Global Climate Models

Climate Data Series	GCM	Modelling Group	Country
1	CCCMA T47	Canadian Climate Centre	Canada
2	CCCMA T63	Canadian Climate Centre	Canada
3	CNRM	Meteo-France	France
4	CSIRO-MK3.0	CSIRO	Australia
5	GFDL 2.0	Geophysical Fluid Dynamics Lab	USA
6	GISS-AOM	NASA/Goddard Institute for Space Studies	USA
7	IAP	LASG/Institute of Atmospheric Physics	China
8	INMCM	Institute of Numerical Mathematics	Russia
9	IPSL	Institut Pierre Simon Laplace	France
10	MIROC-M	Centre for Climate Research	Japan
11	MIUB	Meteorological Institute of the University of Bonn,	Germany
		Meteorological Institute of KMA	Korea
12	MPI-ECHAMS	Max Planck Institute for Meteorology, DKRZ	Japan
13	MRI	Meteorological Research Institute	Japan
14	NCAR-CCSM	National Center for Atmospheric Research	USA
15	NCAR-PCMI	National Center for Atmospheric Research	USA

It is noted that to maintain relativity and ensure consistency in the pilot study, modelled streamflow data was used throughout. However in practice in determining 'historical' secure yield, best use is made of the observed data for each utility. Thus the historical estimates in Table 2 differ slightly from the current best estimates of secure yield, which include consideration of the observed data. Thus the Steering Group recommends applying the percentage change in secure yield in column (9) of Table 2 to the utility's current best estimate of secure yield in order to obtain the climate changed secure yield estimate.

Table 2: Comparison of Secure Yield Estimates[#]

Water Utility	Estimated Secure Yield (ML)				% Change in Secure Yield From Historical Data Set			
	Historical Data Set*	Median of 15 Global Climate Models (GCMs)	Lowest GCM	Lowest GCM with 25% severity	Median of 15 GCMs $\frac{[(3) - (2)] \times 100}{(2)}$	Lowest GCM $\frac{[(4) - (2)] \times 100}{(2)}$	Lowest GCM with severity of 25% $\frac{[(5) - (2)] \times 100}{(2)}$	Adopted % Change in Year 2030 Secure Yield due to Climate Change [lesser of (6) & (8)] (%)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	21,500	20,000 [14]	17,500 [9]	19,500	-7%	-19%	-9%	-9%
2	3,400	3,500 [1]	3,200 [9]	3,600	+3%	-6%	+6%	+3%
3	12,400	12,200 [1]	11,400 [6]	12,600	-2%	-8%	+2%	-2%
4	7,700	7,200 [13]	6,700 [3]	7,200	-6%	-13%	-6%	-6%
5	5,200	4,900 [4]	4,500 [9]	4,800	-4%	-13%	-8%	-8%
6	495	450 [12]	400 [3]	435	-9%	-19%	-12%	-12%
7	4,850	4,150 [4]	3,250 [3]	3,600	-14%	-33%	-26%	-26%
8	3,600	3,600 [8]	2,900 [3]	3,400	0%	-19%	-6%	-6%
9	480	360 [8]	220 [4]	240	-25%	-54%	-50%	-50%
9+	1500	1260 [7]	880 [4]	1060	-16%	-41%	-29%	-29%
10	185	175 [4]	115 [9]	135	-5%	-38%	-27%	-27%
11	16,900	15,300 [4]	14,300 [13]	15,700	-9%	-15%	-7%	-9%

On the basis of '5/10/10 rule' in ML/a, except for columns (5) and (8), which involve a severity of 25% (ie. a '5/10/25 rule').
 * 111 years of data (1896 to 2006) from the "Future climate and runoff projections (in 2030) for NSW and ACT" Database.
 + Enlarged storage for proposed augmentation.
 In columns (3) and (4), the relevant GCM is shown within square brackets, eg. for Utility 10 the secure yield shown in column (3) is based on GCM 4.

Figure 1 shows the general location of the 11 NSW water supply systems examined which covered a range of attributes: large, small, on-stream storage, off-stream storage, coastal, inland and multi-sources.

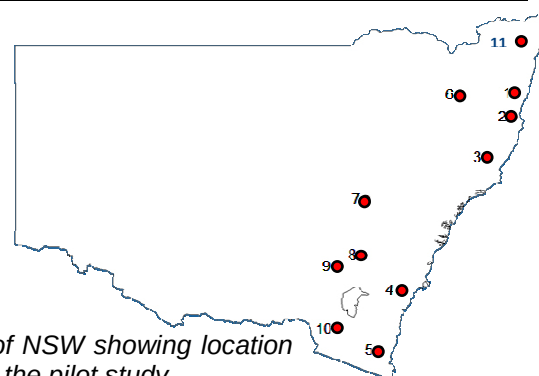


Figure 1: Map of NSW showing location of the utilities in the pilot study

RESULTS OF THE PILOT STUDY

Climate Change

The projected impacts of climate change in ~2030 on the average annual rainfall, streamflow and evapotranspiration for each utility's water supply, in comparison with the historical data sets are shown in Figures 2, 3 and 4 respectively. Note that there is a tendency towards drying in NSW.

Following determination of the average annual rainfall for each of the 15 GCMs for each utility, the GCM with the highest average annual rainfall is shown as 'Highest' in Figure 2, expressed as a percentage change in comparison with the historical average annual rainfall. Similarly, the GCM with the lowest average annual rainfall for a utility is shown as 'Lowest' and the GCM with the median average annual rainfall from the 15 GCMs is shown as 'Median' in Figure 2.

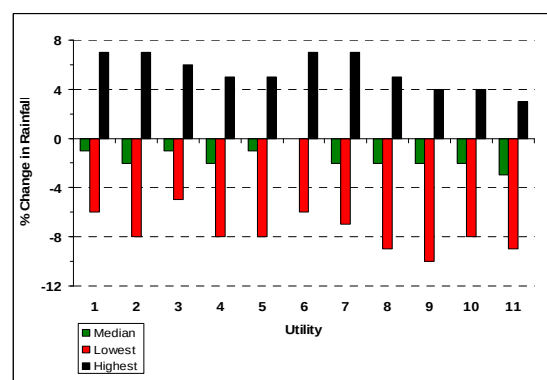


Figure 2: % Change in the Average Annual Rainfall for the Global Climate Models (GCMs) shown compared with the result for the Historical Data Set

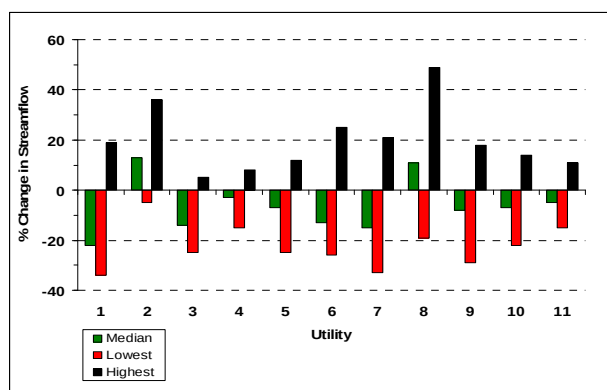


Figure 3: % Change in the Average Annual Streamflow for the Global Climate Models (GCMs) shown compared with the result for the Historical Data Set

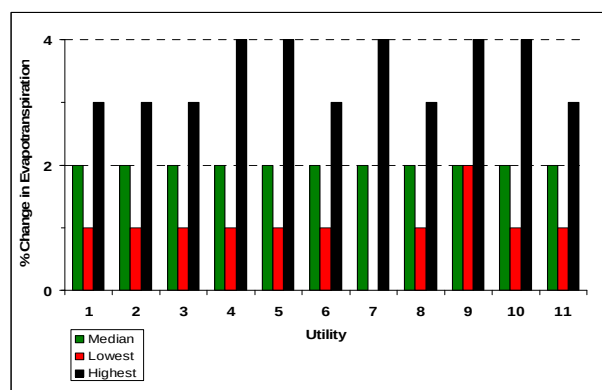


Figure 4: % Change in the Average Annual Evapotranspiration for the Global Climate Models (GCMs) shown compared with the result for the Historical Data Set

Figure 2 shows that the changes in the average annual rainfall for the GCM with the median change range from no change (Utility 6) to a reduction of 3% (Utility 11) (median is a 2% reduction). For the GCM with the lowest change, the range is reductions of 5% (Utility 3) to 10% (Utility 9) (median is an 8% reduction). For the GCM with the highest change, the range is increases of 3% (Utility 11) to 7% (Utilities 1, 2, 6 and 7) (median is a 5% increase).

Figure 3 shows that the changes in the average annual streamflow for the GCM with the median change range from an increase of 13% to a reduction of 22% (median is a 7% reduction). For the GCM with the lowest change, the range is reductions of 5% to 34% (median is a 25% reduction). For the GCM with the highest change, the range is increases of 5% to 49% (median is an 18% increase).

Figure 4 shows that for the GCM with the median change, the change in the average annual evapotranspiration is a 2% increase in each case. For the GCM with the lowest change, the range is increases of nil to 2% (median is a 1% increase). For the GCM with the highest change, the range is increases of 3% to 4% (median is a 3% increase).

Secure Yield

The results of the pilot study with respect to secure yield are shown in Table 2. Columns (2), (3) and (4) show the secure yield for each of the 11 utilities in the pilot study for the historical data, the median of 15 GCMs and the lowest GCM on the basis of the '5/10/10 rule'.

Columns (6) and (7) show the changes in secure yield for the median of 15 GCMs and the lowest GCM in percentage terms. For the median GCM (column (6)) the change in secure yield varies from an increase of 3% (Utility 2) to a reduction of 25% (Utility 9). For the lowest GCM (column (7)) the change in secure yield varies from a 6% reduction (Utility 2) to a reduction of 54% (Utility 9).

As discussed in Samra & Cloke (2010 :5) the Steering Group considers that a balanced approach to determining the secure yield after climate change would be to adopt the lesser of:

- a) secure yield for the median of 15 GCMs on the basis of the '5/10/10 rule'
- b) secure yield for the GCM with the lowest secure yield on the basis of a '5/10/25 rule'; the 25% severity of restrictions under this rule amounts to being able to 'survive' occurrence of the lowest GCM, albeit with relatively harsh water restrictions to cope with the reduced availability of water.

Thus a utility's core planning under a) above would be on the basis of the '5/10/10 rule'. However, under b) above, the utility would also need to ensure its system would be able to survive the lowest GCM under the severe restrictions involved in a '5/10/25 rule'.

Column (5) of Table 2 shows the secure yield of the lowest GCM on the basis of 25% severity of restrictions (ie. a '5/10/25 rule'). For comparison purposes, the percentage change in secure yield is shown in column (8).

The above approach is considered to provide a reasonable balance between avoiding excessive capital expenditure by the utilities and avoiding very harsh future drought water restrictions. The 25% severity for the GCM with the lowest secure yield is considered to be acceptable in view of the low probability of occurrence of such a GCM and is informed by the outcomes of at least 35% reduction in consumption achieved by several NSW utilities in the current drought, including Goulburn, Orange and the Central Coast (Samra & Cloke, 2010: 5).

The adopted change in the Year 2030 secure yield due to climate change for each utility is shown in column (9) of Table 2 and Figure 5. This is identical with the values shown in column (6), for 4 utilities (2, 3, 4 and 11). *The adopted changes for the other 7 utilities are on the basis of 25% severity of restrictions for the lowest GCM, and are up to 25 percentage points lower than for the median GCM.*

The 3 utilities with a reduction in the adopted secure yield of over 25% are inland utilities in mid and southern NSW. This finding is consistent with the Victorian expectation of increasing drought severities.

Storage behaviour diagrams for each utility are shown in Figures A1 to A12 in Appendix A on page 11. These show the storage behaviour (expressed as % of full storage capacity) while delivering an annual demand⁷ equivalent to the secure yield determined for the historical data for a repeat of:

- the historical climate conditions and
- for a repeat of the climate changed conditions that produced the
 - o highest,
 - o median and
 - o lowest climate changed secure yield for each utility.

Using the climate changed inflows, Figures A1 to A12 show that except for Utility 10 (Figure A11), the storages did not empty while supplying a demand equivalent to the historic secure yield for each utility. This includes the results in Figures A9 and A10 for Utility 9 which had the largest reduction in secure yield. It is important to note that the existing small storage capacity for Utility 9 results in a 50% reduction in secure yield (column 9 of Table 2). However after the proposed augmentation of the storage dam, there would be only a 29% reduction in the secure yield, which demonstrates that the impact of climate change is system dependent.

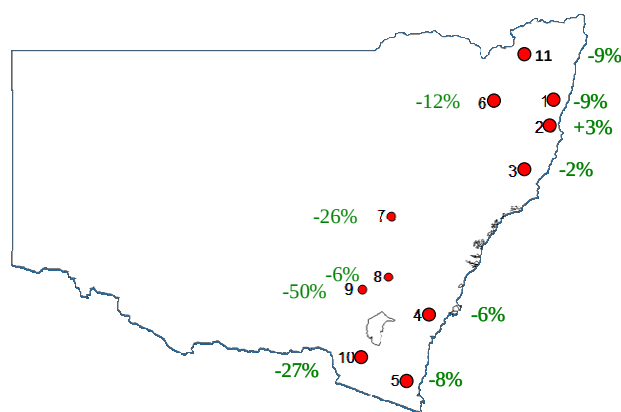


Figure 5: Map of NSW showing adopted % change in Year 2030 Secure Yield due to climate change for each utility in the pilot study

Note:

For Utility 9, the changes in secure yield for the existing small storage dam and for the proposed enlargement of the dam were -50% and -29% respectively.

⁷ Unrestricted demand was supplied until the storage volume fell to the restriction volume for each utility (typically about 50% to 60% of full capacity). Thereafter 90% of the demand was supplied until there was a significant recovery in the storage volume, when the unrestricted demand was resumed. As it was necessary to use the first year of each dataset to initialise the daily rainfall-runoff models, each simulation was generally carried out with the remaining 111 years of daily hydroclimate data.

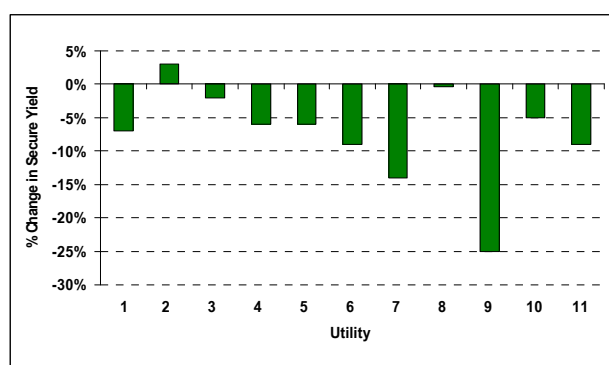


Figure 6: Median % Change in the Secure Yield from the 15 Global Climate Models compared with the result for the Historical Data Set

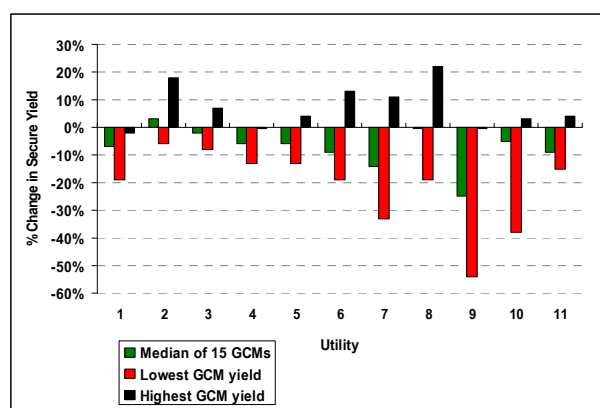


Figure 7: % Change in the Secure Yield for the Global Climate Models (GCMs) shown compared with the result for the Historical Data Set

Figure 6 provides a graphical representation of the percentage change in secure yield for the GCM with the median secure yield, in comparison with the historical data set. These results are as shown in column (6) of Table 2 and range from an increase of 3% to a reduction of 25%.

Figure 7 also provides a graphical representation of this percentage change for the GCM with the lowest secure yield (from column (7) of Table 2) and that for the GCM with the highest secure yield, in comparison with the historical data set. As also noted above, the results for the GCM with the lowest secure yield range from a reduction of 6% to a reduction of 54% (column (7) of Table 2). The results for the GCM with the highest secure yield range from an increase of 22% to a reduction of 2%.

The GCMs which provided the median, lowest and highest changes in the average annual rainfall, streamflow and evapotranspiration⁸ (refer to Figures 2 to 4) are not necessarily those which resulted in the median, lowest and highest changes in secure yield (refer to Figure 7).

A report on the pilot study will be published on the NSW Office of Water website in 2010 in order to disseminate the results and findings of the study.

Tables 3 and 4 show the key characteristics of the 4 simulations shown for each utility in Figures A1 to A12 on page 12, Table 3 provides a comparison of the resulting minimum storage volume for each simulation and indicates that the minimum storage volume for the historical data set ranges from 31% to 49% of the full storage capacity (column (3)). For the median of GCMs, the minimum storage volume ranges from 23% to 49%, with 3 utilities having a minimum storage volume of 23% to 25% of capacity (column (4)). However, for the lowest GCM, 4 utilities have a minimum storage of under 15% of capacity (Utilities 7, 9, 10 and 11), with the storage volume for the small Utility 10 emptying for a period of 6 months (column (5)). For the highest GCM, the minimum storage volume ranges from 32% to 51% of capacity (column (6)).

Table 3: Comparison of Minimum Storage Volumes

Water Utility (1)	Storage Capacity (ML) (2)	Minimum Storage Volume (%) while supplying the Historical Secure Yield			
		Historical Data Set (3)	Median of 15 Global Climate Models (GCMs) (4)	Lowest GCM (5)	Highest GCM (6)
1	35,600	39	30	20	40
2	5,500	31	33	27	41
3	4,500	43	49	31	51
4	4,900	46	44	42	46
5	3,780	49	34	24	37
6	460	34	31	22	42
7	22,500	37	23	10	43
8	15,500	38	38	23	46
9	850	37	25	9	37
9+	2,470	37	30	14	42
10	100	31	29	0 for 6 months	32
11	14,800	33	23	14	39

+ Enlarged storage

⁸ Eg. for Utility 1, the median rainfall, streamflow, evapotranspiration and secure yield resulted from GCMs 5, 5, 9 and 14 respectively.

Table 4: Comparison of Storage Drawdowns

Water Utility (1)	% of the time storage is drawn down below volumes shown while supplying the Historical Secure Yield											
	Historical Data Set			Median of 15 Global Climate Models (GCMs)			Lowest GCM			Highest GCM		
	(2)			(3)			(4)			(5)		
	60%	40%	20%	60%	40%	20%	60%	40%	20%	60%	40%	20%
1	1.4	0.1	0.0	1.5	0.5	0.0	3.1	0.7	0.1	1.2	0.0	0.0
2	3.7	0.8	0.0	2.8	0.7	0.0	5.0	0.8	0.0	1.1	0.0	0.0
3	0.7	0.0	0.0	0.8	0.0	0.0	1.3	0.1	0.0	0.5	0.0	0.0
4	1.5	0.0	0.0	2.1	0.0	0.0	2.9	0.0	0.0	1.6	0.0	0.0
5	0.2	0.0	0.0	1.1	0.2	0.0	2.1	0.3	0.0	0.7	0.0	0.0
6	1.4	0.2	0.0	1.1	0.2	0.0	2.3	0.4	0.0	0.7	0.0	0.0
7	5.0	0.4	0.0	9.5	1.4	0.0	18	5.2	0.8	2.5	0.0	0.0
8	7.0	0.2	0.0	6.1	0.3	0.0	16	2.9	0.0	1.0	0.0	0.0
9	1.4	0.2	0.0	1.7	0.6	0.0	2.5	0.8	0.2	0.8	0.1	0.0
9+	1.4	0.2	0.0	1.5	0.4	0.0	2.4	0.5	0.1	1.0	0.0	0.0
10	2.0	0.5	0.0	2.7	0.8	0.0	4.3	1.4	0.7	1.5	0.4	0.0
11	1.5	0.3	0.0	3.4	0.7	0.0	4.9	1.3	0.4	1.6	0.1	0.0

+ Enlarged storage

In summary, Table 3 shows that for the median GCM, the minimum resulting storage volume for most of the utilities is a little lower than that for the historical data, indicating slightly more severe droughts than had been experienced historically. For the lowest GCM, all the minimum storage volumes are much lower than the historical data set. This indicates the occurrence of much more severe droughts, with 5 of the utilities experiencing a minimum storage volume of under 15% of full capacity, in comparison with the historical data set, where the minimum storage volume was 31% of full capacity.

For the 4 simulations for each utility discussed in Table 3 above, Table 4 provides a comparison of the percentage of time each storage is drawn down below 60%, 40% and 20% of full capacity. These draw downs indicate the relative vulnerability of each water supply to supply failure due to emptying of the storage. For the historical data set (column (2)) of Table 4 shows that the percentage of time the storage volume falls below 60% of full capacity exceeds 5% only for Utility 8, where restrictions are implemented at a storage capacity of 55% under the '5/10/10 rule'. Column (3) of Table 4 shows that for the median of GCMs, 2 utilities (Utilities 7 & 8) have storage volumes under 60% of capacity for more than 5% of the time. Only these 2 utilities have such storage volumes for more than 5% of the time for the lowest GCM, but the duration now extends to 16% to 18% of the time for this GCM (column (4)). For the highest GCM, the duration of such storage volumes does not exceed 2.5% of the time for any utility (column (5)).

Table 4 also shows that for the historical data set (column (2)), the percentage of time the storage volume falls below 40% of full capacity, which could be expected in a severe drought, does not exceed 0.8% for all the utilities. Column (3) of Table 4 shows that for the median of GCMs, only Utility 7 has such storage volumes exceeding 0.8% of the time. However, for the lowest GCM only 7 utilities have such storage volumes not exceeding 0.8% of the time, with the other 4 utilities (Utilities 7, 8, 10 and 11) experiencing durations of 1.3% to 5.2% of the time (column (4)). For the highest GCM, the duration of such storage volumes does not exceed 0.4% of the time (column (5)).

In addition, Table 4 shows that for the historical data set (column (2)), the median of GCMs (column (3)) and the highest GCM (column (5)), the storage volume never falls below 20% of full capacity, which could be expected to occur only in an extreme drought. However, for the lowest GCM, 5 utilities (Utilities 1, 7, 9, 10 and 11) have a storage volume below 20% of capacity for at least 0.1% of the time (column (4)).

As previously noted, the *Best-Practice Management Guidelines* require each NSW water utility to prepare a comprehensive 30-year IWCM Strategy. The IWCM strategies will need to include assessment of the secure yield of the utility's water supply on the basis of new NSW guidelines proposed for release in late 2010. The utilities will be able to soundly plan for the security of their water supply for climate change by developing and implementing their 30-year IWCM strategy on the basis of the climate changed secure yield determined along the lines of the pilot study for 11 NSW water supplies.

As noted on page 3, the pilot study has focused on climate change projections for the Year 2030 based on predictions for the A1B mid range warming emissions scenario. This is not only due to the availability of the daily database but because there is only a small difference in the climate change projections between different emissions scenarios for the year 2030. These differences will be magnified for longer-term projections, such as year for the year 2050 or 2070.

DISCUSSION

The 1895-1902 Federation Drought

The severe 2001-2007 drought has been claimed as the worst drought since records began in Australia and has resulted in questioning of the reliability of several major water supplies in Australia. Fortunately NSW country town water supplies that had been planned on the basis of the NSW security of supply basis (ie. 5/10/20 rule) have been able to maintain the expected supply. It is hypothesised that this is because the 5/10/20 rule incorporates the very severe Federation drought of 1895-1902 and allows for maintaining a 20% restricted supply through in effect a '1 in 1000 year' drought (Cloke & Samra, 2009 :13).

It is understood consideration of Perth's and Melbourne's water supply reliability was until recently based on flow records post the Federation drought, as shown in their plots of inflows (from 1911 for Perth and from 1913 for Melbourne) (Gill, 2008 and Rhodes et al, 2010). The plot of inflows to Perth's water supply headworks has been repeatedly shown as an example of a shifting climate.

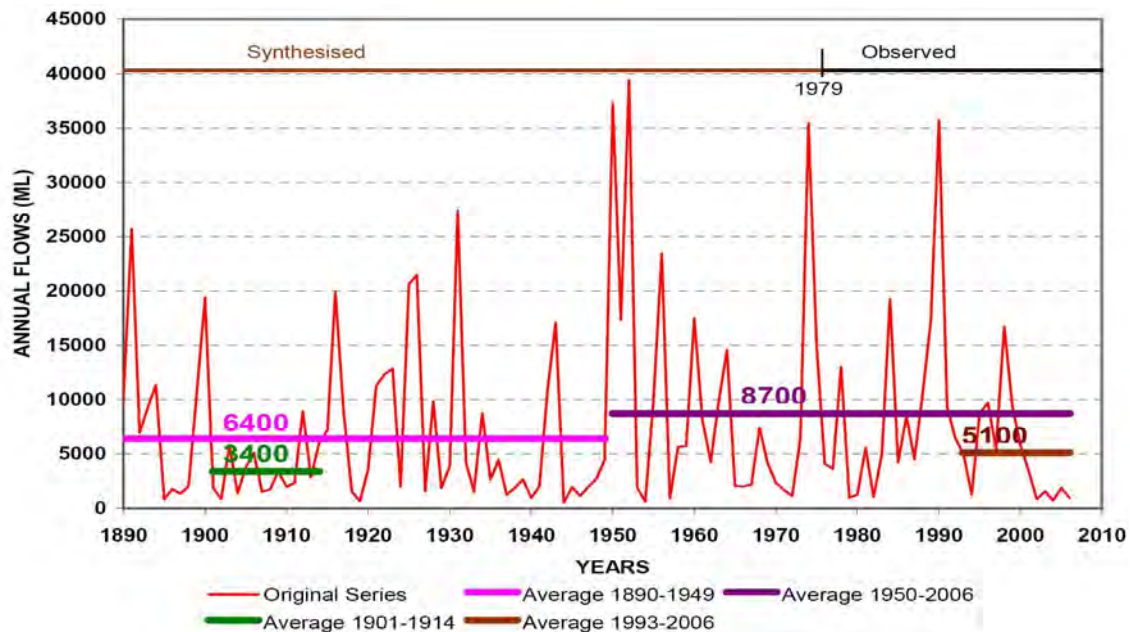


Figure 8: Annual Historic Flows Periodic Comparison

An equivalent plot of inflows for a Tablelands water utility in central NSW [catchment area 100 km²] is shown in Figure 8. With the inclusion of the Federation drought it suggests that the 2001-2007 drought was more likely to be due to climate variability rather than climate change and in terms of water supply headworks was not the worst drought on record.

If the Federation drought and pre 1915 droughts had not been incorporated in the water supply planning, secure yields for many NSW water supplies would have been determined to have been much higher and may have then been impacted by the 2001-2007 drought. **For example for Utility 7, post the Federation drought, the secure yield would have been determined as some 25% higher and post 1915, some 50% higher than the historical secure yield.** This highlights the importance of including the Federation Drought in any security of supply simulation studies to avoid such over-estimation of secure yield.

Accordingly, it is considered that the robustness of the NSW security of supply basis, combined with analysis for climate change as developed in the pilot study, will continue to provide reliable and cost-effective water supply security for NSW country towns.

Reducing uncertainty in climate models

The overall summary of the **Ozwater '10 Workshop on Climate Change Impacts on the Water Sector** (Claydon, et al., 2010: 3) includes:

'Reducing uncertainty in climate models is an active area of research – in particular coupled ocean-atmosphere general circulation models (GCMs). There have already been (published) steps made to provide this more refined (downscaled) output in Bureau of Meteorology and CSIRO climate projections, especially for drought. However, the core aspects of how best to apply these various models using sophisticated integrated modelling procedures remains an ongoing interesting research and operational issue.'

It is acknowledged that reducing uncertainty in climate models and how best to apply them is an area of ongoing research.

However, water supply planning and decision making requires assessment of the impact of climate change on water supply security. At present, the best available downscaled daily hydrometeorological data in Australia is for 15 GCMs along the lines developed by the Murray Darling Basin Sustainable Yields Project. Such data is now available for all of NSW and Victoria, as well as for all of the Murray Darling Basin, including Adelaide. It is therefore considered that the analysis carried out in this pilot study could be used to assess the Year 2030 climate change impacts for urban water utilities in the areas with such downscaled data which have surface water supplies with storage dams.

In addition, there are some major research activities such as the research in SEACI⁹ Theme 2 which focus on improving hydroclimate change projections for south-eastern Australia. They are specifically investigating

- (i) GCM assessment and selection for hydrological application and
- (ii) assessing the relative merits of different downscaling methods and relative uncertainties in various components in estimating climate change impact on runoff (GCM projections, downscaling methods and hydrological modelling) (Vaze J., 2010).

The above research includes consideration of dynamic downscaling, which has the potential to improve the projections of drought persistence for severe droughts.

Accordingly, as such better hydroclimate change data becomes available in the future, it should be applied in future planning. In this regard, where a utility has sufficient supply capacity to enable it to defer a major capital investment decision for additional surface water supplies for 5 or more years, it should do so, as the better hydroclimate change data likely to be available by that time would enable the utility to make a more robust investment decision.

CONCLUSIONS

- 1 A sound basis has been developed for non-metropolitan urban water utilities to assess the impact of climate change for the Year 2030 on the secure yield of their urban water supply. This is an adaptive management approach which enables utilities to carry out sound climate change planning and decision making immediately, using the existing 112 years of downscaled daily hydrometeorological data sets for 15 GCMs. As better hydroclimate change projections become available in the future, these will need to be applied in future planning by the utilities.
- 2 The results for the 11 utilities in the pilot study are shown in Figure 5 on page 6. These indicate that the main impacts on Year 2030 secure yield are:
 - no greater than a reduction of 9% for the 7 coastal and tablelands utilities
 - reductions of almost 30% for the 3 inland utilities in mid and southern NSW, after allowing for the proposed augmentation of the existing small storage capacity for Utility 9.
- 3 Future utility 30-year IWCM strategies in NSW will need to include assessment of the secure yield of the utility's water supply in accordance with the analysis reported for the pilot study. Implementation of these strategies, together with the required 6-yearly updates, will address the future water security of these utilities.

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The many NSW Councils which have engaged NSW Public Works over the years to carry out yield studies, thus enabling use of the study models for the analysis reported in the pilot study.

REFERENCES

- Chiew, F.S., Vaze, J., Viney, N.R., Perraud, J-M., Teng, J., Jordan, P.W., Kirono, D. and Young, W.J., 2008. *Estimation of Impact of Climate Change and Development on Runoff Across the Murray-Darling Basin* in Lambert, M., Daniell, T. and Leonard, M., (Eds) *Proceedings of Water Down Under 2008*, Adelaide, 14-17 April, pp.1957-1968.
- Chiew FHS, Teng J, Kirno D, Frost AJ, Bathols JM, Vaze J, Viney NR, Young WJ, Hennessy KJ and Cai WJ, 2008 *Climate data for hydrologic scenario modelling across the Murray-Darling Basin*. A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project. CSIRO, Australia.

⁹ SEACI – South-East Australian Climate Initiative

- Claydon, G., McDonald, N., Doolan, J., Harten, G., Galligan, D. and Stone, R., 2010. Workshop Outcomes – Climate Change Impacts on the Water Sector, OzWater '10, Brisbane, March 2010.
- Cloke, P.S., 1995. *Sizing of Water Supply Headworks on a Security of Supply Basis*, in Samra, S. and Cloke, P., (Eds) Preprints of Drought Planning and Forecasting Seminar, Sydney, 20 July 1995, Institution of Engineers, Australia.
- Cloke, P.S., 2008. *Water Supply Security: Do the 5/10/20 Secure Yield Rules Fail the 2001-2007 Drought and Climate Change?* Water Management Conference, Local Government and Shires Associations, Ballina 2008.
- Cloke, P.S., Samra, S., 2009. *Impacts of the 2001-2007 Drought and Climate Change on Security of Water supplies in Country NSW*, H₂O09 Hydrology and Water Resources Symposium, Newcastle 2009.
- Department of Water and Energy, 2007. *Best-Practice Management of Water Supply and Sewerage Guidelines*.
- Gill, J., 2008. Sustainable Water Management in A Drying Climate, Lambert, in M., Daniell, T. and Leonard, M., (Eds) *Proceedings of Water Down Under 2008*, Adelaide, 14-17 April, pp. 26-27.
- NSW Office of Water 2010 (1). *2008-09 NSW Water Supply and Sewerage Performance Monitoring Report*.
- NSW Office of Water 2010 (2). *2008-09 NSW Water Supply and Sewerage Benchmarking Report*.
- NSW Public Works, 1986. *Water Supply Investigation Manual*.
- Rhodes, B.G., Tsioulos, C., Tan, K., Baxter, K., and Elsum, G., 2010. Climate Change Adaption - Learnings from a changed Climate, Ozwater'10, Brisbane, March 2010.
- Samra, S. & Cloke, P.S. 2010. NSW Strategy for Addressing Impact of Climate Change on Non-Metropolitan Water Supplies, Ozwater'10, Brisbane, March 2010.
- Samra, S. and French, R., 1988. *Risk and Reliability for NSW Country Town Water Supply Headworks*, Preprints of National Workshop on Planning and Management of Water Resource Systems, Adelaide, 23-25 November 1988.
- Vaze, J. Teng J., Post D., Chiew F., Perraud J-M. and Kirono D. 2008. *Future climate and runoff projections (~2030) for New South Wales and Australian Capital Territory*, NSW Department of Water and Energy, Sydney
- Vaze, J., 2010. Personal communication.

APPENDIX A

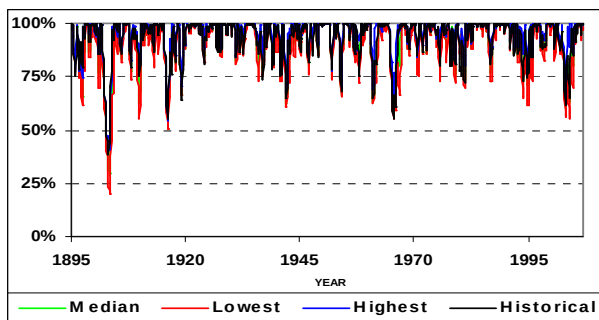


Figure A1: Storage Behaviour Diagram for repeat of years 1895 to 2006 for different climate conditions for Utility 1

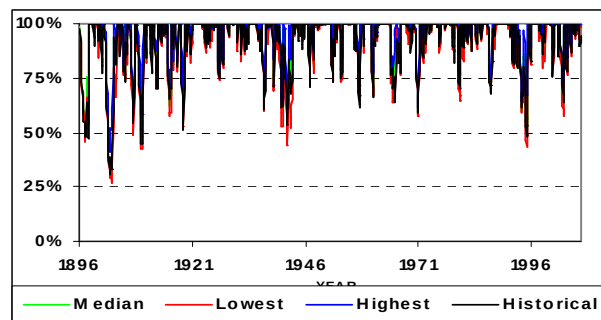


Figure A2: Storage Behaviour Diagram for repeat of years 1896 to 2006 for different climate conditions for Utility 2

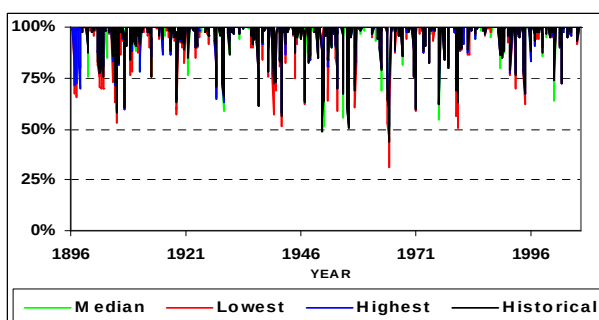


Figure A3: Storage Behaviour Diagram for repeat of years 1896 to 2006 for different climate conditions for Utility 3

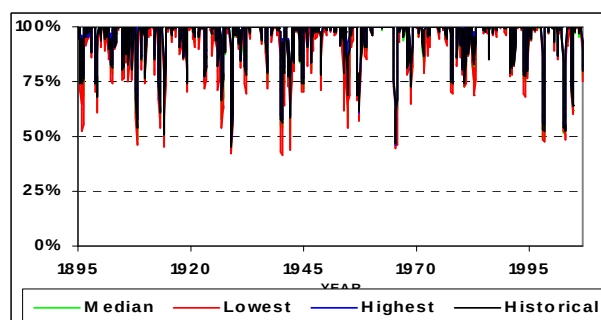


Figure A4: Storage Behaviour Diagram for repeat of years 1895 to 2006 for different climate conditions for Utility 4

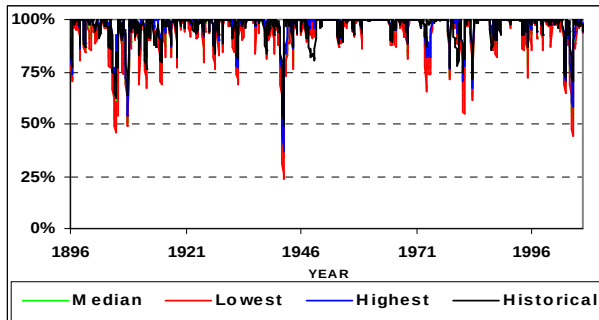


Figure A5: Storage Behaviour Diagram for repeat of years 1896 to 2006 for different climate conditions for Utility 5

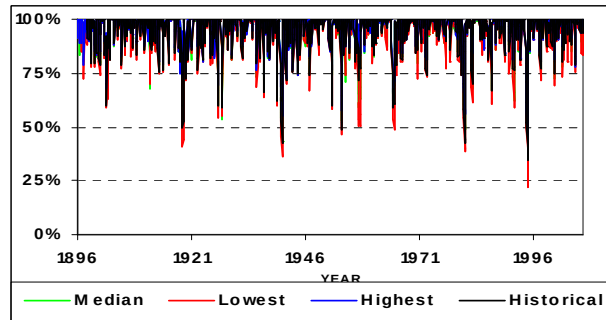


Figure A6: Storage Behaviour Diagram for repeat of years 1896 to 2006 for different climate conditions for Utility 6

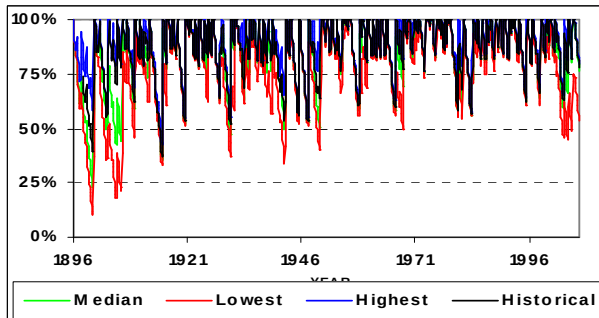


Figure A7: Storage Behaviour Diagram for repeat of years 1896 to 2006 for different climate conditions for Utility 7

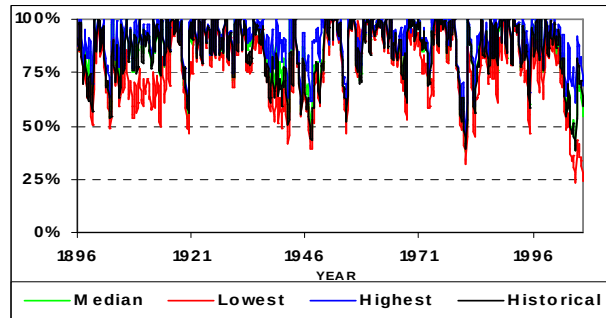


Figure A8: Storage Behaviour Diagram for repeat of years 1896 to 2006 for different climate conditions for Utility 8

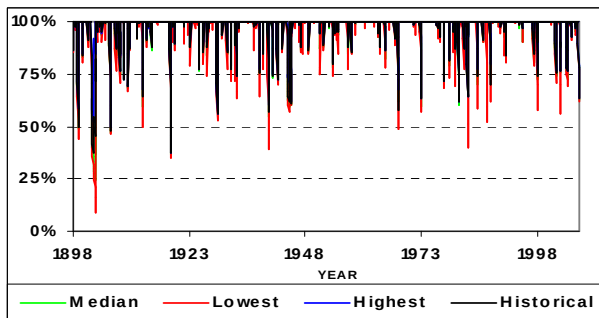


Figure A9: Storage Behaviour Diagram for repeat of years 1898 to 2006 for different climate conditions for Utility 9 – Existing Storage

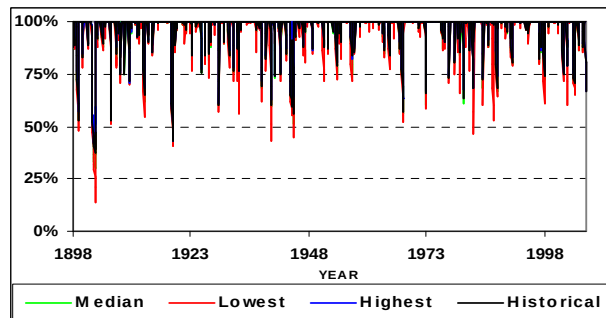


Figure A10: Storage Behaviour Diagram for repeat of years 1898 to 2006 for different climate conditions for Utility 9 – Enlarged Storage

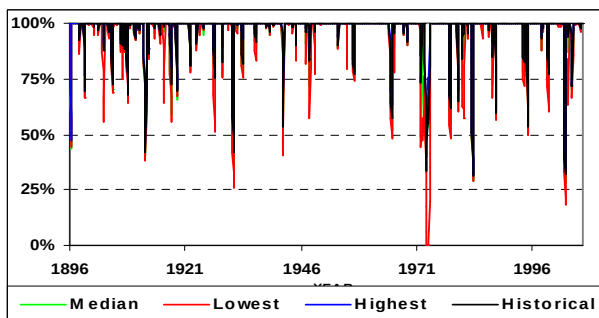


Figure A11: Storage Behaviour Diagram for repeat of years 1896 to 2006 for different climate conditions for Utility 10

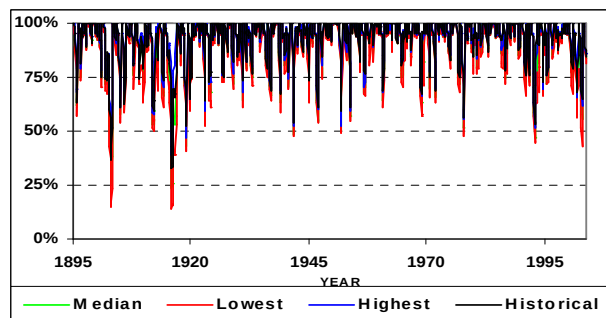


Figure A12: Storage Behaviour Diagram for repeat of years 1895 to 2003 for different climate conditions for Utility 11