JOINT SUBMISSION TO THE PRODUCTIVITY COMMISSION 'MURRAY-DARLING BASIN PLAN: FIVE-YEAR ASSESSMENT'

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16 April 2018

We welcome the opportunity provided by the Productivity Commission to make a submission to the enquiry. In this submission we address three issues, namely: 1) water accounting; 2) environmental monitoring and 3) the importance of independent, transparent peer review of the science underpinning the Basin Plan.

All three issues are central to the terms of reference of the inquiry, in particular those relating to "the extent to which the current framework for implementing the Basin Plan, including the framework for monitoring, compliance, reporting and evaluation, is likely to be sufficient."[1]

In a separate join submission, with other contributors, Grafton provides a response to the terms of reference in relation to economic modelling that has informed the MDBA. In reference to the request for information on cost effectiveness, the Commission is advised to consult Grafton and Wheeler (2018), which has full details.[2] In this publication, the authors show that the cost of water recovery, based on the MDBA's own estimates, for subsidies of on-farm and off-farm irrigation is, on average, 2.5 times more per ML than the cost of the direct purchase of water entitlements from willing sellers. Depending on assumptions about the effects of increases in irrigation efficiency on recoverable return flows (see Item 1 below) the cost per ML from irrigation could be infinite as the net volume recovered for the environment may be zero, or even negative.

1. WATER ACCOUNTING: Hydrological analysis and modelling of water flows under irrigation

A comprehensive, robust, rigorous and transparent water accounting framework is a fundamental requirement for the effective implementation of the Basin Plan. Such a framework underpins trade-off decisions required to reset the balance between the environmental health of rivers and groundwater systems and the consumptive use of water in the Basin. Such water accounting must be built on quantitative hydrological analysis and modelling tools that can describe all the water flows under irrigation, at scales from catchment to whole-of-Basin. These tools must be able to show that mass is conserved (that water in the system is consistent with the Law of Conservation of Mass, i.e. it is not created or destroyed). Hydrological measurements, coupled with various modelling tools which can describe reliably the flows of water in an irrigated landscape, are essential to inform water management and water sharing arrangements in the Basin Plan, including estimates of water security and supply, sustainable diversion limits and environmental water recovery targets. The model tools currently used are considered by the Murray-Darling Basin Authority (MDBA) to be the 'best available' and 'fit-for-purpose'. Further, the MDBA claims that most of its river system models have been rigorously peer reviewed and accredited, but also acknowledges that hydrological analysis and model input variables "contain assumptions and elements of uncertainty, model results must be considered in conte[x]t and using expert knowledge."[3]

The MDBA has repeatedly claimed that the Basin Plan, and its underpinning modelling frameworks, are based on the 'best available science', as required under the Water Act and the MDBA's strategic goal of "improving the knowledge base to support sustainable water resource management."[4] The implication is that MDBA staff and their State agency counterparts who are responsible for water accounting frameworks and hydrological models are using the best available evidence and data as inputs to those models, and "making sure the best available knowledge and information was being used to constantly monitor, evaluate and improve Basin Plan outcomes."[5]

Here we highlight major uncertainties for key water accounting components which are critical to the fundamental understanding and computation of water recovery for the overall management of the hydrological systems of the Basin. These uncertainties have been known for some time, but their persistence in a range of reports (cf. below) indicates a lack of improvement in the adequacy of water accounting and knowledge of water flows, contrary to assertions by the MDBA.

(i) Return flows from irrigation

Improved irrigation water efficiency is a desirable outcome of water reforms, leading to increased food and fibre production and profitability for irrigators. Nevertheless, the view that increased irrigation efficiency will result in more water savings that could be used for environmental purposes is fundamentally flawed. Such an assumption holds only in particular conditions, including a requirement that there are reductions in water diversions.[6] In fact, improvements in irrigation efficiency have, typically, not led to overall water savings that are available to be reallocated.[7]

Absence of information on return flows from irrigation was noted in passing as a research need in the 2017 Productivity Commission draft report on National Water Reform, based on a submission from the Australian Academy of Technology and Engineering: "improved understanding of the interactions between water extraction and use, and surface and groundwater systems, including the ecosystems that depend on them, at a regional-catchment and basin scale."[8]

It is important to note that in 2010 the Productivity Commission stated that in regard to investment in improved irrigation infrastructure: "this does not in itself recover any water for the environment. For example, a farmer benefiting from government funding might be left with water that is surplus to what is needed to complete their normal irrigation program, but could choose to either sell this water to another farmer, or use it to irrigate more land", and that "infrastructure upgrades frequently produce water savings at the farm or irrigation district level. Due to hydrological realities, however, these savings can be at least partly at the expense of downstream water users and/or ecosystems."[9]

Increased irrigation efficiency is unlikely to provide public benefits from increased river and groundwater flows unless irrigation diversions are reduced by more than the amount of the water saved by capture and reduction of returns flows that occurred prior to implementation of irrigation efficiency. Very large errors in the estimates of water recovery for public benefit can occur when reduced return flows to groundwater and streams from irrigation efficiency programs are not properly accounted for and reflected in corresponding reductions in diversion for irrigation to compensate for loss of return flows. This appears to be the case in the Murray-Darling Basin, as is demonstrated in our analysis below.

As depicted in Figure 1, water flows under irrigation are partitioned according to an international terminology[10] into a consumed fraction which includes: (i) beneficial transpiration by the crop; (ii) non-beneficial transpiration by weeds or other non-crop plants; (iii) non-beneficial evaporation from foliage, soil, storages and canals, and a non-consumed fraction which includes: (iv) return flows to usable groundwater and surface water systems; (v) surface and sub-surface return flows to non-recoverable sinks (e.g. saline lakes, aquifers, spills and evaporative discharge sites). All these components of the water balance system are essential elements of water accounts and computation of water recovery for the environment requires their identification and quantification. From the publicly available reports of the MDBA we have consulted, these components have not been fully identified or quantified, and certainly are not routinely measured and monitored in the Basin. Water Recovery (WR) for environmental purposes from on-farm and off-farm irrigation efficiencies is illustrated in Figure 1.

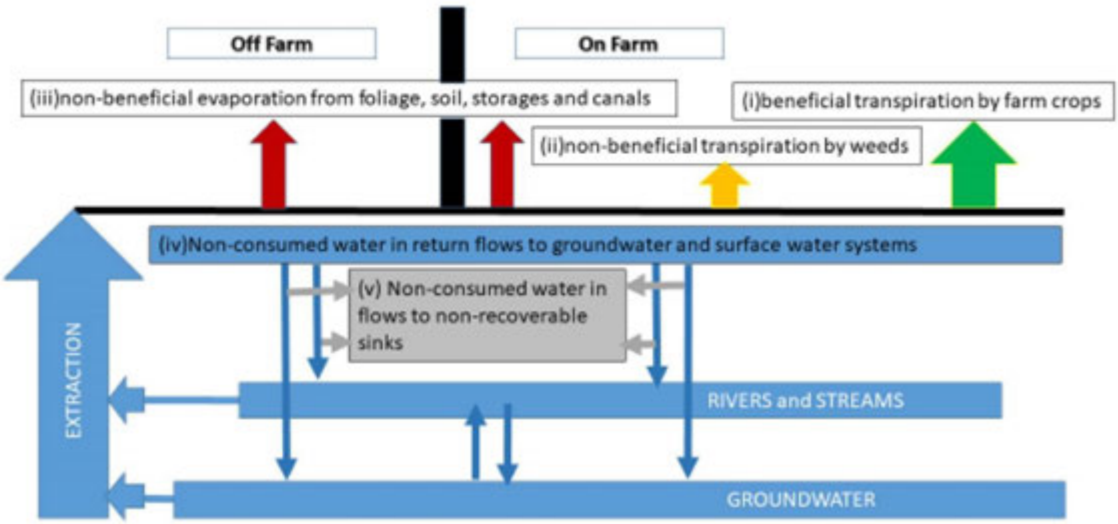

Figure 1. Diagram of water flows in the hydrological cycle for any diversion for irrigation

Consistent with the conservation of mass in the hydrological system, the total water losses (S), attributable to irrigation efficiency (IE) must come from:

- Items (ii) and (iii) in Figure 1, namely a reduction in evaporation from soil, water surfaces in storages or channels, plus reduction in evapotranspiration from weeds or other non-crop plants, which we designate as ΔET;
- Item (iv) in Figure 1, namely a reduction in recoverable return flows from surface returns to streams and sub-surface returns involving seepage beneath the root zone to groundwater systems and these groundwater flows to streams, which we designate as ΔRF;
- Item (v) in Figure 1, namely a reduction non-recoverable flows (often saline) to surface lakes, reservoirs and evaporative discharge sites, plus non-recoverable seepage beneath the root zone to groundwater disconnected from regional groundwater and streams, which we designate as ΔNRF.

Such that S = ΔET + ΔRF + ΔNRF; therefore the reduction in Return Flows (ΔRF) can be expressed as:

$R\Delta F = S - (\Delta ET + \Delta NRF)$ (1)

Water Recovery (WR) for environmental purposes can now be written as

$WR = \Delta DI - \Delta RF$ (2)

where ΔDI is the reduction in Diversion for Irrigation.

If we set F = ΔRF/S, then we can write

$WR = \Delta DI - SF$ (3)

For the most common arrangement in the MDB water efficiency programs we can write $\Delta DI = 0.5S$ and correcting ΔDI for long term average Capacity Utilisation (CU) of water entitlements at 0.8[11] yields

$\Delta DI = 0.4S$ (4)

It follows from (3) and (4) that

$WR = S(0.4 - F)$ (5)

Consequently, from (5), if all the savings are from ΔET and ΔNRF such that F = 0, then Water Recovered (WR) is 0.4S. Conversely, if all of the savings are from return flows (ΔRF) so that F = 1, then Water Recovered (WR) is -0.6S or a reduction in water for environmental purposes equal to 60% of the total savings.

This analysis shows that determining the magnitude of water recovery (WR) for the environment requires a good quantitative understanding of water losses and how much water is 'saved' by increased irrigation efficiency. As Figure 2 shows, it is essential to know the magnitude of $F = \Delta RF/S$, i.e. the proportion of water savings contributed by reduction and capture of recoverable return flows. Without this knowledge it is not possible to establish the volume of water recovered for environmental purposes in the Basin to date from investment in Irrigation Efficiency (IE) programs. Our assessment indicates that information on the nature and quantification of recoverable return flows has not been undertaken or made available by the MDBA.

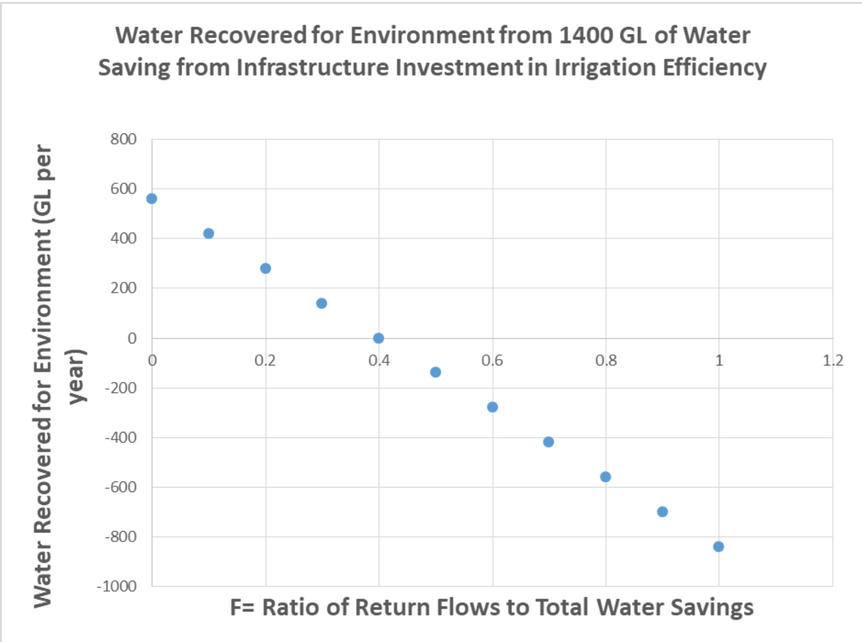

Figure 2. Water Recovered for Environment from 1400 GL of Water Saving from Infrastructure Investment in Irrigation Efficiency as a function of the ratio of recoverable return flows to total water savings

There are few published water balance assessments for irrigated agriculture in Australia, but from those available it appears F is around 0.4 to 0.5.[12] When our analysis is applied to the whole-of-Basin data (Figure 2) for water recovery (WR) for the environment to date from investment in Irrigation

Efficiency (IE), it suggests that the actual water recovery could range from -140 GL to zero, in contrast to the figure of 700 GL published by MDBA.[13]

In terms of water accounting, failure to estimate and model reductions in return flows means that much less water has been recovered for the environment through investment in Irrigation Efficiency. For instance, the MDBA reported that as of 31 October 2017 "water recovery sits at 76.6% of the original target", representing 2,106 GL of the 2,750 GL target for environmental water.[14]

Further, purchase of entitlements from willing sellers will similarly be in error if the magnitude of the change in return flows is not quantified (see Equation 2 above), and an adjustment made to the actual Water Recovered. If return flows were 0.3[15] of entitlement and Capacity Utilisation (CU) of water entitlements was 0.8[16], then water recovery from purchase of entitlements would be 789 GL, not the 1408 GL as claimed, yielding a total Water Recovery of between 648 GL and 789 GL, in contrast to the 2,106 GL currently claimed.

Such a very high level of uncertainty in the water accounting is an issue of fundamental importance. This uncertainty results from a failure to address the nature and magnitude of return flows and the other key water balance components set out in Figure 1.

It is disturbing that return flows have been overlooked for so long, considering the issue is well-known in the international scientific literature.[17] In our view, the level of uncertainty in water accounting of the order we outline places in serious doubt the magnitude of the water recovery for environmental benefit claimed by the MDBA.

Nevertheless, the Australian Government Department of Agriculture and Water dismisses claims that more efficient irrigation water use can reduce return flows to rivers as "spurious",[18] despite the fact that possible reductions have not been measured or modelled. The Department also claims that reductions in return flows is "a good thing" because this water contains "high levels of nutrients, salt or other pollutants." There is no evidence from long-term water quality monitoring programs in the Basin that return flows deliver elevated pollutant levels to rivers downstream. In fact, water quality has generally improved in the southern Basin between 1978 and 2012.[19]

(ii) Floodplain water harvesting

Floodplain harvesting involves diversion of rainfall runoff from floodplains into typically extensive, shallow (up to 3-4 m depth) on-farm storages for irrigation use. This water would otherwise return to rivers as inflows. Water harvesting is prevalent in Northern Basin river valleys, particularly the Macquarie, Barwon-Darling, Gwydir, Namoi, Border Rivers and Condamine-Balonne. In introducing its Floodplain Harvesting Monitoring Policy, NSW Department of Primary Industries stated: "The unrestrained harvesting of water from floodplains lessens the amount of water reaching or returning to rivers for downstream river health, wetland and floodplain needs as well as downstream users."[20]

In NSW, floodplain harvesting requires an appropriate water access licence, a basic landholder right or a licence exemption, as well as local government approval for construction of storages. Licencing and monitoring of floodplain harvesting is important to ensure that licence holders stay within their limits and do not impact downstream users. Management plans, including voluntary registration of storage structures, have commenced in the Barwon-Darling and Gwydir valleys.[21] In Queensland, floodplain harvesting has effectively been unconstrained; not requiring licencing, though local planning laws may apply to construction of levees and contour banks.[22]

The magnitude and extent of floodplain harvesting and its impacts on declines in river flows is another very large uncertainty in water accounting. There is no systematic measurement of floodplain harvesting in the Basin and consequently the volume of water harvested has been grossly underestimated for many years. Without such measurements, including evaporative losses from storages of harvested water, not only does the water balance of the Basin remain glaringly incomplete, but any policy of water allocation and recovery cannot be fully assessed in terms of its costs and benefits. With such large uncertainty in the water accounts arising from a failure to describe and quantify the magnitude of floodplain harvesting it would be highly risky to consider any revision to the SDL in the Northern Basin.

The MDBA has estimated that interceptions (which include floodplain harvesting) account for 20%, or 2,733 GL, of overall consumptive use.[23] MDBA has admitted that although it takes the issue of floodplain harvesting very seriously, it has no power to intervene in regulation or approval processes; responsibility for which rests with local and State governments.[24]

In the Border Rivers valley, the cotton growing properties 'Kalanga' and 'Mobandilla' near Toobeah occupy 18,000 ha on the Macintyre floodplain, with extensive water harvesting and storage of approximately 9,500 ha.[25] With a mean of 6 days per year of rainfall of >25 mm at Goondiwindi PO (annual mean 621 mm) the volume of water harvested during 6 days is in excess of 15 GL, stored within 5-8 km of the Macintyre River. Annual reductions in river inflows from this single operation are likely to be in the order of 20-30 GL (having accounted for soil infiltration and evaporation): about 10% of end-of-system outflows from the Macintyre River to the Barwon River.[26]

Based on remote sensing by researchers at UNSW, the Macquarie River Valley was estimated to have an area of about 1,900 ha of floodplain storages, representing a storage capacity in the order of 20-30 GL.[27] To our knowledge, this is likely the only publicly-available, peer-reviewed research report of the extent of floodplain harvesting in the Murray-Darling Basin. The managers of Cubbie Station in the Condamine-Balonne Valley, a property that has a water harvesting storage area in excess of 13,000 ha, claim: "flood harvesting is a potentially more environmentally friendly means of water capture than the traditional headwater storage/run-of-river regulated supply system."[28] This claim is contrary to the position on floodplain harvesting of the NSW Department of Primary Industries, as outlined above.

In 2016, the MDBA stated that the Murray–Darling Basin Ministerial Council (Aug. 2000) agreed that "diversions from floodplain and overland flows are included in Cap accounting arrangements as a matter of priority" and that "the MDBA is committed to bringing the floodplain diversions within the Cap according to the Council's above decision. It has taken several statutory and administrative measures to achieve this. These measures include amendments to Schedule E of the Murray–Darling Basin Agreement and the diversion formula register, and completion of two investigation projects to develop a method to estimate land-surface diversions…Significant progress was made by the projects, and methods and models that were developed to estimate land-surface diversions."[29]

We urge that MDBA, as a matter of priority, make publically available its estimates and methods of calculation in relation to the extent of floodplain water harvesting, the volumes of water involved and their likely impacts on river flows and flood regimes of wetlands. This information is urgently needed to improve our understanding of water balance and water accounting in the Basin, including the setting of baseline diversion limits, compliance arrangements and future development of policy options for water allocation and recovery.[30]

(iii) Groundwater diversions

Volumetric allocations of water for groundwater diversions increased dramatically by about 40% under the Basin Plan.[31] Despite this increase, there appears to be no assessment by the MDBA of the effects of increased groundwater diversions on groundwater inflows to rivers. This deficit represents a major gap in our understanding of the water balance of the Basin.

What progress in research and modelling has the MDBA made since 2012 in evaluating the effects of increased allocations and diversions of groundwater on baseflow of those river systems that rely on groundwater inflows? Have any assessments that the MDBA has made affected their views about the implications of increased groundwater diversions on achieving key objects 3d(1) and 3d(ii) of the Water Act (2007)[32] and, in particular, the need to "protect, restore and provide for the ecological values and ecosystem services of the MDB"? Again, we urge that MDBA make publically available its estimates on the effects of increased groundwater use on inflows to rivers.

2. ENVIRONMENTAL MONITORING

The determination of the environmental watering requirements in the 2012 Basin Plan remains obscure. The final report of the Australian Senate inquiry into the Management of the Murray–Darling Basin (March 2013) recommended the MDBA provide a "concise and non-technical explanation of the hydrological modelling and assumptions used to develop the 2,750 GL/year return of surface water to the environment within the Basin Plan."[33] This recommendation has still not been acted upon.

From the perspective of environmental monitoring and assessment, such an explanation forms the basis for a collective understanding of where, how, why and for what the environmental watering targets were set and whether those targets can be met into the future. Such an explanation can then underpin the development of a comprehensive environmental monitoring framework for the Basin, consistent with a process of reporting on progress towards environmental targets set for each valley.

Non-technical, publicly-accessible, environmental reporting frameworks have been used as part of the Australian State of the Environment Report and the South-east Queensland Waterways Healthy Land and Water Report Card.[34] Such assessments are essential to communicate comprehensive, integrated long-term trends in environmental condition and to build public trust that the Basin Plan is achieving its objectives. In this regard, the Victorian Government has recently released its Basin Plan Environmental Report Card, supported by a detailed technical report, written in plain English.[35]

While we welcome the Victorian Government initiative, no such assessment currently exists for the Murray-Darling Basin as a whole. The Sustainable Rivers Audit (SRA)[36] was abolished in 2013 after two Basin-wide assessments (2004–07 and 2008–10). This SRA methodology allowed a whole-of-Basin assessment, including rivers with little or no irrigation development as well as the highly developed rivers. We acknowledge that certain elements in the design of the SRA would not necessarily be suitable for the current Basin Plan (e.g. the use of pre-development conditions as the baseline reference for ecosystems that have been highly modified). Nevertheless, an updated, carefully-designed, whole-of-Basin environmental monitoring system would allow assessment of progress against the background of high climate variability and also climate change. None of the current monitoring programs allow this. A Basin-wide monitoring approach is critical to building confidence over the long term that the health of the Basin rivers and wetlands are responding to interventions under the Basin Plan.

It is hard to believe that monitoring at Basin-scale would be abandoned at the very time that Australians embarked upon the largest expenditure of public money ever to restore the health of the Basin rivers and wetlands. It is critical to note that the case for the water reform in the MDB was in many respects built on the SRA assessments, which demonstrated that most rivers were in 'poor condition' and, hence, the need for major interventions to improve the health of the rivers, wetlands and groundwater systems.

The MDBA, in response to questions on notice by the Australian Senate Select committee on the Murray–Darling Basin Plan (Feb. 2016), stated that "Basin state and territory governments decided to cease funding the SRA program as it did not align with the monitoring of ecological health required under the Basin Plan. The SRA monitored ecological health compared to a pre-European benchmark. It was also not linked to specific water management actions like the Basin Plan. Since the end of the SRA, the MDBA has established a monitoring program to gather information about the environmental impact of the Basin Plan at the Basin scale."[37] For the record, and to date, the MDBA has most certainly not established an integrated, long-term environmental monitoring program at Basin-scale.

Current monitoring and reporting arrangements are fragmented, involving multiple agencies. For example, in compiling data on environmental monitoring for the 2018 Victorian report on progress towards environmental outcomes under the Basin Plan, the author had to contact 24 'knowledge holders' in some 10 agencies.[38] Environmental reporting of a major wetland such as Barmah-Millewa Forest on the River Murray may involve monitoring by: (1) contractors to the Commonwealth Environmental Water Office (CEWO) to monitor ecological effects of Commonwealth environmental water releases; (2) NSW Office of Environment and Heritage and NSW Office of Water, for Millewa Forest; (3) The Environmental Water Manager of the Goulburn-Broken Catchment Authority and The Victorian Department of Environment and Primary Industries, for Barmah Forest; (4) contractors to the MDBA for The Living Murray Program. This monitoring approach is complex, inadequate, lacking in transparency, and is a failure of the MDBA to meets its public commitments and legal obligations under the Basin Plan.

The current jurisdictional arrangements for environmental monitoring are summarised on the CEWO website as follows: "Murray-Darling Basin Authority is responsible for reporting on the achievement of the environmental objectives of the Basin Plan at a Basin scale. As reflected in the Basin Plan principles, this means that the Murray Darling Basin Authority has a key role in coordinating monitoring and evaluation activities across the Basin. Basin States are responsible for reporting on the achievement of environmental objectives of the Basin Plan at an asset scale (via long-term environmental watering plans). Together with regional natural resource management agencies, the States have valuable on-ground knowledge and experience of particular ecosystem characteristics as well as the capacity to deliver, monitor and evaluate watering events efficiently and effectively. Commonwealth Environmental Water Holder is responsible for reporting on the contribution of Commonwealth environmental water to the environmental objectives of the Basin Plan."[39]

Much of the environmental monitoring for the Basin Plan has been small-scale, event-based, short-term and cannot be integrated with existing long-term data sets or compared with data from other river valleys, despite claims that the monitoring is long-term.[40] Some of the monitoring being undertaken fails the basic design principles for effective ecological monitoring.[41] Further, much of the data has been collected by contractors, including University researchers and their students, who have no statutory responsibility for ensuring effective environmental monitoring is conducted or that the data collected is made publically available or conducted to a high standard and is fit for purpose. CEWO has stated "All evaluation reports and monitoring data related to the Long Term

Intervention Monitoring Project will be made available to the public."[42] Data collected to date is not currently publicly available.

3. TRANSPARENT, INDEPENDENT PEER REVIEW

Our examination of the peer review process by MDBA clearly indicates that it lacks the scientific rigour that we would expect for decision making that involves the expenditure of billions of dollars of public funds. In particular, we see little evidence of transparency in review processes used by MDBA, or of critical review by individuals and groups who are independent of the MDBA in terms of funding, financial arrangements and influence through governance linkages. There is little evidence of review by Australian or international scientific experts with experience in hydrological analysis, water accounting and environmental monitoring.

We add that very little, if any, of the biophysical analysis or the socioeconomic assessment upon which the MDB Plan is based has been subject to independent international peer review, including the nature and appropriateness of the critical questions being examined. For scientific peer-review to be credible, it must be conducted by independent groups or by individuals with no funding links or other conflicts of interest, real or perceived, with the agency conducting the work under review.

The Australian Academies have long experience in the credible and legitimate conduct of robust peer review. However, as far as we are aware, they have not been engaged in order to provide the highest possible level of scientific scrutiny appropriate to the science underpinning such large public expenditure. Further, well established protocols for peer review are required to give confidence to the public and the scientific community in the analyses and recommendations of the MDBA. We highlight that public trust in policy recommendations is based on robust science that is thoroughly-examined, debated and tested, including findings and perspectives that may conflict with the research findings of the MDBA and its research partners. Such a process has not been encouraged by the MDBA.

In summary, good public policy is always best based on science which has been subject to independent, peer review that draws upon the global knowledge base in the relevant fields. Robust, independent peer review is the basic quality control process for mainstream science.

We urge that the Productivity Commission to consider our recommendation of an independent review into current arrangements and governance procedures for environmental monitoring to ensure accountability and transparency of reporting, integration of data, design principles, methodology, practice and peer review processes. We contend that such an independent review that provides a comprehensive long-term picture of environmental change is necessary to restore public confidence in the Basin Plan and its implementation by the MDBA.

Notes

1 Productivity Commission (2018) Murray-Darling Basin Plan: Five-year Assessment, Issues Paper, p. 36.

2 Grafton, R.Q. and Wheeler, S. (2018, in press) Economics of water recovery in the Murray-Darling Basin, Australia. *Annual Review of Resource Economics* [Published online March 9, 2018]

3 MDBA (n.d.) Hydrological modelling.

4 Water Act 2007, S21(4)(b); MDBA (2017) Annual Report 2016–17, p. 66; MDBA, The Northern Basin Amendments are based on strong science and evidence. Media release, 6 February, 2018.

5 MDBA, Scientific collaboration key to securing a healthy Murray-Darling Basin. Media release, 22 March 2018.

6 Grafton, R.Q. & Williams, J. (2017) Supplementary submission to the House Standing Committee on Agriculture and Water Resources, Inquiry into water use efficiency in Australian agriculture, p. 1, fig. 1;

7 Ward, F.A. & Pulido-Velazquez, M. (2008) Water conservation in irrigation can increase water use. *Proceedings of the National Academy of Sciences* 105, 18215–18220; Gómez & Pérez-Blanco (2014) Simple myths and basic maths about greening irrigation. *Water Resources Management* 28, 4035 – 4044; Pfeiffer, L. & Lin, C.-Y. (2014) Does efficient irrigation technology lead to reduced groundwater extraction? Empirical evidence. *Journal of Environmental Economics and Management* 67, 189–208.

8 Productivity Commission (2017) National Water Reform Draft Report. Box 8.3, p. 259.

9 Productivity Commission (2010) Market Mechanisms for Recovering Water in the Murray-Darling Basin, p. 123.

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11 MDBA (2017) Transition Period Water Take Report 2012–13 to 2015–16: Report on Cap compliance and transitional SDL accounting, p. 84, Table 20.

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13 MDBA (2017) 2017 Basin Plan Evaluation, p. 27.

14 MDBA (2017) Progress on water recovery.

15 Droogers, P. & Bastiaanssen, W.G.M. (2002) Irrigation performance using hydrological and remote sensing modeling. *Journal of Irrigation and Drainage Engineering* 127, 11–18; and

16 MDBA (2017) Transition Period Water Take Report 2012–13 to 2015–16: Report on Cap compliance and transitional SDL accounting, p. 84, Table 20.

17 cf. references cited at Note 7 above; also: Qureshi, M. E., Schwabe, K., Connor, J. & Kirby, M. (2009) Environmental water incentive policy and return flows. *Water Resources Research* 46, W04517; Lopez-Gunn, E., Zorilla, P., Prieto, F. & Llamas, M.R. (2012) Lost in translation? Water efficiency in Spanish agriculture. *Agricultural Water Management* 108, 83–95; Ahmad, M.D., Masih, I., Giordano, M. (2014) Constraints and opportunities for water savings and increasing productivity through Resource Conservation Technologies in Pakistan. *Agriculture, Ecosystems and Environment* 187, 106–115.

18 Department of Agriculture and Water (2017) Response to claims about the impact of improved water infrastructure on environmental outcomes in the MDB.

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23 Water Act 2007 – Basin Plan 2012, Schedule 1—Basin water resources and the context for their use Table 1: Murray-Darling Basin long-term annual inflow and water use.

24 ABC News 14 Feb 2018 Murray Darling Basin Authority powerless to act against farmers harvesting floodwaters.

25 Estimated using Google Earth Pro.

26 CSIRO (2007) Water Availability in the Border Rivers. A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields project. CSIRO Water for a Healthy Country National Research Flagship, Canberra, p. 51.

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28 Cubbie Ag Irrigation Project. Environment.

29 MDBA (2016) Water Audit Monitoring Report 2011–12, p. 27.

30 MDBA (2011) Plain English summary of the proposed Basin Plan — including explanatory notes, pp. 85–86.

31 MDBA (n.d.) Sustainable diversion limits.

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37 Select Committee on the Murray–Darling Basin Plan. Murray–Darling Basin Authority response to questions on notice. Murray–Darling Basin Authority – 2 February 2016

38 Hunt, T. (2018) Progress towards outcomes from environmental water in Victoria: five years into Basin Plan implementation. Department of Environment, Land, Water and Planning, Melbourne, p. 10, Table 3.

39 Commonwealth Environmental Water Office, Monitoring and evaluating Commonwealth environmental water.

40 See, for example, Commonwealth Environmental Water Office (2016) Long-Term Intervention Monitoring Project Murrumbidgee River System evaluation report 2014-16.

41 cf. Lindenmayer, D.B. & Likens, G.E. (2010) Effective Ecological Monitoring. CSIRO Publishing, Melbourne, pp. 53–71.