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Submission to the Senate Parliamentary Enquiry

The Management of the Murray Darling Basin

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1. About DHI

DHI is an independent, not-for-profit international research and consulting with offices in over 25 countries including a long term presence in Australia. Our objectives are to advance the technological development and competence within the fields of water, environment and health. DHI has been designated an Advisory Centre for the Global Water Partnership, Collaborating Centre for United Nations Environment Program and the World Health Organization.

DHI is world renowned as the developers of the MIKE suite of advanced water models focused on hydrological, hydraulic and ecological processes. In Australia DHI have been active as a supplier of advanced water modelling software to the government and private consulting sectors for over 25 years. Our MIKE 11 and MIKE FLOOD river modelling systems are the de-facto standard for river flood and hydraulic studies in Australia, and have underpinned many of the ecological studies that have been carried out as part of the Living Murray Program, and applied in hundreds of other hydraulic and river flow studies across the nation. DHI's MIKE SHE integrated hydrological model is the world's most advanced and integrated hydrological model with more than 25 years in development. Through many independent reviews it is regarded as the only model to comprehensively account for all processes in connected surface-groundwater systems. The model has recently been adopted by the Department of Water in Western Australia for integrated catchment modelling in that state because of its unique ability to accurately model the interaction between surface and groundwater. Because of the many years of on-going developments in our models, we are seen by many as industry leaders in the modelling of rivers, floodplains, groundwater systems and environmental hydraulics.

2. Overview

We congratulate the MDBA's efforts in attempting to undertake, for the first time, an assessment of environmental and key ecosystem water requirements for the entire Murray Darling Basin. While the report states that the best available science has been used in formulating the plan, this needs to be considered in the context of the time given to MDBA to formulate a Plan of this scale, which has not been undertaken anywhere else in the world. The extremely tight timeframe for the delivery of Basin Plan has meant that MDBA has turned to readily available models for the core hydrological assessments. Consequently the Plan represents the application of the best, readily available models and tools that could be applied in a short time frame. It must be recognised that timeframes for delivery have constrained the range of models and investigations that could have been undertaken.

In developing the final Sustainable Diversion Limits (SDLs), it is imperative to reduce or constrain the current uncertainty in the recommended environmental flows, which at present are as high as +/- 20%. MDBA admits that the much of the source data has not been validated or subjected to peer review (Vol 2 p86). As hydrological models have been used to quantify most of the SDLs, it follows that the integrity of the modelling framework and the data used must be a prime consideration if the current high levels of uncertainty in the Basin Plan recommendations are to be reduced.

The release of the Basin Plan has led many to question some of the key findings, which, if implemented, will significantly impact rural communities across the entire Basin. It is incumbent on the Government to allow the MDBA the time needed to apply a true world's Best Practice approach to the Plan, so that the desired environmental and ecological outcomes can be confidently linked to changes in the river flow regimes. This requires the application of more advanced modelling tools than have been utilized to date. In particular the application of true integrated surface-groundwater models to close the Basin water balance is required. In addition, the use of hydraulic models is necessary and lacking in the current plan. Hydraulic models are necessary to assess the changes to flood extents and depths at the 106 key environmental sites and thereby provide a link to the eco-hydraulic outcomes that the plan is attempting to address The current hydrological models are not able to fully link the changes in flow regime to ecological outcomes and this leads to further uncertainties in the SDL estimates.

Our submission is intended to promote a discussion on the modelling approaches that could and should be adopted in order to provide maximum confidence in the hydrological and hydraulic assessments. It is not our view that the work undertaken to date needs to be rejected as it represents a solid and well executed body of work that has enhanced the understanding of the Basin environment. However gaps are apparent, and we believe that pause is needed to address these and reduce the levels of uncertainty inherent in the current SDL recommendations.

Our comments are based on our position as a leading international developer of advanced modelling tools, and from extensive experience gained in the application of these tools to many hundreds of applications in Australia and around the world.

3. Suitability and Review of the Surface Water Models

The surface hydrological models used in the Basin Plan are based on 24 existing State jurisdiction river-system models, which have been linked together to represent the Basin hydrology and water sharing arrangements. Groundwater assessments, carried out separately, have been undertaken using 11 existing groundwater models.

The surface water models were originally developed by the State jurisdictions and then further refined as part of the CSIRO Sustainable Yields Project. Different Australian developed model platforms are used, reflecting the division of water policies between the States and Commonwealth over the past decades: IQQM in NSW, REALM in Victoria and Big-MOD on the River Murray. The models are essentially of the same type, and are basically water accounting tools (rather than hydraulic models as such) with varying degrees of empirical conceptualisation of key catchment processes, including catchment runoff, flow routing, weir and dam storages, dam operations, floodplain inundation, evapotranspiration, groundwater recharge and stream base flows, to name a few.

The MDBA Guide states that it has used best available science in the determination of SDLs for the Basin, and that this has been confirmed by a panel of international reviewers. Modelling underpins the findings of the Basin Plan, however it is not (yet) clear whether the international panel included persons with high levels of expertise in modelling, or whether the models, which are not in widespread use outside of Australia, have been subjected to an international peer review and designated as “fit for purpose” for the Basin Plan. It is also important to ensure that the peer reviews are truly independent. The water modelling industry is very small at the global level. It is important that the review is done in a truly independent way or it may be subject to rebuke in a similar way that the global climate change debate was undermined because of a lack of independence between the proponent and the reviewer. We understand that MDBA will be releasing model review documents that will provide objective evidence of the rigour applied to the determination of the SDLs and we look forward to their release.

Recommendation: The models utilized in the determination of SDL’s are internationally peer reviewed by independent modelling experts to ascertain their fitness for the requirements of the Basin Plan.

4. Addressing Uncertainty in the Modelling – Learning from the Climate Change Debate

There are two main sources of uncertainty in the surface water hydrological modelling undertaken for the Basin Plan:

i. Uncertainty in the model input data, which has been assigned a medium level of confidence by the MDBA
ii. Uncertainty in the models themselves (model structure and parameters), due to the high degree of conceptualisation in the model processes

These uncertainties translate to significant uncertainties in the model outputs. This means when comparing one scenario (such as the without-development scenario) to a SDL scenario, the uncertainties in each model prediction can cloud the apparent conclusions drawn from the comparison. For example it may mean that when testing a scenario to reduce diversions by 25%, the comparison with the non-development case may in reality be inconclusive as the uncertainty in each model is of the same order as the reduction in flows.

Uncertainties can be handled in a number of ways. Data uncertainties can be quantified by varying model inputs within statistically realistic bounds and analysing the sensitivity of the model outputs. Model parameter uncertainties can be addressed in a similar way.

Model structure uncertainties (due to the way a model has been conceptualised) on the other hand can be addressed through what is termed a “multi-model ensemble”, a technique adopted by meteorologists and exemplified in the climate change debate. Meteorological organisations commonly use an “ensemble” of models, each driven by the same physical data but, due to the differences in the way each model describes the physical processes, producing different weather forecasts. The Bureau of Meteorology for example utilizes the results of nine different meteorological models to produce the daily weather forecasts for Australia. The use of ensemble modelling to constrain the inherent uncertainties in different models has most recently been used in the climate change debate. The IPCC provides results from 21 different global circulation models for understanding the uncertainty in climate change projections and to define the most likely outcomes from given changes to greenhouse gas emissions. The same approach has also taken root in the hydrological community and is being used for example overseas for flood forecasting (Butts et al. 2004a, Butts et al. 2004b, Butts et al. 2005). A similar approach could successfully be adopted for the Basin Plan, so that the final recommendations are based on a consensus of different modelling approaches. In fact MDBA has adopted this approach for the economic analyses of the Plan. (Vol 2, p132) and it would be reasonable and appropriate that a similar approach is applied to the hydrological modelling.

Recommendation: The MDBA give due consideration to the adoption of a multi-model ensemble approach to better understand the uncertainty in the SDLs.

5. Closing the Water Balance: Fully Integrated Modelling of the Basin

The modelling that has been undertaken to date is piecemeal and relies on a total of 35 different surface and groundwater models, with groundwater-river linkages invoked in only a quite superficial way. In order to build up a picture of the entire water balance in the Basin, it has been necessary to manually exchange flows between the different surface models as well as make an independent assessment of the surface water recharge to the groundwater models, and baseflows from groundwater systems to rivers and streams. Closing the water balance, ie accounting for all of the water in the system, is therefore difficult and uncertain within the present modelling framework.

Identified shortcomings in the current approach are:

- The Plan has undertaken a separate treatment of surface and groundwater resources (ie separate SDLs have been developed for surface water and groundwater), despite more than 60% of groundwater systems in the Basin having been assessed as being highly connected to surface-water (Vol 2, p116).

- The impact of groundwater extractions on streamflow is one of the key uncertainties in determining Basin water resources (Vol 2, p42). MDBA state that the separate management of surface-water and groundwater resources in the past has often led to the same resource being counted twice.

- Basin recharge to groundwater estimates have been based on a separate recharge model (WAVES) which has been applied basin wide to compute diffuse recharge rates. It is unclear to what degree the WAVES model has been calibrated, and therefore what level of confidence can be placed in the recharge estimates. WAVES was not calibrated for the Murray-Darling Basin Sustainable Yields project, and it is unclear whether the model has been updated following a recent more rigorous approach which was applied to the Tasmanian Sustainable Yields project (Crosbie etc al, 2009)

- It is unclear how base flows from groundwater systems to rivers have been accounted for in the current modelling framework as these models are not integrated. It is understood from the MDB Sustainable Yields project that the linkages were simplistic (eg. output from one model used as input to another in a sequential approach), and not iterative, as would be required to achieve scientific rigour.

- The models do not account for the all diversions in the Basin. Diversions from unregulated rivers, and interceptions by farm dams and forestry plantations are not explicitly included in the hydrological models. These account for 20% of total diversions.

- Forestry plantations intercept both surface and groundwater, however the rainfall/recharge interception has been dealt with under the surface water SDLs only; this further enhances the potential for double counting when interception is considered as part of the groundwater models. In addition changes in run-off yield have not been considered in cases where commercial plantations replace native forests, although water usage may be considerably higher.

- Salinity is a major issue in the Basin and is highly dependent on recharge to the groundwater and leakage back into the river systems. Separating surface water, recharge and groundwater models increases the uncertainty in model predictions of salinity transport in each regime.

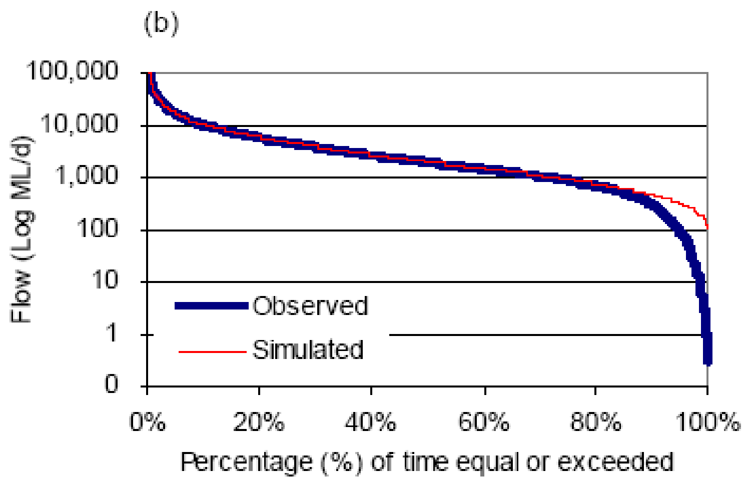
It is possible to reduce these uncertainties through the application of an integrated surface-groundwater model. Fully integrated commercial models have been available for some time (Middlemis 2004, Rassam and Werner 2008,) and have been used both in Australia and overseas. For example fully integrated approaches have been used in several rivers in the Northern Territory and adopted for the Northern Australia Sustainable Yields project for CSIRO. In addition the Western Australia Department of Water (DOW) has adopted an integrated model as the main decision support tool to assess land developments in the south east of the State where strong surface-groundwater interactions exist (Hall, 2010).

Application of a fully integrated model on the scale of the Basin would however be unprecedented. Nonetheless as MDBA point out the development of the Basin Plan itself has not been attempted before on a scale the size of the Murray Darling before. There is no reason why a fully integrated surface-groundwater model of the Basin could not be developed, possibly as one of an ensemble of models, as described above. There is no need for MDBA to develop model codes to handle this task, as well proven commercial codes are already available which have a track record of successful regional scale application.

Recommendation: MDBA consider the use of an integrated hydrological model as part of a multi-model ensemble modelling approach for the Basin.

6. Model Calibration and Quantifying Environmental Water Requirements

The surface water hydrological models used in the Basin Plan have been calibrated against indices that are not directly related to the key outputs used for determining the environmental water requirements. The hydrological models have been calibrated against a so-called Nash-Sutcliffe coefficient of efficiency, for flow duration and annual flow volumes. Examples are shown below for the Upper Murrumbidgee where the focus was on inflows to Burrinjuck Dam. (Gilmore, 2008)



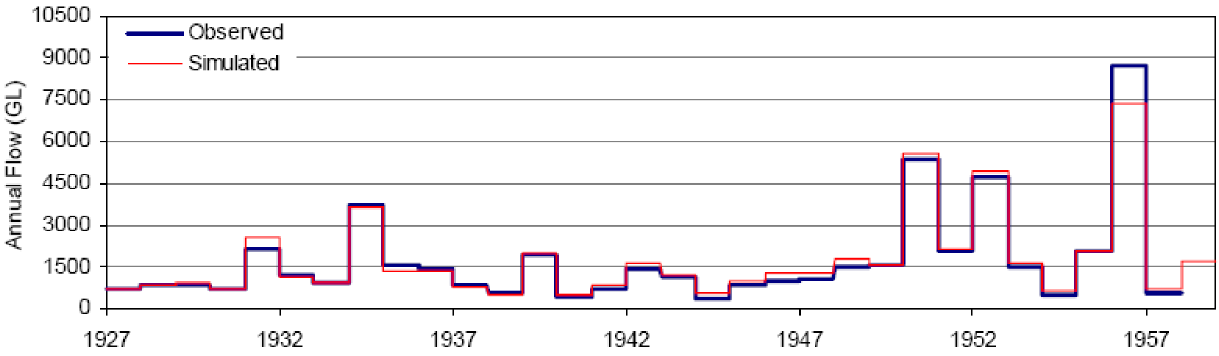


Figure 1 Calibration results for the Upper Murrumbidgee model (CSIRO, 2008)

In this case the models tend to over-predict low flows (shown by the top curve) but underestimate a wet year in 1955 (bottom plot). However the extent of over or under-prediction cannot be ascertained. The calibration was considered to be good as the overall volumes matched with the data. However the environmental assessment is based on durations of flows above certain thresholds. For example to maintain 70% of the mid-Murrumbidgee wetland in good health, the following flows are required:

a) 26,850ML/day for 5 days, between Jun-November, in 60% of years (low uncertainty)
b) 35,650ML/day for 5 days, between Jun-November, in 40% of years (low uncertainty)
c) 44,000ML/day for 3 days, between Jun-November, in 35% of years (low uncertainty)
d) 63,250ML/day for 3 days, between Jun-November, in 15% of years (low uncertainty)

As these are the key outputs from the model it is important to ascertain that the models can in fact reproduce these types of short duration variations in the past. The current focus of model calibrations only on overall flow durations and annual flow volumes does not meet this requirement.

Recommendation: Models to be calibrated against indices relevant to the intended use of the model.

7. Quantifying the Ecological Response

SDLs have been based on defining flows for at 18 hydrologic indicator sites for key environmental assets and 88 sites for key ecological functions. Environmental and ecological health has been assumed if the end of system flow targets are met. However there is no direct linkage to specific environmental outcomes (such as a certain fish population parameters, vegetation health indices etc) and the flows which have been defined. Important information, such as floodplain levels, river velocity, inundation areas and depths cannot be accurately defined at present due to the limitations of the hydrological models that have been applied. Detailed studies at a number of the 18 environmental asset sites have been undertaken for the Living Murray programme and for DECCW where 2-diminesional hydrodynamic models have been used to accurately quantify these parameters. Hydraulic models accurately simulate real river behaviours, such as hysteresis where floods on the rising part of a flood convey more flows than on a falling flood (Tuteja, 2009). This behaviour, which cannot be simulated in a hydrological model, may affect the total volume of flow needed to inundate a wetland for example, and therefore affect the SDL. In the case of Koondrook, the hysteresis effect appears to have been parameterised and included as in the hydrological model. However only a small number of the indicator sites used to determine the SDL's have been modelled using a detailed hydraulic approach.

The detailed river response behaviour simulated in a hydraulic model can also be fed into ecological response models. A hydrodynamic model can, for example, inform on the duration of a specific flow speed and depth on the floodplain, which may be important for fish breeding and migration.

Recommendation: More of the 106 key environmental sites are subjected to detailed hydraulic modelling so that ecological effects can be more accurately quantified.

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