Submission to Murray-Darling Basin Royal Commission

Professor Richard Kingsford

Centre for Ecosystem Science, UNSW, Sydney

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1. Executive Summary

The Murray-Darling Basin Plan is a significant policy initiative, critical to restoring the environmental health of the rivers of the Murray-Darling Basin. The buy-back of environmental water was essential for restoring some of the wetlands and their dependent organisms. Most importantly, this water has also served significant ecosystem services for native fish species relied on by anglers, tourism, floodplain graziers, cultural sites and river health concerns of the Traditional Owners and many who rely on water quality. It also provides essential water for urban and other rural communities as well as diversions for irrigated agriculture. The overarching goal of restoring the rivers of the Murray-Darling Basin remains vulnerable to policy and management shifts more in favour of a particular socio-economic sector (i.e. irrigation), than other socio-economic sectors and meeting environmental health goals. This undermines the objectives and outcomes of the *Water Act 2007* and the Murray-Darling Basin Plan and in particular the environmental outcomes, particularly those relevant to international obligations under the Ramsar Convention and migratory shorebirds.

In particular, these policy and management concerns relate to five main areas in relation to implementation of the Basin Plan:

- **(1) Ongoing reductions in the volume of environmental flow for the rivers due to**
    - *policy decisions resulting in reductions of overall large scale volumes of environmental flow (i.e. recommended reduction of 70GL of environmental water from the Northern Basin Rivers by the Murray-Darling Basin Authority, substitution of water efficiency projects for 605GL of environmental water, see below);*
    - *illegal take of planned or held environmental water through*
        - unauthorized floodplain harvesting earthworks illegally harvesting water;
        - authorized or legal floodplain earthworks intercepting environmental flows and diverting these to channels and storages or onto crops;
        - accessing water by pumping surface water from the river when it is illegal to take water;
    - *retrospective 'grandfathering' of floodplain earthworks with licencing policies shifting to new baselines, failing to respect previous baselines such as those of the Murray-Darling Basin Cap at 93/94 levels of development (NSW, SA, Vic) and later for Queensland rivers;*
    - *'inflated' licencing of volumes, gifted for floodplain harvesting, with no data as to actual diversion or alignment in terms of the Murray-Darling Basin Cap or previous baseline decisions;*
    - *increasing capacity of floodplain storages, sometimes through federally funded efficiency programs, to take more water in the absence of rigorous measuring of take or monitoring and regulation of floodplain harvesting;*
    - *inadequate policy and management for protection of planned environmental water under*

climate change, relative to held environmental water, resulting in inequitable sharing of declining flows and inundation under a drying climate;

- *inadequate dividends in environmental water from all efficiency projects, including 36 priority projects, to adequately compensate for removal of large volumes of environmental water from the rivers (ie 70 GL per year and 605 GL per year);*
- *engineering works for efficiency projects delivering perverse environmental outcomes, causing more environmental impacts than benefits with reductions in water for surface and groundwater environments (e.g. Menindee Lakes);*
- *inadequate protection of held environmental flows through inadequate policy and practice at the state level resulting in pumping of this water once it moves to another water planning area (i.e. no 'shepherding' protection);*
- *idiosyncratic variation of management rules across different rivers, as a result of different interpretations of storage and release management, which are rarely accountable or transparently reported;*
- *inadequate transparency and reporting on reliability of environmental water bought for the environment, including the financial costs to taxpayers against the environmental benefits (e.g. Tandou purchase of 22, 000 ML, $78 million);*
- *alteration of 'cap factors' that potentially reduce the amount of planned environmental water in favour of licenced water (held environmental water and other licences);*
- *effects of diminishing return flows to the environment because efficiency projects reduce the return flows back to rivers, reducing the positive impacts of environmental flows on the rivers of the Murray-Darling Plan and outcomes of the Murray-Darling Basin Plan;*

- **(2) lack of transparency in accounting and auditing of water use with inadequate compliance efforts;**
  - *inadequate reporting of diversions at all scales and levels across the Murray-Darling Basin Rivers (i.e. river reach, floodplain, entire river, basin scale) with no regular independent assessment, as was provided previously (e.g. Independent Audit Group, National Water Commission);*
  - *little to no measurement or rigorous assessment of the amount of water taken for floodplain harvesting;*
  - *poor metering and reporting on water taken from many rivers in the Darling River tributaries (only 25-51% metered, Murray-Darling Basin Authority 2017b);*
  - *inadequate acknowledgement of the uncertainties of current hydrological modelling, particularly in relation floodplain inundation and the absence of adequate measurement of flows;*
  - *inadequate consideration of international obligations for the management of the Murray-Darling Rivers and their wetlands, particularly Ramsar sites and migratory shorebirds;*

  - *lack of transparency on the water savings of efficiency projects, particularly the 36 major efficiency projects and rigorous assessments of water savings;*
  - *insufficient compliance effort and inadequate implementation of 21st century technology for monitoring (remote sensing, automatic metering stations);*
  - *calculation of 'cap factors' lacks transparency;*
  - *toolkit measures rely on implementation by State governments and yet there is no commitment in a legal framework for this;*
- ***(3) inadequate use of scientific evidence and technology;***
  - *relatively poor use of significant scientific research and understanding for rivers and connections with river flows to support decision-making;*
  - *insufficient use of multiple lines of evidence for decision making, utilizing independent scientific sources of information and data;*
  - *transparent reporting of data and models, providing opportunity to consider uncertainties;*
- ***(4) need for improved focus for planning and management on the whole river system;***
  - *increased specification of objectives linked to overall goals;*
  - *monitoring clearly linked to management actions;*
  - *include other issues related to water management (e.g. floodplain developments, barriers, cold water pollution, invasive species);*
- ***(5) no punitive measures available for the Australian Government to hold States to account for inadequately implementing the Murray-Darling Basin Plan;***
  - *need for a legislative mechanism whereby States, primarily responsible for implementation of the Murray-Darling Basin Plan, can be punished for inadequate implementation; previously the Australian Competition Council was able to advise the Australian Government to withhold grants from the states.*

2. Expertise and qualifications

I have a Bachelor of Science and PhD from the University of Sydney. I am the Director of the Centre for Ecosystem Science (CES), UNSW Sydney, established in 2009. I have worked for 37 years as a river scientist in government and university sectors. Much of my work, with my colleagues, has focused on rivers and wetlands of the Murray-Darling Basin. My research has been supported by the Australian Research Council, all governments of Australia, including the Australian Government (various environment agencies, Murray-Darling Basin Authority), and non-government organisations (e.g. Birdlife Australia). I have visited every major river system in the Murray-Darling Basin, across all of the states and territory.

All of my research has supported instruments of government and communities, in implementation of policies and management for the sustainability of Murray-Darling Basin Rivers. I also have an established track record in the research and management of river ecosystems and their biodiversity, both within and outside protected areas. My publications predominantly focus on the ecology, management and policy of rivers and wetlands, particularly in the Murray-Darling Basin. These include co-authorship of 141 peer reviewed publications, 26 book chapters, five books and 95 technical publications and reports. I have a long history of completing research and technical projects for governments in relation to river and wetland management, particularly focused in the Murray-Darling Basin. I have been committed to providing evidence for policy and management decisions in the Murray-Darling Basin.

I lead a project which regularly surveys all the major environmental assets in the Murray-Darling Basin for waterbirds and inundation, including the internationally listed wetlands of the Murray-Darling Basin (the Ramsar sites). In addition, we survey 10% of all wetlands across the Murray-Darling Basin, using systematic surveys each year (Kingsford and Porter, 2009). These surveys focus on all waterbirds including migratory shorebirds, a key focus for the Murray-Darling Basin Plan. As well as waterbirds, I have also published research on platypus, fish, floodplain vegetation (e.g. river red gum), frogs, turtles, invertebrates, ecological processes, flooding and inundation patterns in the Murray-Darling Basin. I have also independently modelled river flows, comparing the performance of modelling used in the management of river flows to independent statistical models. In particular I have a strong track record in two key matters relating the legislation underpinning the Murray-Darling Basin Plan, particularly the environmentally sustainable level of take (ESLT) and how this relates to the external powers of the Australian Government in relation to management of the 16 Ramsar-listed wetlands and also migratory shorebirds which move twice a year between the northern and southern hemisphere.

In addition, I have and continue to advise State and Australian Governments on matters related to the policy and management of rivers of the Murray-Darling Basin. I worked for the environment agency in NSW (currently called NSW Office of Environment and Heritage) for 18 years. I advised the Director and Ministers for the Environment and Water in relation to management of the sustainability of rivers of the Murray-Darling Basin. This included representing the government conservation agency on an intra-government taskforce composed of major government agencies involved in water management including Agriculture, Conservation, Fisheries, Planning and Water which reported about every three months to respective Director-Generals and was also supported by the Cabinet Office and Treasury. While working for the NSW Government, I also represented New South Wales on a number of interstate committees (e.g. Wetlands and Waterbirds Committee) and also represented the NSW Environment Minister on the Border Rivers Council, an interstate committee for managing the rivers along the border between New South Wales and Queensland.

In addition, I have assisted state and Commonwealth governments through the following: the include Expert Panel for the River Murray, NSW Ministerial Water Advisory Council; Scientific Advisory Panel for the Lake Eyre Basin; Stakeholder Water Advisory Committee for the Commonwealth Government; Environmental Water Scientific Advisory Panel for the Commonwealth Government; Coorong and Lower Lakes Committee for the Commonwealth Government; Scientific Advisory Committee on the adaptive management of river red gum forests for NSW and Victoria and the Queensland Government Advisory Panel on the management of Wild Rivers. I am also the current Chair of the Scientific and Cultural Advisory Committee to advise the Nature Conservation Water Fund on environmental flows.

In summary, I have a strong background not only in research but also in policy and management of rivers in the Murray-Darling Basin over a period of nearly forty years. I also have a good knowledge of all the rivers and understanding of the challenges as well as the background of people dependent on the rivers of the Murray-Darling Basin.

3. Approach to this submission

I have taken the approach of commenting on the key challenges identified by the terms of reference first and then I have listed other matters for consideration by the Royal Commission. Wherever possible, I have provided peer reviewed scientific evidence to support my conclusions.

4. Water plan accreditation – July 2019

There is considerable complexity to development of water plans which are compliant with the Murray-Darling Basin Plan and importantly deliver the objects of the *Water Act* 2007 and the outcomes of the Murray-Darling Basin Plan and the developed Environmental Watering Plan. The current issues are of some concern in delivering on the necessary outcomes and in particular environmentally sustainable systems.

a. Lack of explicit objectives linked to a vision

There is a long history of poor planning with insufficient detail and transparency on delivery. Most water plans lack specific direction on the future desired state of the environment on which they are managing. This can be done by developing a shared vision with stakeholders, consistent with the Basin Plan and the legislative and policy context for a river (e.g. protected areas, Ramsar sites, Environmental Watering Plan). This then allows the development of broad objectives, which can be progressively developed as finer scale objectives which are consistent with the vision and eventually produce specific and linked measureable objectives at the finest scale – a strategic adaptive management approach (Kingsford *et al.*, 2011a; Kingsford and Biggs, 2012; Kingsford *et al.*, 2017b). Importantly, these can also provide the relevant indicators that provide effective information for management. Further, this objective setting process allows for the identification of responsibilities for different agencies and other organisations for collection of data and responsiveness to management.

Water plans need to have measureable objectives which can be clearly linked to delivery of an environmentally sustainable river system. Such explicit objectives need to refer to establishing self-maintaining populations of different aquatic dependent organisms. For example, an explicit objective may be to maintain a certain area (e.g. 1,000 hectares) of river red gum *Eucalyputus camaldulensis* in self-maintaining populations for a particular wetland. This can then be explicitly linked to the condition of the trees, their germination and recruitment. It is then possible to identify the amount of water required to deliver on such an objective. Water plans tend to focus primarily on water delivery objectives and not on explicit environmental objectives.

No water resource plans have this detailed architecture, ultimately necessary for delivering on the objects of the *Water Act 2007*. Few have more than broad objectives which are often not measureable or transparent. They are also not explicitly linked to indicators that guide management. Generally there are broad objectives which are applied across all rivers and do not reflect the different assets or importance of particular environmental values. For example, the vision and objectives for the Macquarie Marshes (Kingsford *et al.*, 2011a; Kingsford and Biggs, 2012; Kingsford *et al.*, 2017b) should be different to those for the Coorong, Lower Lakes and Murray Mouth, while also respecting broad Basin Plan objectives.

b. Limitations of current water resource plans

i. Inadequate jurisdiction

Water resource plans primarily focus on water management and yet there are significant aspects of water management which are critical and not part of water resource planning. In particular, structures on floodplains can have significant impacts on river flows and dependent ecosystems (Steinfeld and Kingsford, 2013; Steinfeld *et al.*, 2013), including diversion of environmental water for other uses. In addition, there is little focus on water quality or the effects of instream barriers affecting river flows and dependent organisms (Harris *et al.*, 2017). There are also impacts of cold water pollution in many rivers where water is released from the bottom of dams and so is much colder than naturally, affecting many dependent organisms downstream which rely on temperatures cues for breeding (Sherman *et al.* 2007). Introduced fish, particularly European carp *Cyprinus carpio*, can have devastating impacts on river systems (Koehn 2004). It is important that all of these different aspects of river management are included in planning so there are opportunities to prioritise limited resources for management.

ii. Inadequate accounting for diversions in planning

There is generally poor auditing or inclusion of floodplain diversions or harvesting in water plans. This area is particularly problematic in the Darling River basin where ongoing development of floodplain has continued to occur. In particular, the Murray-Darling Basin Ministerial Council (the governments of the Murray-Darling Basin) agreed that a Murray-Darling Basin Cap should be implemented for the rivers of the Murray-Darling Basin in 1995. Specifically this was "*The volume of water that would have been diverted under 1993/94 levels of development*". However the Queensland Government successfully argued that this should apply later to the Queensland rivers. And yet, floodplain development growth continued on many of the rivers of the northern river basin past this period. There was no auditing of the potential for these structures to take water. In New South Wales, there was an explicit policy decision made to 'grandfather' through the *Water Management Amendment Bill 2014*, essentially ignoring the potential growth in floodplain works capable of diverting water at 1993/94 levels of development. If the NSW Government had adequately committed to the Murray-Darling Basin Cap, they would have audited all floodplains and determined which structures were taking water above 1993/94 levels of development.

iii. Variation in water management rules

There is broad articulation of the management rules for different types of extracted water and planned and held environmental water for water plans. However there is insufficient detail or understanding on actual practice of water management. For example, there are variable water management practices in NSW, varying between river systems, despite the fact that there is the same legislation (*Water Management Act 2000* (NSW), *Water Act 2007* (Federal)), policy (NSW policies, Murray-Darling Basin Plan) in place. And even the same water agency manages the water but legacy and interpretation govern actual delivery of water, with implication for regulation, protection of environmental water and long term management. For example, water management in the Macquarie River differs considerably to water management in the Gwydir River in relation particularly to the management and allocation of water from storage.

For the Macquarie River, allocation of water is not based on how much water is held in storage in the dam (actual water) but on how much water is to be expected based on the history of record of inflows. Contrastingly, in the Gwydir River, water allocations are based on the amount of water held at any one time in storage. The Macquarie River water management becomes seriously problematic when there is a dry period which exceeds any of the past data record. This occurred during the Millennium Drought, 2002-2009. Because the predicted flow had not reached the dam, the allocations were too high and the water plan at the time had to be abandoned. This problem has not been addressed. Under current predictions and projected increased drying in the southeast of the Murray-Darling Basin, there may be a new record dry in the future (Chiew *et al.*, 2014) which might require the Macquarie Water Resource Plan to be turned off. The Basin Plan was supposed to avoid such problems which were known before the development of the Basin Plan.

Further, this is complicated by a range of usually unspecified and certainly poorly understood management operation rules including carry over rules, calculation of storage capacity, release water for planned environmental water.

c. Timing of delivery of water resource plans

Only one of the 33 water resource plans is currently delivered and this is for an unregulated river system with little to no development. Given the complexity of these plans, the Murray-Darling Basin Authority considers it unlikely that all plans will be accredited by mid-2019, given planning is "well behind" (Murray-Darling Basin Authority, 2017a).

d. Auditing water resource plans – water and environmental objectives

There needs to be clarity and transparency in the auditing of water resource plans to ensure that they adequately deliver on water and environmental objectives. It is currently not clear how detailed this process will be and whether it will be in sufficient detail to deliver on the environmental objectives and water delivery objectives. From arguments above, it is clear that many of the planning mechanisms lack sufficient detail to allow for adequate assessment and learning. Auditing will be correspondingly difficult. There is a least a necessity for managers of water resource plans to provide data, including multiple lines of evidence in relation to whether they are adequately delivering the Murray-Darling Basin Plan's objectives for environmental sustainability.

e. Other plans relevant to water

Many agencies are responsible for different aspects of water management within a river catchment in a State, including the water agency, environment agency, fisheries agency and sometimes the agricultural agency. Regional bodies, or what used to be called catchment management authorities also play a role. Further, water and environment agencies exist at State and Federal levels, including the Murray-Darling Basin Authority. At a federal level, the key agencies are the Commonwealth Environmental Water Office http://www.environment.gov.au/water/cewo responsible for managing environmental water. Other parts of the federal agency are responsible for managing threatened species http://www.environment.gov.au/biodiversity/threatened while the Federal Department of Agriculture and Water Resources is also primarily developing policy and management for water http://www.agriculture.gov.au/ . Further, the Murray-Darling Basin Authority https://www.mdba.gov.au/ is the independent statutory authority with responsibility for the rivers of the Murray-Darling Basin. Even within agencies, there are varying and important functions and responsibilities. For example, in New South Wales there is WaterNSW https://www.waternsw.com.au/ and the NSW Office of Water http://www.water.nsw.gov.au/ .

Each with a different but sometimes overlapping responsibilities. Similarly in the environmental area, there is NSW Office of Environment and Heritage (OEH) http://www.environment.nsw.gov.au/ but it has different functions for regulating water quality through the Environment Protection Authority (EPA) https://www.epa.nsw.gov.au/ and with a clear function to manage environmental water http://www.environment.nsw.gov.au/topics/water/water-for-the-environment and yet this part of the organization is separate to the part that needs to manage dependent protected areas through the National Parks and Wildlife https://www.nationalparks.nsw.gov.au/ . Each of these organisations will have staff and responsibilities for planning and management. Other states have similar overlapping responsibilities within and among organisations.

As a result, in addition to water plans, there are many other poorly coordinated or integrated planning processes. In addition, there is often confusion about responsibilities of different organisations. As a result identifying why objectives are met or not met is also difficult.

f. Recommendation

Ideally, water plans are expanded to ensure that only one plan includes all of the different aspects of planning but with a coherent and integrated vision and goal. This can be achieved through implementation of strategic adaptive management. In addition, fine scale objectives can then be developed, recognizing and integrating the different types of objectives. This would mean for example that the current lack of oversight by the Murray-Darling Basin Authority on floodplains could be rectified through an integrated planning system.

5. Basin Plan adequacy - achievement of the objects, purpose and desired outcomes of the Water Act and Basin Plan

a. Background

The Murray-Darling Basin represents Australia's most developed river basin in terms of water resource use for consumptive purposes, predominantly irrigation (Kingsford, 2000a; Leblanc *et al.*, 2012). This has resulted in significant environmental consequences, particularly for floodplain ecosystems (Walker, 1985; Lemly *et al.*, 2000; Sheldon *et al.*, 2000; Thoms and Sheldon, 2000; Kingsford *et al.*, 2006; Davies *et al.*, 2012; Kingsford *et al.*, 2015; Bino *et al.*, 2016; Appendix 1). The development of water resources through the building of dams, particularly during the 20th century paid limited consideration to the environmental consequences of water resource developments on the rivers of the Murray-Darling Basin (Walker, 1985; Jones et al., 2001). In particular, even the last major dam built (enlargement of Pindari Dam on the Macintyre River in 1995) paid little attention to the environmental consequences of water resource developments (Kingsford, 1999a).

As a consequence, decisions about the Murray-Darling Basin Rivers in relation to the *Water Act 2007* and the Murray-Darling Basin Plan have a historical context of little consideration of the environmental impacts during decision making and a long history of decisions which have favoured development of the rivers over their long-term sustainability. There has been a strong socio-economic drive to develop the rivers of the Murray-Darling Basin for irrigation, significantly impacting on the river environments. Current arguments that decisions about the Murray-Darling Basin rivers need to adequately consider socio-economic impacts ignore this long history of development and essential commitment by governments to develop the rivers of the Murray-Darling Basin. Further this has had considerable impacts on socio-economic viability of other communities which rarely been adequately considered in decision-making.

b. Objects of the Water Act and Basin Plan

i. *Background*

A key object is to "return to an environmentally sustainable level of extraction" for the ground and surface water resources of the Murray-Darling Basin. This required an exhaustive process, utilising the best available science to identify the appropriate sustainable level of extraction. Initially in the Guide to the Murray-Darling Basin Plan proposed a target of between 3,856GL per year and 6,983 GL per year needed to achieve the environmental health of the rivers of the Murray-Darling Basin. For socio-economic reasons (impacts on irrigation communities and there dependent industries and communities), the Murray-Darling Basin Authority assessed this would be too difficult for dependent communities in the Murray-Darling Basin, recommending 3,000-4,000 GL per year in its guide to the basin plan (Murray-Darling Basin Authority, 2010). Subsequently, the Murray-Darling Basin Plan recommended 3,200 GL per year, with 2,750 GL per year as the final initial target.

Recent decisions about the environmental water to be returned to the rivers of the Murray-Darling Basin, such as the proposed reduction of 70 GL per year from the Northern Basin (Murray-Darling Basin Authority, 2016a) have argued about the socio-economic consequences to irrigation industries without the background about both the considerable environmental costs but also socio-economic costs already incurred by the riverine environment, up until decisions were made to recover environmental water.

ii. *Environmental sustainable level of extraction*

There is some difficulty in defining this phrase because it varies at the scale of the river and is highly dependent on estimates of how much impact will be tolerated for the level of extraction. Many of the environmental indicators for the rivers of the Murray-Darling Basin are in decline (Murray-Darling Basin Authority, 2010; Davies *et al.*, 2012; Kingsford *et al.*, 2015). Environmental water is fundamentally important in returning some of the ecological health of the rivers but there is little evidence that there is sufficient environmental water to adequately restore the floodplains of the many of the major rivers, particularly those in the Northern Basin or Darling River tributaries.

c. Outcomes of the Basin Plan

i. *Socio-economic outcomes*

Clearly removing water from the irrigation industry can impact on irrigation communities and other dependent industries, although this is dependent on the way communities are affected in terms of water delivery. For buy-back, there will be particular willing sellers who will gain at the market price. In general, there has been relatively little analysis of economic costs of environmental degradation or the impacts of extraction of water on other communities (e.g. floodplain grazing). Further, these deleterious impacts are not confined to environmental values, with considerable impacts on livelihoods of floodplain graziers (Murray-Darling Basin Authority, 2016b; Fessey, 2017; Hall, 2017; Petersen, 2017) and Aboriginal communities and their cultural values (Murray-Darling Basin Authority, 2016c). Further, reductions in flow into Menindee Lakes as a result of upstream development of water resources have reduced Broken Hill's water supply to such an extent that the New South Wales Government now plans to build a 270km pipeline from the River Murray to supply the town at the cost of $500 million to taxpayers. These remain poorly considered in much of the decision-making on reaching an environmentally sustainable level of extraction. The cost of simply dealing with the lack of water reaching the Lower Lakes, the Coorong and Murray Mouth during the Millennium drought was estimated to be more than $2billion (Kingsford *et al.*, 2011b), including the desalination plant required to assure Adelaide's water supply. There were also significant other impacts on tourism, irrigation and environmental management.

ii. Giving effect to international agreements – Ramsar and Migratory bird agreements

Ramsar. There are 16 Ramsar sites in the Murray-Darling Basin, with many highly reliant on river flows (Pittock and Finlayson, 2011). Three of these sites are the focus of Article 3.2 notifications of the Ramsar Convention (Australia is a signatory), informing the international community that the ecological character of these sites had changed as a result of human impacts: Coorong, Lower Lake and Murray Mouth; Gwydir wetlands; and Macquarie Marshes. The latter two are in the Northern Basin. Narran Lakes Nature Reserve is also a key Ramsar site in the Northern Basin, with one of the main criteria for inclusion being its outstanding value for the breeding of colonial waterbirds (RIS (Information sheet on Ramsar Wetlands) - Narran Lakes, 2011).

The Murray-Darling Basin Authority commissioned research into the requirements for breeding (Brandis and Bino, 2016b; Brandis and Bino, 2016a; Merritt *et al.*, 2016), given the value of this site for breeding of waterbirds. These studies identified a threshold when breeding occurred. Researchers from the Centre for Ecosystem Science used historical ibis breeding data over five decades (1970-2016) to determine the flow requirements for colonial waterbird breeding and modelled the impacts of water resource management options (current and restoration) on breeding. We identified thresholds (>154,000ML in 90 days with a secondary threshold of >20,000ML in the first 10 days) of river flow volume, necessary to stimulate breeding. Water resource development reduced the frequency of large flows resulting in ibis breeding by 170%, from 1 in 4.2 years to 1 in 11.4 years. Restoration efforts by government to recover water for the environment was predicted to improve colonial waterbird breeding frequency associated with large flow events to 1 in 6.71 years, representing a 59% reduction from pre-development periods. This fails to meet obligations of the Australian Government or New South Wales Government in the management of this Ramsar-listed site. It is likely that there will be a future requirement for an Article 3.2 notification of the Ramsar Convention for this site. Further, there is a potential danger that there may not be sufficient water to complete a breeding event because of upstream extraction of water, requiring considerable cost expenditure by tax payers and risking considerable mortality of chicks, as occurred relatively recently (Brandis *et al.*, 2011b). In 2008, 74,095 pairs of ibis bred for the first time in seven years, establishing two contiguous colonies at Narran Lakes, a month apart. Most (97%) of the colony consisted of the straw-necked ibis (*Threskiornis spinicollis*) with the remainder consisting of glossy ibis (2%, *Plegadis falcinellus*) and Australian white ibis (1%, *T. molucca*). Following cessation of river flows, water levels fell rapidly in the colony site, resulting in a crisis management decision by governments to purchase and deliver water (10,423 ML) to avert mass desertion of the colonies. There were significant impacts on the reproductive success with only 17% of chicks fledging in late breeding birds as a result of falling water levels (Brandis *et al.*, 2011a).

Further in its recommendation to remove 70GL of environmental flow from the Northern Basin (Murray-Darling Basin Authority, 2016a), the Murray-Darling Basin Authority assessed Macquarie Marshes and Gwydir wetland systems with too much environmental water, based on hydrological modelling (see commentary on hydrological modelling). For the Gwydir, the assessment concluded that there should be a reduction of environmental flows of 14,000 ML a year and for the Macquarie, it is 12,000 ML a year, based on shared and local recovery (Murray-Darling Basin Authority, 2016a). This decision exposes the Australian and State Governments to criticism about not meeting their international obligations for these wetlands, given their current state of decline.

In addition, the ability of the environmental flow targets to adequately measure ecological impacts is uncertain. For example for the Macquarie Marshes, the four targets are relatively simple and do not adequately reflect the complexity of the system. There are also concerns that their specification does not adequately represent their variability, combined with the uncertainties of the hydrological modelling (see below). Further the application of 'cap factors' lacks transparency. Considerable rigorous research was done in the Ramsar-listed Macquarie Marshes to support decision-making (Ren *et al.*, 2010; Ren and Kingsford, 2011; Thomas *et al.*, 2011; Steinfeld and Kingsford, 2013; Bino *et al.*, 2014; Ocock *et al.*, 2014; Bino *et al.*, 2015; Catelotti *et al.*, 2015; Steinfeld *et al.*, 2015; Thomas *et al.*, 2015). Most of this research was not mentioned in the Northern Basin Review, despite its rigor and relevance to decision-making.

Current water recovery is not sufficiently providing for the ecological character of the three internationally listed wetlands which the Australian Government has publicly admitted to the international community are in ecological decline in the Murray-Darling Basin, as a result of direct and indirect human actions, primarily the reduction of river flows. The sustainable management of Ramsar sites was a major rationale for a federal role in the management of the rivers of the Murray-Darling Basin, through the *Water Act 2007*, taking over responsibilities of the states under the Constitution. It will reflect a failure in the *Water Act 2007* and the Basin Plan if the Australian Government does not adequately manage the sustainability of Ramsar sites. The recommendations of the Northern Basin Review will clearly reduce the ability of the Australian Government and the New South Wales Government to meet their state, national and international responsibilities.

Migratory shorebirds*.* There is increasing evidence that migratory species for which Australia has an international responsibility are declining (Gosbell and Clemens, 2006; Clemens *et al.*, 2016), across the continent. Inland survey data are also showing that migratory shorebirds are declining and some of this decline is due to the development of water resources on the rivers of the Murray-Darling Basin (Nebel *et al.*, 2008). Reduction in water recovery will further decrease habitats for migratory shorebirds species, particularly on floodplains.

Migratory shorebirds rely on wetlands such as the Macquarie Marshes, Narran Lakes, Gwydir wetlands, Menindee Lakes, Tallywalka lakes and Darling Anabranch lakes to provide resources while overwintering in Australia. All of these major wetlands are affected severely by reductions in flows from water resource developments. They are also potentially affected by the water efficiency projects (e.g. Menindee Lakes). Further reductions in flow recovery as recommended by the Murray-Darling Basin Authority will further impact on shorebird populations.

The Australian Government has international responsibilities for migratory shorebirds which was another major rationale for a federal role in the management of the rivers of the Murray-Darling Basin, through the *Water Act 2007*. It will expose the Australian Government to criticism in terms of not only not meeting the objectives of the Murray-Darling Basin Plan but also not meeting its international obligations, which were a major driver for the Australian Government taking control of the management of the Murray-Darling Basin.

iii. Environmental targets

Many of the environmental targets under the Murray-Darling Basin Plan cannot currently be met, given insufficient environmental flows. It is also clear that the increased environmental flows have improved wetland and riverine environments although separating out levels of difference between long-term variability and the role of environmental flows is difficult, given legacy and lag effects (Thompson *et al.*, 2017). Recent analyses of the recommendation on water recovery by the Murray-Darling Basin Authority for the Northern Basin found that only 22 of the 43 targets of the current Murray-Darling Basin Plan were met and yet they recommended a reduction in environmental flows. The major goal of the Basin Plan, supported by the *Water Act 2007*, was to restore the sustainability of the Murray-Darling Basin, including its wetlands, rivers and dependent organisms, ecological processes and ecosystem services. A substantial body of rigorous work underpins this analysis, setting targets for each of these river systems. For only about half to be achieved in the Darling River catchments, in the best case scenario, is a serious concern.

Although the environmental targets are an important index, they also only measure a fraction of the variability and complexity of river systems. They do not adequately measure impacts or restoration effects, as they rely on simple thresholds being met, with inadequate measurement of duration, sequencing or behaviour of flooding regimes, essential for sustainability. For example, environmental targets in the Macquarie Marshes modelled to be met in the Northern Basin Review (Murray-Darling Basin Authority, 2016c), did not adequately represent the complexity and reliance on flooding for maintenance of the environmental values of the Macquarie Marshes. Specifically there were four targets which were supposedly met, using hydrological modelling, under a 320 GL target, resulting in the recommendation to reduce the amount of environmental water to reach the Macquarie Marshes by 12,000 ML per year. Importantly, this process of decision-making neglected to take account of the multiple lines of evidence for the poor health of the Macquarie Marshes. These targets were thresholds of at least one event of a certain volume of flow, measured at Marebone Break (100GL and 250GL over five months and 400 GL and 700GL over seven months, June to April). There are seven reasons why these thresholds did not adequately represent targets that reflected the environmental sustainability of the Macquarie Marshes.

- There was no analysis provided of frequencies of when more than one flood occurred at the different thresholds. So, some flow volumes may deliver more than one flood (e.g. 390GL vs 320GL) but there was no measure of this difference in the assessment in the Northern Basin Review.

- Measurement of these indicators at Marebone Break, as opposed to Marebone Gauge is critical because of the different flow patterns. It was not clear what impact this could have on the assessments.
- The sequencing of floods was important. There was some spells analysis in the assessment but sequencing of different sized floods remains critically important for ecologically complex wetlands and this was inadequate to determine potential effects of different water recovery options.
- There was an assumption that different thresholds translate to flooding regimes on a linear basis. This may not be true. In addition, there will be complex hydraulic features that will be highly variable on the floodplain and affected in different ways by flow volume.
- Measurement of flooding at Marebone Break did not adequately measure the behaviour of creeks which contribute to the overall health of the Macquarie Marshes, including Gunningbar Creek and Marthaguy Creek.
- There was no measure of duration of flooding; this is a key indicator of the value of different types of floods.
- There was no transparency or connection between the scenarios modelled for the environmental outcomes (320a, 320b, 320c) and the final recommendation based on different models (most likely 320j but could also be 320i and 320k). It was not possible to know how the final models affected flow targets because these were not reported (only 320a, 320b, 320c results reported in the environmental outcomes report).
- The definition of the 'cap factor' was not transparent with significant implications for water recovery.

iv. Ecosystem resilience to climate change

Rivers and their dependent wetlands ultimately depend on the amount of water delivered in relation to its frequency, timing and duration (Kingsford *et al.*, 2016). Climate change impacts are affecting run-off and reducing long term river flow patterns in the Murray-Darling Basin rivers (Chiew *et al.*, 2010). In addition, temperatures are rising in the Murray-Darling Basin, reducing the amount of water reaching users for extractive use and the riverine environments (Chiew *et al.*, 2014). River dependent ecosystems are inevitably affected by reductions in flows (Kingsford, 2000b), but also reduced duration through increased evaporation. Relatively little is known of the long-term ramifications of such impacts on the ecosystems of the Murray-Darling Basin but they will exacerbate the negative effects of water resource development (Kingsford, 2011). Our recent analysis of the effects of a drying climate on waterbird populations estimated that environmental flows under the Basin Plan (2,800 GL per year) were projected to increase waterbird numbers by about 18% over pre plan levels but with projected climate change of a median climate scenario in 2030, this improvement was projected to decrease to 1% (Kingsford *et al.*, 2017a).

Further, the Murray-Darling Basin Plan has relatively little provision for adjustments to water shares, including environmental flows, under projected climate change scenarios (Pittock *et al.*, 2015). In addition, there is evidence that planned environmental water is reduced more than extractive forms of water, including held environmental water, under increased effects of climate change (Young *et al.*, 2011).

v. Water quality including salinity

Salinity in the Murray-Darling Basin rivers has increased with water resource developments of the rivers of the Murray-Darling Basin, exacerbating naturally high levels, dryland salinity and irrigation salinity (Jolly *et al.*, 2001; Goss, 2003). Increasing salinity in the Murray-Darling Basin through irrigation development and land clearing have mobilized salt which is increasingly concentrated in the rivers, requiring development of 18 salt interception schemes along the river which divert about a million tonnes of salt each year (https://www.mdba.gov.au/managing-water/salinity). Environmental flows are critical in flushing salt out of the Murray-Darling Basin Rivers (Goss, 2003). Such increasing salinity has negative impacts on the riverine environment, affecting organisms which depend on rivers (Nielsen *et al.*, 2003b), potentially decreasing plant and invertebrate diversity (Nielsen *et al.*, 2003a). In the Darling River, periods of low flow have contributed to increased salinity by allowing saline groundwater to enter the river (Murray-Darling Basin Authority, 2018), intensified by increased diversions (Meredith *et al.*, 2009). Increasing salinity can also exacerbate the blue-green algal problem because it decreases turbidity, allowing light to penetrate and stimulate algal growth (Bowling and Baker, 1996).

Blue-green algal (cyanobacteria) blooms occur when there are high nutrients and low flow. In the summer of 1991, the Darling River had the longest blue-green algal bloom recorded in the world, affecting more than 1,000 km of the river (Bowling and Baker, 1996; Donnelly *et al.*, 1997). Their toxicity (Baker and Humpage, 1994) and effect on water quality disrupt drinking supplies, pose a risk to livestock, wildlife and human health, because some species of cyanobacteria produce neurotoxins (http://www.agriculture.gov.au/water/quality/blue-green-algae). In the Darling River, flow and turbidity were more important than nutrients and seasonal temperatures in determining variations in density and community composition (Hötzel and Croome, 1994). Flows of 300 ML per day as an environmental flow were effective in removing established cyanobacterial blooms (Mitrovic *et al.*, 2010).Blue green algal blooms can increase with decreased flows (Bowling and Baker, 1996). For example, there was potentially an increase in blue-green algal blooms in the Darling River when the river was below a threshold of 500 ML per day (Bourke Weir, (Oliver *et al.*, 1999). As a result of increased water diversions and reductions in river flows, algal blooms have increased in the Barwon-Darling, with further increases after 2010 (Murray-Darling Basin Authority, 2018). There are also increasing probabilities of reductions in water quality including increasing algal blooms and increasing salinity. Increased algal blooms may affect human health, requiring a reduction in access to the river for human recreational activities (Pilotto *et al.*, 1997). Importantly, for landholders and urban areas supplied by water along the Darling River, toxins in the water may affect livestock and drinking supplies for people and should be avoided (http://www.agriculture.gov.au/water/quality/blue-green-algae). This necessitates the establishment of risk profiling and reporting for blue-green algal alerts (https://www.waternsw.com.au/water-quality/algae). For example, regular reporting occurs for NSW Rivers, including the Darling River where sites are identified if they are at dangerous levels (algal bloom) (https://www.waternsw.com.au/water-quality/algae#stay).

vi. Environmental water coordination

There is considerable need for environmental water coordination, given not only that different organisations are responsible for different amounts of environmental water (e.g. Commonwealth Environmental Water Office, NSW Office of Environment and Heritage, NSW rivers). There is reasonably good coordination among these agencies but there is a need for a clear unifying plan with objectives that ensure that all these agencies are focused on the same outcomes. This needs to be institutionalised within an agreement or policy framework. These arguments are presented more fully above in relation to water planning.

In addition, there is currently insufficient commitment by water agencies to delivery of environmental flows, including providing opportunities to release environmental flows when needed by the environment, different to other water users, issues of priority in relation to environmental needs if they clash with irrigation needs, ensuring that models for managing rivers adequately model environmental water and do not treat this as simply a diversion for irrigated agriculture.

There is also a need to protect planned environmental water. This requires coordination in terms of policy related to increasing effects of climate change among state and federal agencies. It is also important to adequately and transparently identify management rules used to determine dam management and water release rules (see discussion above).

6. Efficiency measures – achievement of enhanced environmental objectives

There is a long history of governments attempting to improve the 'efficiency' of river systems. For example, a bypass channel was constructed through the Macquarie Marshes to ensure that water flow was more efficient downstream. Water in wetlands was often considered 'wasted' (e.g. opening of Burrendong Dam on the Macquarie River, Kingsford, 1999b). All of these historical efficiency improvements have failed to adequately consider the ecological complexity of rivers and have caused long-term ecological impacts which have often become serious economic impacts requiring funding for restoration.

There is considerable commitment to 36 priority efficiency projects by Federal and State Governments. In general, there is little detail of the costs and benefits of these projects both in terms of financial, environmental and social (Wentworth Group of Concerned Scientists, 2017). Only one of 36 projects was sufficiently costed for a rigorous assessment of the costs and benefits (Wentworth Group of Concerned Scientists, 2017). The Australian Productivity Commission found that funding buy-back of environmental water from willing sellers was the most efficient and effective method for increasing environmental flows, rather than spending on infrastructure (Australian Productivity Commission, 2010).

For example, the Menindee Lakes is a large and important wetland system, ecologically, culturally and recreationally. It has significant numbers of waterbirds, including threatened species and migratory shorebirds which will be affected by the proposed developments of the system as an efficiency project. Essentially, governments are proposing a major engineering project which will reduce amount of flooding in Lake Cawndilla and ensure that Lake Menindee holds water less frequently. The system will have reduced habitat for waterbirds and is now known as a major source for golden perch populations reaching the River Murray. About 28% of Kinchega National Park is included in the wetlands. There are also major areas of Aboriginal importance along the Darling River and the lakes. Many people from Broken Hill and tourists also regularly use the lakes as a recreational destination. Despite all of these values, the costs and benefits of the project to the local environment are not transparently provided or presented. Equally, the water savings resulting from considerable public investment are not adequately and transparently provided to the community.

Ultimately, many of these efficiency projects do not pass any rigorous environmental assessment and lack sufficient detail on hydrological assessments. There is little rigorous environmental evidence or even analysis to demonstrate that many of the efficiency projects allow for a reduction in the quantity of water to achieve equivalent environmental outcomes with a smaller quantity of water. Usually this inadequately considers the groundwater and surface water interactions or the importance of connectivity or the critical value of floodplains. It is particularly important to consider the complexity of hydrological dynamics in such intricate and mult-connected systems. Engineering approaches to efficiency do not translate well to complex ecosystems. Finally, it is particularly important to ensure that ecological outcomes at places like Menindee are just as importantly considered as ecological and hydrological outcomes at sites such as the Coorong, Lower Lakes and Murray Mouth. There are many important ecological assets up and down the length of the Murray-Darling Basin, dependent on complex flow and flooding regimes.

7. Alleged or found illegal take of water – appropriate enforcement

The interim independent investigation into NSW water management and compliance (Matthews, 2017)(Matthews, 2017) was a welcome initiative by the NSW Government. It identified some clear concerns in relation to alleged corruption, as raised in the ABC Four Corners program, *Pumped* (Besser, 2017). It remains a concern that other policy processes including floodplain harvesting in particular, may also be affecting the outcomes of the Murray-Darling Basin Plan (including the management of environmental water). There is a considerable need to improve compliance efforts and ensure prosecution. For example, the NSW Government has demonstrated a poor response to enforcement of water law (NSW Ombudsman, 2017), a record that needed to be subsequently reduced because of poor attention to detail (NSW Ombudsman, 2018)

8. Protection of water purchased for environmental use from consumptive use

The importance of protecting environmental water in the Murray-Darling Basin and the complexity associated with doing so was clearly identified in the recent Matthews (2017) report. Specifically, he noted that “Protection of environmental flows is a major and complex issue…. [this report] observes the significant public concern about it, encourages intensified work by basin state officials on an enduring solution…”

In particular, it is critical that arrangements in relation to ‘shepherding’ of environmental flows to protect them from consumptive use (including via floodplain works) (Brewster, 2017; Davies, 2017) must be addressed (Steinfeld and Kingsford, 2013). This has been the subject of considerable discussion by the Commonwealth Environmental Water Holder and State governments and different Senate Inquiries and requires urgent attention.

Environmental water can be planned environmental water or held environmental water in relation to regulated and unregulated rivers. Held environmental water is managed as a right, similar to other forms of extractive use but for environmental outcomes. Currently there are some major challenges in the delivery and management of held environmental water. The following recommendations are made for improvement. Held environmental flows should be protected throughout the Murray-Darling Basin. This requires that it be protected when it move between connected river valleys and not be pooled into available water and later extracted. Environmental flows are not simply destined for one location as during extraction for irrigation; environmental flows serve a function all along the river system, ensuring longitudinal connectivity.

Both types of held and planned environmental water are potential vulnerable to illegal take. There are currently allegations for the Darling River system of unlawful extractions. In addition both types of water may be diverted for consumptive use through floodplain earthworks, or floodplain harvesting. Australia is increasingly recognized as developing world's best practice in water legislation and policy, particularly in relation to the Murray-Darling Basin water management. Despite this, there are inadequacies relating to the management of floodplain flows which could be addressed with appropriate amendments to Federal and State legislation.

It is important to underscore the importance of floodplains and their flows for the ecology of rivers. Much of the major sustainability problems affecting the rivers in the Murray-Darling Basin are related to major ecological impacts on floodplains, caused by the regulation of rivers and developments on floodplains (Kingsford, 2000b; Steinfeld and Kingsford, 2013; Kingsford *et al.*, 2015; Thompson *et al.*, 2017). These have affected the breeding of waterbirds (Leslie, 2001; Arthur *et al.*, 2012; Bino *et al.*, 2014), vegetation health (Mac Nally *et al.*, 2011; Bino *et al.*, 2015; Catelotti *et al.*, 2015), frogs (Ocock *et al.*, 2014; Ocock *et al.*, 2016), microbats (Blakey *et al.*, 2017) and even woodland birds (Selwood *et al.*, 2017). There have also been declines in inundation extent and frequency (Thomas *et al.*, 2015). Most wetland areas (>80%) on rivers are floodplains in the Murray-Darling Basin (Kingsford *et al.*, 2004).

These dependent organisms and ecological processes rely on overbank flows where floodplain harvesting and its licensing is critical. Most of these areas are also privately owned, where landholders derive a benefit from the overland flooding (Nairn and Kingsford, 2012). When such areas have reduced flooding, there can be considerable impacts on ecosystem services and social well-being and economic livelihoods (Fessey, 2017; Hall, 2017; Petersen, 2017). These impacts are increasingly recognized within government decision-making (Murray-Darling Basin Authority, 2016b).

This overall context is critical for understanding the potential effects of floodplain harvesting on planned and held environmental water. Reductions in river flows, particularly overbank flows, have caused many floodplains to contract in size and sustainability, exacerbated by developments on the floodplain to harvest or move water (Kingsford, 2015). In addition, considerable volumes which are not accounted for are diverted from rivers in New South Wales with floodplain harvesting, particularly threatening good management of the Darling River basin and its tributary rivers (Murray-Darling Basin Authority, 2017b). Little of this water has been included in Baseline Diversion Limits and was not included adequately in hydrological modelling underpinning either the Basin Plan or the Northern Basin Review. This is reflected in significant differences in estimates. For example, only 210GL was included for the entire Murray-Darling Basin, including 17.7GL for the Gwydir River catchment and yet the estimated volume in the NSW Water Reform Action Plan may be as much as 600GL for the Gwydir alone.

Despite more than two decades of understanding of the challenges of floodplain harvesting, the data underpinning good decision-making (i.e. locations, functions and size of structures (levees, channels, storages)) remains poorly known. Such data are essential and combined with multiple lines of evidence in monitoring could provide a useful platform for effective regulation and policy of floodplain harvesting.

Historically, developments, including those that access and alter flows on floodplains, have remained largely unregulated and outside the law or policy framework. Many governments have tried to address this issue by designating floodplains or drawing up guidelines for development. However, these frameworks are ultimately inadequate, not least of all because guidelines are ignored (e.g. Macquarie Marshes floodplains, Steinfeld and Kingsford, 2008). Furthermore, certain regulatory frameworks actually increase extraction from floodplains. For example, in the Lower Balonne, the Queensland Government has provided allocation of water for irrigation that used to flow across developed floodplains.

Finally, once structures on floodplains are developed, there is poor commitment to adequately dealing with unlawful structures that change flooding to downstream communities and their environments. These floodplains structures can be 'grandfathered' (e.g. NSW), essentially providing a right to water which was not within the policy or legislative intention at the time. The Murray-Darling Basin Cap of 1995, agreed by all Governments (albeit that Queensland agreed later) specified a halt to diversions at 93/94 levels of development.

Floodplain structures are very well developed in the Northern (Darling) Basin. Many cause considerable problems to environments, changing flow regimes, and also affecting agriculture downstream. These problems have been exacerbated in irrigation areas as a result of levee banks allegedly changing access to water resources for irrigation enterprises, as recently detailed in ABC Lateline report (Brewster, 2017). There are also other allegations that floodplain works may be diverting environmental water (e.g. Gwydir River, Davies, 2017). There is a clear need to adequately audit the locations and potential of structures to divert water across the Murray-Darling Basin and respect past policy decisions in relation to levels of development and diversions. Specifically, all floodplain harvesting earthworks and volumes diverted should be at 1994/1994 levels of development in New South Wales, Victoria and South Australia and 1999 levels of development in Queensland to respect the intent of the Murray-Darling Basin Cap. This is essentially because increased development is allowing for increased diversion of environmental water – in other words inadequate protection of environmental water.

There needs to be a sequential analyses, using available historic data (aerial photography, satellite imagery) of the development of structures capable of floodplain harvesting, including levees, channels and storages. In particular, this audit should be valley by valley and identify timing, location and size of each structure. Each should then be examined in relation to significant government policies related to floodplain harvesting including the Murray-Darling Basin Cap and the Basin Plan but also include guidelines by government for floodplain developments.

All floodplain harvesting structures capable of diverting planned or held environmental water need to be examined to first determine when they were built in relation to major government policies (see above) and then develop mitigation options for reducing the impacts of these floodplain harvesting structures on the diversion of environmental water.

The 'volume' or 'history of use' for establishment of the floodplain harvesting licence will be critical and needs to take account of a drying river environment, as this policy will probably favour extraction over the environment. If not, there is likely to be further overallocation of the water resource by establishing a volume for floodplain diversions. This is complicated further as the location of a structure on the floodplain and its frequency of inundation will determine how much water it can divert. This will need to be considered in providing the volumetric licences for works.

Previous NSW governments established floodplain guidelines in which no structures were to be built and flow could be unimpeded (e.g. Macquarie). Floodplains now have a number of structures built within the 'no development' floodways that affect the flow of the river and allow for floodplain harvesting of environmental water (Steinfeld and Kingsford, 2008).

Management of the diversion limits for river valleys relies on modelling changes to flows at different nodes on each river. It is critical that each valley reexamining the data used to set diversion limits, given that poor quality of data on floodplain harvesting and in anticipation of more rigorous and accountable data (see above).

9. Other matters

There are seven other matters which could be considered by the Royal Commission in terms of improving management of the Murray-Darling Basin Rivers to meet the outcomes of the *Water Act* 2007 and the Murray-Darling Basin Plan.

a. Agency technical expertise and support

There is a critical shortage of expertise for regulation and technical advice in relation to rivers of the Murray-Darling Basin. Much of the knowledge is held by relatively few people because of the complexity of the management system and its relationship to legislation and management. There is a need to recruit trained staff and improve current capacities and understandings for water management. Further, staff in some agencies such as the NSW Office of Water have been restructured recently, losing considerable capacity or knowledge. A key initiative for good policy and management would be to ensure that government agencies adopt a whole of government approach to water. This approached worked well in the NSW Government for a number of years in the late 1990s and early 2000s.

In addition, regulation of water use is a key issue of concern with relatively few staff and poor records of prosecution. There is a need to support staff involved in regulation and ensure they also have the necessary tools (e.g. remote sensing) that allows them to identify unlawful use of environmental water. In particular, there needs to be metering of all water diverted for consumptive use. There needs to be event based monitoring of floodplain harvesting using aerial photography, metering and satellite imagery and tracking each flow based event at the valley level. Such information is essential to adequately address this key issue and provide independent data and improve the modelling.

b. Multiple lines of evidence

There is a strong dependence for management of the Murray-Darling Basin Rivers on hydrological data and much of this uses hydrological models for understanding changes to rivers. There are considerable largely undefined or transparent uncertainties to these models on which significant decisions are made. Because this hydrological modelling lens extends to all rivers of the Murray-Darling Basin, it has become the main and sometimes the only major assessment process for determining options for environmental flow management and outcomes for the Basin Plan. It is a useful tool but there are significant weaknesses in its implementation (see below).

Policy makers and managers need to use the best available scientific evidence for decision-making, even if this is patchy across the basin. Currently there is insufficient use or tracking of other monitoring data for the rivers of the Murray-Darling Basin or the opportunities to use multiple lines of evidence for decisions.

c. Hydrological modelling

Hydrological modelling remains the primary analytical tool used to determine impacts of reductions in water recovery on environmental assets and communities. There were six issues of concern in relation to the presentation and output from the hydrological modelling in the Northern Basin Review, the main surrogate used for assessment of environmental and socio-economic impacts.

i. *Mismatch modelling to environmental assessment*

For the Northern Basin Review, environmental flow assessments for the final 320 GL per year threshold of water recovery were based on modelling scenarios 320a, 320b and 320c (Murray-Darling Basin Authority, 2016c). The final model scenarios on which decisions were made by the Murray-Darling Basin Authority to reduce water recovery from 390GL to 320GL was one of the following model scenarios 320i, 320j or 320k without accompanying environmental assessments. It was not possible to make an objective assessment of the environmental or other consequences of these different scenarios. This process lacked transparency. There were another five model scenarios (320d-320h) for which there was no output presented. It was not clear what had differed among all these different modelled scenarios. Most importantly, there was no prospect of a transparent assessment of the environmental effects of the final decision by the Murray-Darling Basin Authority on the water recovery. It was also not clear what role the "Toolkit" had played and what guarantee that the options for water recovery in the toolkit would be implemented.

ii. *Inadequacy of IQQM for measuring environmental impact*s

IQQM is the primary model used for managing NSW and Queensland rivers. There is good scientific evidence that current hydrological modelling does not adequately test effects of reductions to flow on inundation patterns of wetlands. A comparative analysis of IQQM (Integrated Quantity and Quality Modelling) modelling, used in the Northern Basin analysis, and a statistical analysis using actual flow data and rainfall for the Macquarie Marshes showed that IQQM underestimated impacts to wetlands significantly (Ren and Kingsford, 2011).

Specifically IQQM overestimated flows after development and underestimated flows before development in the Macquarie River and Macquarie Marshes. The result was an underestimation of hydrological impact of about 10% to one of the gauges (Oxley) in the Macquarie Marshes. These analyses, published in a peer reviewed international scientific journal, received no reference in any documentation of the Northern Basin Review despite their relevance to decision-making and interpretation.

iii. *No hydrological data for floodplains*

Compounding this problem of underestimation, hydrological models used for the Murray-Darling Basin assessments and the Northern Basin Assessments only had data for the main channels of rivers. There were no data to test the effects on the floodplain. So there is insensitivity to the importance of large flows on the floodplain which are critical for ecosystems because these are not adequately captured by the gauges in the main stem of the rivers. Consequently, the impacts of water resource development are underestimated as are the ecological importance of increased environmental flows for recovery. Hydrological modelling does not adequately measure impacts of a reduction in the water recovery on dependent plants, animals, other organisms and ecological processes.

iv. *Uncertainty of input data to hydrological models*

There was little transparency about the assumptions of the hydrological models and poor state of input data, critical for a complex mechanistic hydrological model used to assess changes to flows in the Barwon-Darling and its tributaries. Such complex hydrological models rely on many different variables, often with unspecified assumptions (Ren and Kingsford, 2011). In particular, there is poor understanding of actual patterns of water use in the northern river valleys of the Northern Basin, a key input into the hydrological modelling, particularly in relation to floodplain harvesting.

d. Cap factors and toolkit measures

Environmental water is highly dependent on a range of management tools and policies. In particular the challenges of using uncertain hydrological modelling, with adjustments for 'cap factors', supported in the Darling River Basin (Northern Basin) by the toolkit is considered integral to achieving cost recovery. There was a general lack of transparency about how this would be implemented across the Northern Basin and what audit or compliance issues can be put in place to ensure this occurs. There was also a general lack of transparency about how such savings measures actually provide additional environmental water. There seems little guarantee that different toolkit measures will necessarily be implemented as they are reliant on State process and would not be part of enforceable legislation.

e. Transparent reporting and auditing

There is an overall lack of transparency and accountability in water management. This affects the Murray-Darling Basin Plan and its implementation, which in turn reduces community confidence, as identified by the independent report into NSW water management and compliance (Matthews, 2017). Many of the rivers in the Murray-Darling Basin, particularly in the Northern River Basin of the Darling tributaries do not have metering which adequately records water diverted from rivers, particularly from floodplains.

Previously, there was reasonable auditing of water management by the National Water Commission and the Murray-Darling Basin Independent Audit Group to the public. These entities ensured transparent reporting on the state of Murray-Darling Basin rivers, water use and potential breaches of limits on diversions (previously known as the Murray-Darling Basin Cap).

In the spirit of introducing robust reporting frameworks, even this reporting was not completely effective as it failed to adequately assess and disclose information about interceptions on floodplains. It also relied too much on modelling outputs, without reporting of actual data (see solutions below). While modelling of river flows and changes are inevitably uncertain, it is clearly important to specify this uncertainty and also the many assumptions underlying hydrological models used for reporting and the quality of input data. The hydrological models primarily report on flows in the main channel of the river, not floodplain inundation. Such modelling tends to underestimate floodplain impacts (e.g. Macquarie River, Ren and Kingsford, 2011).

Just as importantly, there is a need for multiple lines of evidence in relation to water use. This can be achieved through use of satellite imagery, water meter data (with adequate compliance) and by monitoring developments on floodplains. The current modelling does not allow for transparent and rigorous reporting on water use, particularly in relation to floodplain flows.

- Modelling of environmental flow water needs to transparent, clearly showing that modelling recognizes where licenced water is delivered. Current modelling inadequately treats environmental flow volumes as if they are from the locations of the original extractive licences.
- There needs to be improved management of environmental flows to ensure that channel capacity constraints or delivery options are not driven by current practices which primarily favour delivery of flows for irrigation on town water supplies.
- There needs to be clear separation in the accounting of held environmental water, separate from planned environmental water.
- Metering of pumps needs to clearly demonstrate that held environmental water is not pumped for extractive irrigation use.
- Multiple lines of evidence need to be used for regulation and transparent reporting of access to planned environmental water, including modelling, satellite imagery, metering and water use by crops.
- There is a need to develop agreements with landholders where appropriate which allows for natural flooding to occur in the way that it previously did before river regulation. This may require the negotiation of flood easements.

f. Inadequate punitive powers to enforce the Water Act 2007 and Murray-Darling Basin Plan

The implementation of the Murray-Darling Basin Plan to achieve the objects and outcomes of the *Water Act 2007* depend on the States and Australian Capital Territory. There is currently no ability for the Australian Government to hold the States and Territory to account if they inadequately implement the Basin Plan. In the past, the National Competition Policy would apply to member states of the Murray-Darling Basin (Haisman 2004), with punitive measures be imposed if a particular State was not complying with the policies of the Murray-Darling Basin at the time. For example, Queensland faced national competition policy penalties for its intention to build a dam on the Condamine-Balonne River system at St George, affecting river flows in the Murray-Darling Basin.

Currently, there is no such mechanism available to the Australian Government. In such a key area of reform and investment by taxpayers, there is a need to re-establish such a mechanism.

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Appendix 1. Timeline of documented historical changes of Murray–Darling River flow-dependent ecosystems

See below for numbers matching supporting references

Period	Pressures	Plants	Invertebrates	Fish	Frogs	Turtles	Waterbirds	Other
1820–1900		Decline in wetland aquatic plants[1–5]	Decline in plant-associated wetland invertebrates[2, 3, 5, 6]	Decline in Murray cod abundance and distribution.[7–10]			Hunting impacts on some waterbird species[11]	Changes in wetland diatom assemblages, and increased salinity, nutrients, sedimentation and turbidity[1, 3–5, 12–14]
	Catchment and riparian vegetation extensively cleared, contributing to high erosion[15]			European perch, tench, common carp, brown trout and rainbow trout become established[16]				
	Grazing livestock, rabbits and foxes introduced							
	Alien fish species introduced							
	Commercial fishing, hunting of waterbirds and water diversions began							

Period	Pressures	Plants	Invertebrates	Fish	Frogs	Turtles	Waterbirds	Other
1900–1950	Commercial fishing and hunting of waterbirds increased	Decline in wetland aquatic plants[17]	Decline in plant-associated wetland invertebrates[17]	Decline in populations of native fish species. Rise of alien species[9, 10, 18–20]			Hunting impacts on egret populations and some duck species	Reduced platypus populations[21]
	Dams and weirs constructed, flows regulated, and water diversions increased	Wetland plants invade margins of Lower Murray weir pools[22, 23]	Wetland species – freshwater mussel (*Velesunio ambiguus*); yabbie (*Cherax destructor*) – become common in Lower Murray weir pools[24]					
	Gambusia introduced							
1950–2000	Dam and weir construction and floodplain development continued; water diversions continued to grow and peaked	Changes in composition and condition of vegetation communities,alteration of structure, including favouring invasive species[25–31]	Loss or decline of aquatic snail species in the lower Murray River[32]	Reduced range, abundance and breeding of many native species[33–42]	Reduced range and abundance of several species[43–47]		Decline in populations and breeding[48–56]	Increasing salinity,[57] increasing fragmentation of floodplains[58]
	Boolarra strain of common carp introduced to Murray–Darling Basin and rapidly dispersed and became abundant	Decline of *Ruppia* spp. in Coorong	Decline in distribution and abundance of Murray crayfish (*Euastacus armatus*)[59]					

Period	Pressures	Plants	Invertebrates	Fish	Frogs	Turtles	Waterbirds	Other
	Chytrid fungus accidentally introduced		Change in composition of Murray River fauna after about 1970[60]					Increasing occurrence of planktonic algae and cyanobacterial blooms[13, 61]
			Artemia replaces *Parartemia* in Coorong, South Lagoon					
2000–2010	Millennium Drought	Widespread canopy loss and dieback of floodplain eucalypts[62–67]	Reduced occurrence of drought-sensitive species[68, 69]	Reduced populations of drought-sensitive species[44, 70–74]	Reduced populations and recruitment of many species. Severe decline of summer-breeding floodplain specialists due to loss of refuge habitats[53, 75, 76]	Reduced populations of long-necked turtles[77]	Decline in populations and breeding[37, 50, 78–80]	Decline in water levels, salinisation and acidification of Lower Lakes[81]
								Changes to bird fauna with declines and partial recovery[82–85]
	Increased salinities and major water level recessions in Lower Murray, Lower Lakes and Coorong; riverbank collapse.							

Period	Pressures	Plants	Invertebrates	Fish	Frogs	Turtles	Waterbirds	Other
			Saltwater species, including tubeworm (*Ficopomatus enigmaticus*), invade Lower Lakes. Loss of freshwater mussel (*Velesunio ambiguus*) population in Lake Alexandrina[81]	Several small native species approached extinction and became conservation-reliant[86, 87]		Salinity in Lower Lakes caused short-neck turtle (*Emydura macquarii*) deaths from tubeworm infestation[81]		
2010–2015	Continuing water diversions, persistent alien species, anthropogenic climate change	Floodplain eucalypts partly recovered[88]	Some species that declined during Millennium Drought recovered but others did not[9, 69, 89]	Some species that declined during Millennium Drought recovered, but most did not[90–94]	Some species that declined during Millennium Drought recovered but others did not[53]			

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