Model representation of dry period low inflows to Menindee Lakes System in the Lower Darling River

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Abstract: Inflows to Menindee Lakes are derived from the Barwon Darling IQQM model for the development condition scenario of interest. A comparison of model derived flows with historical data for recent period shows that model overestimates flow during the low flow period and underestimates the periods of no inflows. This paper discusses an approach to reanalyse the model derived inflows to better reflect the cease to flow conditions in the Menindee Lakes system.

The cease to flow periods of the baseline development conditions model scenario were compared with the historical inflows. Comparison was also done against the historical flow records of Darling River main channel at Wilcannia and at Menindee Town gauge for quality assurance. The comparison showed that the modelled inflows to the Menindee lakes under the baseline conditions scenario do not accurately represent the historical data, particularly during the low flow dry periods. The model has low inflows inflated with almost no cease to flow period. Similar discrepancy was found when model flow of Darling River at Wilcannia was compared with the historical record. This suggests that origin of the discrepancy is further up in the Northern Basin and that cease to flow inaccuracy in the Menindee Lakes inflow is a result of cascading effect of the discrepancy propagating down from upper catchments in addition to inaccuracy that the Barwon Darling model itself may have. Considering the project timeframe and the amount of modelling work that would be required in the Northern Basin catchments to properly do it, as an interim measure, an approach to improve low flow estimates and subsequent changes required to the model inflow was developed. This would assist assessment of downstream impacts including Lower Darling local users in a more rigorous manner.

The modified inflows have an improved representation of low flow regime and is statistically similar to the historical data in terms of cease to flow periods while retaining the peak and the long-term average of the model inflows. Source Murray Model was simulated for baseline development scenario and the modelled results before and after the modification of inflows were compared, including evaporation loss in the Menindee Lakes, outflow from Darling system to the River Murray, system dynamics and interaction with upper Murray, entitlement allocation and consumptive use and end of system flow.

In the longer term, the interim fix should be revised and properly addressed by reviewing/recalibrating the models covering the entire Northern Basin catchments and explicitly representing the upstream reach of the Menindee Lakes system from Wilcannia in the Barwon Darling model.

Keywords: *Menindee Lakes inflow, Source Murray baseline development model, dry period low flow, cease to flow periods*

1. INTRODUCTION

The inflows to Menindee Lakes are derived from the Barwon Darling IQQM model for the development condition scenario of interest. A comparison of model derived flows with observed data for recent period shows that model overestimates flow during the low flow period and underestimates the periods of no inflows. An improved low flow estimates and subsequent changes to the model inflow is required to assist assessment of Menindee SDL adjustment project in a more rigorous manner especially for third party impact to local users.

Considering the project timeframe and the amount of modelling work required in the Northern Basin catchments, as an interim measure, an approach is devised to reanalyse the model derived flows to better reflect the cease to flow conditions in the Menindee Lakes system. This paper describes the interim approach and discusses the analysis undertaken for the study, including: (1) comparison of low flows and cease to flow periods of the baseline development conditions model scenario (2009 level of development) with the historical inflows to the Menindee Lakes system and flow records of Darling River main channel at Wilcannia as well as at Menindee Town gauge, (2) development of a fit-for-purpose approach, as an interim measure, to improve representation of low flow estimates in modelling and subsequent changes required to the model inflow to have cease to flow periods similar to the historical data, and (3) simulation of Source Murray Model of the baseline development scenario using the modified inflows and comparison of modelled results before and after the adjustment including assessment of third party effect locally in the Lower Darling as well in the River Murray.

2. BACKGROUND

Darling River system between Wilcannia and Menindee Lakes is dominated by the Darling River channel and Talyawalka Creek. Past studies indicate when the flow downstream of Wilcannia is within the river channel, the Darling River feeds into the Lake Wetherell. Figure 1 shows Lake Wetherell along with Lake Pamamaroo, Menindee Lake and Lake Cawndilla as major lakes of the Menindee Lakes system that also includes a number of other smaller lakes such as Lake Tandure and Copi Hollow. Talyawalka Creek branches out from Darling River at a location upstream of Wilcannia and starts flowing when flow at Wilcannia exceeds ~23,000ML/day. Because of construction of the main weir, Lake Wetherell is surcharged during the flood. So the creek may commence to flow even at lower flow regime at Wilcannia. In large floods, a significant proportion (10% to 40% of flood volume) of a flood flow would pass down the Talyawalka Creek system with much slower travel time than along the main channel of the Darling, by-passing the Menindee Lakes system (Cooke and He, 2008). After traversing floodplains, part of the Talyawalka creek flow would return to the Darling River downstream of Weir32. Therefore the inflow to the Menindee Lakes from the Darling River system is generally estimated using a mass balance of the lakes system including Talyawalka Creek.

During extremely large floods, it may not always be possible to capture all inflows and outflows. Part of flow in the Talyawalka Creek system may escape and never returns to the Darling River. Historical record of inflows to the Menindee Lakes system does not exist. Gauges in the Darling River at Wilcannia and Menindee Town (~260KM river distance downstream of Wilcannia) are the only reliable gauges that existed before the Menindee Lakes system was developed in 1950s (MDBA, 2010). Flow data at Menindee Town is available up to 1960 and at Wilcannia from 1914 onward. Flow data of Talyawalka creek at the Barrier Highway is available from 1971 onward.

Combined flow at Wilcannia and the Barrier Highway, as an approximation of inflow to the lakes system, is used as a guide to back-calculate estimates of total inflow by applying a simple water balance approach in the Lakes system when storage volume, rainfall and evaporation data are available. In this study, the inflow calculated based on water balance of Lake Wetherell is used as historical inflow. In the Basin Plan study, end of system flow from the Barwon Darling IQQM model was used as inflow to the Menindee Lakes system. It is used as the model inflow for this analysis.

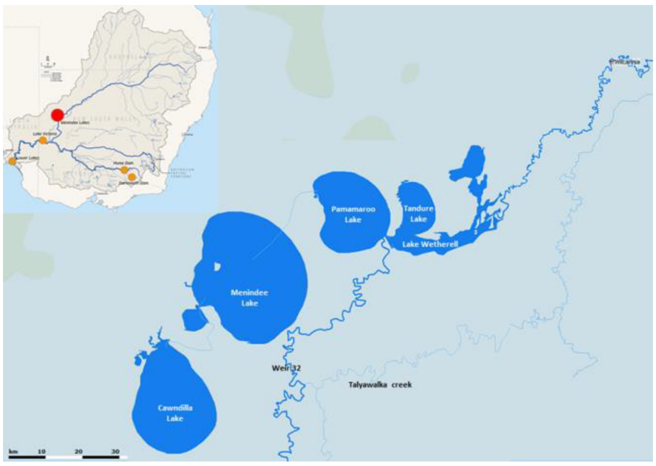

Figure 1. Menindee Lakes System

2.1. Comparison of model inflow with historical inflow

Table 1 provides a summary of percent days inflow to the lakes is below certain thresholds for different time periods for baseline development model scenarios (before and after adjustment), comparing against the historical data that is available. The table shows model inflow has a substantially low cease to flow (ie less than 1ML/d) period compared to the historical inflow and the Darling flows at Wilcannia and at Menindee Town gauge. This is consistently the case with all the time periods under study. For example, for 1914 – 1949 period before the commencement of the lakes development scheme, baseline model shows ~0.3% days of cease to flow (compared to ~10% days of historical flow at Wilcannia and Menindee Town). This means that Darling River would have been much drier than what baseline development model is suggesting.

A probability distribution of model inflow (both before and after adjustment), and historical inflow is provided in Figure 2 including the Darling flows at Wilcannia. For 1979-2009 period, historically Menindee Lakes receive no (or negligible) inflow for ~25% of days whereas model inflow suggests just 0.4% of days (Figure 2a). For drier period, the discrepancy is even greater. For example, for the drier 2001 - 2009 period historically there has been a cease to flow period of ~51% days compared to 0.3% days as suggested by the model inflow (Figure 2b). Historically this dry period corresponds to ~70ML/d flow at Wilcannia (Table 1), which is probably the minimum flow at Wilcannia needed for sustaining longitudinal flow connectivity in the Darling River to the Lake Wetherell.

Additionally, baseline model represents 2009 level of development conditions while historical data at Wilcannia covers transitional changes due to increased development over time. So in theory, the baseline model should have more cease to flow period than what is the historical data is suggesting. Clearly the model's representation of low flow regime and zero flow period is very poor. Similar discrepancy is found when the model flow of Darling River at Wilcannia is compared with the historical records.

Table 1. Comparison of flow periods (% days) for various low flow range

Period	% of days flow less than the below threshold (ML/d)						Flow (ML/d)	
	1	10	20	40	60	80	mean	max
1895 – 2009								
Baseline model inflow*	0.2%	0.5%	0.7%	1.6%	3.3%	5.6%	4,718	137,890
Adjusted baseline inflow	24%	24%	25%	25%	25%	25%	4,718	137,890
1914 – 1949								
Baseline model inflow	0.3%	0.6%	1.1%	2.4%	5.1%	8.4%	2,900	70,725
Historical Flow at Wilcannia	10%	10%	11%	12%	13%	13%	5,261	52,405
Historical Flow at Menindee Town	10%	12%	13%	15%	16%	17%	5,109	90,280
1979 – 2009								
Baseline model inflow	0.4%	0.9%	1.1%	2.8%	4.7%	7.4%	4,204	~54,730
Adjusted baseline inflow	25%	25%	25%	25%	25%	26%	4,204	~54,730
Historical inflow^	25%	26%	27%	28%	30%	31%	4,410	~68,150
Flow at Wilcannia	10%	14%	15%	17%	19%	21%	4,659	~47,950
2001 – 2009								
Baseline model inflow	0.3%	0.8%	1.0%	3.4%	7.9%	14%	1,034	~23,070
Adjusted baseline inflow	51%	51%	51%	51%	52%	52%	961	~23,515
Historical inflow^	51%	54%	56%	58%	61%	64%	726	~15,570
Flow at Wilcannia	29%	40%	43%	46%	50%	53%	895	~19,600

^ Historical inflow represents estimates of inflows derived from Lake Wetherell water balance.
* Baseline model inflow to the Menindee Lakes is based on baseline development model (run #871 from 1895 to 2009).

Figure 2 shows the model has inflated low flow regime at Wilcannia (<200ML/d) with no cease to flow period. Therefore origin of the issue of underestimation of cease to flow periods is further up in the Northern Basin and discrepancy has been propagated down from the Barwon-Darling system with cascading effect to the Menindee Lakes inflow.

It is beyond the scope of this study to correct this issue in the Northern basin given the project timeframe and the amount of modelling work that would be required in the Northern Basin catchments to properly do it. Therefore an interim approach has been devised to make the Lower Darling model more appropriate for assessing the Menindee SDL adjustment project.

3. DROUGHT ADJUSTMENT OF MODEL INFLOWS

3.1. Method applied for adjustment of inflows

As discussed above, the model inflow sequence to the lakes is unrealistic, particularly for the low flow regime during the extended drought. The model portrays the Darling River as perennial and is almost always flowing to the lakes. This underestimates the length of no flow period when in drought as the Darling system goes through a drying cycle and does naturally dry up time to time.

As a corrective measure, the model inflow sequence was adjusted by incorporating the no flow days to the lakes by simulating model inflows through an artificial weir upstream of the Lake Wetherell. Water in the dead storage of the weir is lost through evaporation and seepage. The inflow to the lake ceases until the artificial weir is full. When the flow is passed through an artificial weir, the resulting flow downstream of the weir would either completely disappear or be reduced due to losses including initial loss due to dry river bed.

There are two main parameters of the artificial weir that can be adjusted or calibrated to best match historical behaviours. These parameters are maximum storage volume (dead storage) and surface area of the weir. Instead of adjusting the two parameters, the size of the weir’s dead storage volume is determined from an analysis of Darling River flows between Wilcannia and Menindee Town for a period between 1914 and 1949. During an extended drought condition, the Darling River bed downstream of Wilcannia is expected to be dry. Under this dry-bed condition, the in-channel flow passing Wilcannia would be initially lost due to in-channel filling and seepage and evaporation. These initial losses of Wilcannia flow are aggregated until a dry spell is broken and the river re-commences to flow at Menindee Town gauge. Analysis indicated that the initial loss would vary and could be in the range of 30 to 40GL. The average (~36GL) was used as a dead storage for the artificial weir.

Then surface area of the weir was calibrated to statistically generate zero flow days similar to the historical inflow sequence. When different options were trialled for calibration period (1979 – 2009 per historical data availability), a surface area of 3,600ha was found to result similar no flow days to historical inflow sequence. For completeness, the calculation was extended back to 1895 to cover the entire modelling period.

3.2. The adjusted model inflows

Due to losses in the weir, the model inflow is reduced on average by ~17GL/y for 1895–2009 modelling period. To retain the long term mean and peak values per the model before adjustment, the modified data is scaled up by a factor (1.02). Due to adjustment of low flows in the dry period, the median is reduced.

The model inflows before and after the adjustment are compared, which shows the modified inflow now has a similar cease to flow period as the historical inflow.

The adjusted model inflow has accurately reflected cease to flow days for both 1979-2009 period (~51% days) and drier 2001-2009 period. Hence the underestimation of zero flow days is removed when the artificial weir was assumed to be in place.

Figure 2 shows there are some flows in the 500 to 3,000ML/d range that are still elevated. These flows are either too high for the size of the artificial weir to have adequate corrective effect or the loss rate is too low for the nature of the drought in this period. This is because losses during extreme and extended dry period could be unusually higher than the generalised loss rate used in the calculation as the prolonged dry river bed tends to form cracks and sink holes that leads to exponential increase in the initial loss. The data may also be indicating that there are other unknown model errors being propagated from the reaches upstream of Wilcannia including models of catchments further upstream, investigating which is beyond the scope of the study.

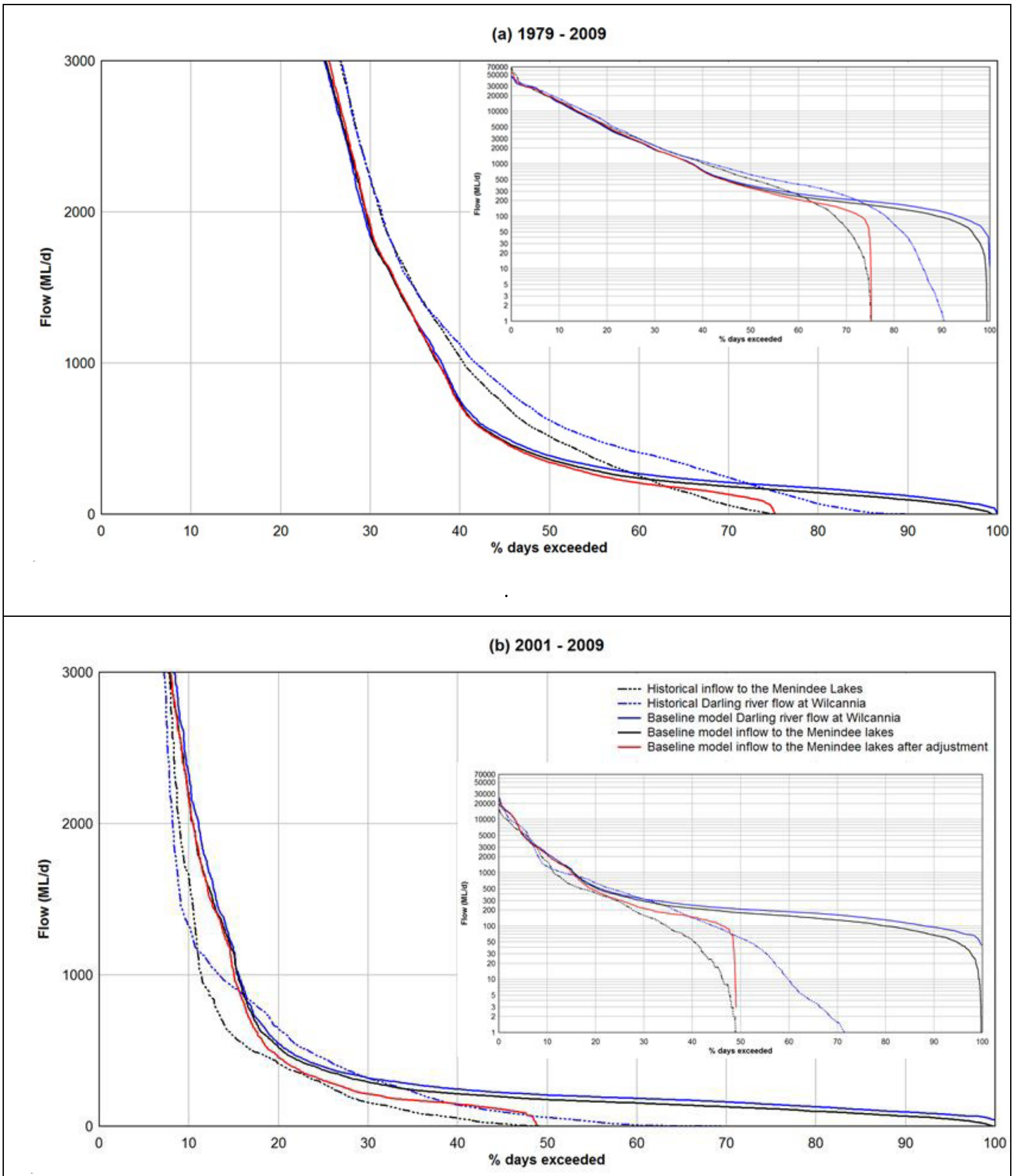

Figure 2. Comparison between baseline model and historical inflow to the Menindee Lakes including Darling flow at Wilcannia: (a) 1979 – 2009 period, (b) 2001 – 2009 period. Note graph in the inset is in log-scale for clarity on low values as well as to capture minimum and maximum range.

Figure 3 provides time series of inflows before and after the adjustment for the whole modelling period (1895–2009). After the adjustment, the low flows are consistently reduced to a lower flow regime with median reduced from 502ML/d to 484ML/d. The mean (4,718ML/d) and the maximum (137,890ML/d) for the modelling period are maintained.

4. MODEL COMPARISON

Source Murray Model was simulated for baseline development scenario and the modelled results before and after modification of inflow were analysed and compared with respect to allocation of water entitlements, diversions for consumptive use, system losses and flows at key locations.

As a result of adjustment of inflows, Lower Darling allocation is corrected down by ~2% on average. This was because the baseline model, due to inflated low inflows, overestimated available water resources during the dry period leading to over allocation of water entitlements for diversions. Annual diversion for July to June water year is reduced by ~1.1GL/y compared to the baseline model and is closer to the historical record. There are big changes in diversions on some years even though the average change is small. This may be due to assumed temporary trades that are only allowed when the lakes are under MDBA's control, no longer occurring with the drought adjusted inflow. Having less inflows during the dry period means lower storage volume that leads to the lakes being more under NSW control (greater chance of falling below 480GL to transition from MDBA to NSW control or if already under NSW's control, less chance of rising above 640GL to transition to MDBA control) so the less opportunity for trading.

A comparison of model annual diversions before and after the adjustment of inflow for the whole modelling period (1895 – 2009) shows the diversions have reduced after the adjustment. For the millennium drought, they are reduced to be closer to the historical record, after the adjustment of inflows.

Evaporation loss from the Menindee Lakes system is reduced by ~5.3GL. This is due to relatively less water available during the dry period because of removal of inflows in the lower range while incorporating cease-to-flow period (25th percentile inflow is reduced by 104ML/d to 71ML/d and Median by 18ML/d to 484ML/d) So the evaporation, in this case, is resource limited hence less. An equivalent volume that is removed from the lower flow range is added back by scaling up the adjusted inflow time series so as to retain long-term average and water balance. This slightly pushes values up in the high inflow range (75th percentile inflow is up by 48ML/d to 3556ML/d and 90th percentile by 263ML/d to 14,437ML/d). This causes a slight increase in spill from Lake Wetherell which leads to an increased flow at Weir32 during the wetter period (~7GL/y on average). Similarly, average flow at Burtundy is increased by ~6GL/y. The increased flow pushes system losses up by ~1GL. Overall on the balance, the reduced loss and less diversion together result a net increased outflow of ~5.8GL to the River Murray system.

Adjustment of Menindee inflow changes River Murray system dynamics slightly. As a follow on effect, system losses in the upper Murray increases slightly by ~0.5GL while the diversion decreases by ~5.4GL on average. This is probably due to the reduced supply of regulated releases from the Menindee Lakes to the River Murray system as the low inflows during the dry period are adjusted down. Overall, the increased contribution from the Lower Darling and the decreased diversion in the upper Murray results an increased flow (~10.8GL/y) to South Australia, which in combination with reduced diversion in South Australia (~1.4GL) result an increased flow of ~11.6GL/y over the Barrages on average.

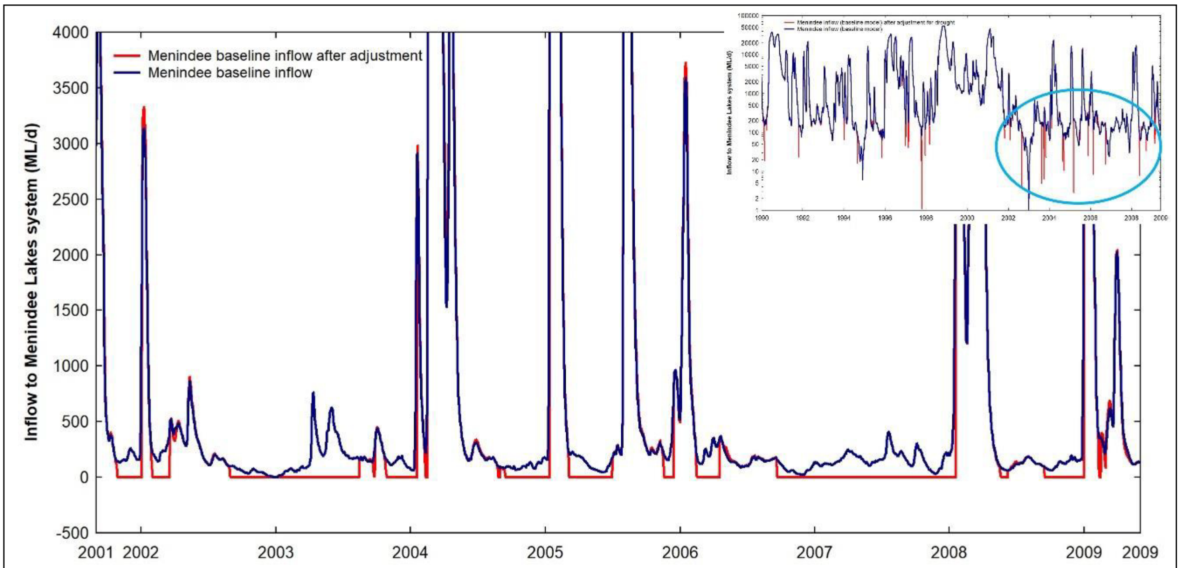

Figure 3. Comparison of baseline model inflow before and after the adjustment: showing 2001-2009 modelling period as an example from the inset of 1990-2009 period which is a sub-set of the whole modelling period (1895 – 2009)

5. DISCUSSION AND CONCLUSION

Inflows to Menindee Lakes are derived from the Barwon Darling IQQM model for the development condition scenario of interest. A comparison of model derived flows with historical data for recent period shows that model overestimates flow during the low flow period and underestimates the periods of no inflows. This paper discusses an approach to reanalyse the model derived inflows to better reflect the low flow conditions in the Menindee Lakes system.

The cease to flow periods of the baseline development conditions model scenario were compared with the historical inflows. Comparison was also done against the historical flow records of Darling River main channel at Wilcannia and at Menindee Town gauge for quality assurance. The comparison showed that the inflows to the Menindee lakes under the baseline conditions scenario do not accurately represent the historical data, particularly during the low flow dry periods. The model has low inflows inflated with almost none cease to flow period. Similar discrepancy was found when model flow of Darling River at Wilcannia was compared with the historical record. This suggests that origin of the discrepancy is further up in the Northern Basin and that cease to flow inaccuracy in the Menindee Lakes inflow is a result of cascading effect of the discrepancy propagating down from upper catchments. Considering the project timeframe and the amount of modelling work that would be required in the Northern Basin catchments to properly do it, as an interim measure, an approach to improve low flow estimates and subsequent changes required to the model inflow was developed. This would assist assessment of Menindee SDL adjustment project in a more rigorous manner especially for third party impact to local users.

The interim method consisted of an artificial weir upstream of Lake Wetherell to improve model representation of low flow regime. Surface area of the weir storage was calibrated so the dry period of the resulting flow through the weir would be statistically similar to the cease to flow period of historical data (~25% of days during the 1979-2009 calibration period and (~51% of days during the 2001-2009 Millennium dry period) while retaining the peak and the long-term average of the baseline model inflow.

Source Murray Model was simulated for baseline development scenario and the modelled results before and after modification of inflow were compared. The comparison showed that with more accurate model representation of low flow regime, there would be relatively: (1) less evaporation loss in the Menindee Lakes due to reduced low flows, (2) less allocation of water and hence the reduced diversions in the Lower Darling, (3) less lower flow to the system also decreases distributable water resources in the Murray system leading to decreased Murray diversions and more water being sourced from Upper Murray, and (4) more flow to South Australia and over the Barrages.

Note that the concept is simple, and the approach is pragmatic and transferrable to other situations where a conceptual approach is required to modify model outputs. It is however acknowledged that the method is conceptual, not physically based, and every time the upstream data is modified (i.e. inflows from tributary models) or representation of processes in the Barwon Darling are changed, the conceptual storage would need to be re-calibrated. Also, the conceptual storage would have an impact on routing of small to medium flows, which may have follow-on effect on the timing of the peak as well as the shape of the hydrograph of the inflows to the Menindee Lakes system. However, this effect is expected to be minimal with the low flows during the drought period, which is the focus of this study.

Despite the limitations noted above, the approach was chosen as a temporary fix because of its simplicity and practicality. In the longer term, the approach should be revised and properly addressed by reviewing/recalibrating the models covering the entire Northern Basin catchments and explicitly representing the upstream reach of the Menindee Lakes system from Wilcannia in the Barwon Darling model. In the meantime, this interim approach could be used for revising Barwon Darling IQQM model derived inflow sequence under other scenarios too. This would lead to a more rigorous and robust assessment of third-party impacts during dry period.

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REFERENCES

Cooke, R. and He, H. (2008). Wilcannia – Menindee Modelling. Calibration of IQQM model for routing of flows and salinity from Wilcannia to Menindee Lakes, NSW Department of Water and Energy, Parramatta, March 2008.

MDBA (2010). River Murray System operations reference manual. Murray-Darling Basin Authority (MDBA), Nov 2010.