

Water reform in the Murray–Darling Basin: a challenge in complexity in balancing social, economic and environmental perspectives

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Abstract

The Murray–Darling Basin is a very good example of a complex system. It is a complex system of environmental function in which snow melt and winter rain feed the south, while subtropical summer-dominant rainfall feeds the northern rivers. It is a complex system of re-engineering and readjustment of the natural and built infrastructure. It is also a complex system of human endeavour facilitating community adjustment and development, strongly driven by extremely high climatic variability and thus agricultural productivity, which is exposed to highly variable prices and demand for its produce. Then across the top of all this complexity is climate change, which is expected to impact further on increased climate variability. Thrust upon these complex interacting, biophysical, economic and social systems has been public policy in water reform to address the large over-extraction of water for agriculture from the rivers and groundwater aquifers of the Basin. Amidst all this complexity, public policy sought to return stressed rivers and groundwater systems to healthy conditions where floodplains, wetlands and riverine ecosystems regain a significant part of their ecological and hydrological function. Over \$11 billion will be spent on the Basin Plan—a complex system in public policy and we are only in the middle of it. Despite this huge expenditure, the policy choices and processes are yet to show evidence that public benefit in a healthy river will be achieved.

Background

The problems confronting the Murray–Darling Basin (MDB) today come from an unfortunate collision of biophysical and economic reality, cultural values and public policy (Williams and Goss 2002; Williams 2011). The clashes and tensions between values, choice of public policies and knowledge have created land and water use patterns that are not well matched to the biophysical constraints of an ancient, flat, salty continent set in a dry, highly variable climate zone. Agriculture and associated development in the Basin have contributed to economic growth and population wellbe-

ing equal to any in the modern world—but this economic growth has been achieved by exploiting the region's natural resources beyond their rates of replenishment. The result has been altered river flow regimes, rising salinity and acidity, loss of soil structure, increased loads of nutrients and sediments to rivers, and large-scale degradation of the rangelands. Measured by the invasion of environmental weeds and feral animals, the loss of flora and fauna species, and the breakdown of ecosystems, the environmental impacts are stark. The costs to the environment of the agricultural production systems are beyond dispute.

This collision of biophysical, economic, social and public decision-making systems can be seen as a clear case of the interactions and connections between at least four complex systems. Such level of complexity inherent in seeking to achieve water reform in the MDB has all the features of a well-known case of a “wicked” problem. It is not surprising, therefore, that it has continued to be a major issue in Australian public policy for over 100 years.

Because the MDB is a good example of a complex system, there is much we do not understand. What we do understand is often in isolated fragments. Some parts of the MDB complexity are discussed below, which will help to explain why there is such difficulty in bringing together a water reform agenda that will deliver healthy working rivers and groundwater systems. These are fundamental to sustainable irrigated agriculture and the diversity of other industries such as tourism, forestry and fishing, and in addition to conservation of the rich and diverse biodiversity of riverine wetlands and floodplain landscapes, which are part of our national and international heritage.

The major issue is how to bring the productivity, the economic resilience and the social wellbeing into play within the boundaries of a safe operating space for the biophysical and ecological functionality of the MDB.

The case for water reform in the Murray–Darling Basin

The story of water reform in the Basin is a long one (Connell 2007; Cummins and Watson 2012; Hart 2015a, b). I will focus on the recent period commencing with the MDB reform agenda of the 1990s, when there were repeated events and increasing

concerns (Mackay and Eastburn 1990) of declining river condition as reflected in rising salinity; algal blooms; loss of native crustaceans, fish and aquatic vegetation; large areas of stressed and dying river red gum forests; and a general decline in the ecological condition of the Lower Lakes and the Coorong.

Whilst the documentation and assembly of evidence was fragmentary, over this period an audit of water use and environmental status was conducted and published in 1995 (MDB Ministerial Council 1995). The audit recommended a cap be placed on the extraction of water from the Basin river systems, but it did not include groundwater. It demonstrated that the river systems were seriously stressed, largely due to excessive extraction of water for irrigation which had radically changed the hydrology of the Basin to such an extent that drought-like flows were being experienced in 61% of years. The MDB Ministerial Council (1995) report stated that the drought which would have occurred in “one in twenty years under natural conditions, is now happening in six out of ten years.”

This audit and the subsequent implementation of the cap ushered in the beginning of the most recent era of water reform in the Basin. Subsequently, increased investment in monitoring resulted in the development of a comprehensive suite of measures to characterise the ecological river conditions across all the rivers of the Basin.

In 2008 this culminated in the publication of the Sustainable Rivers Audit (SRA), which showed (as in Table 1 below) that the health of the river systems was not good and that most of the river systems in the Basin were in poor or very poor condition. This was further confirmed by the subsequent SRA in 2012.

However, the SRA program has now been abandoned. While there are still State and Commonwealth monitoring programs, they are fragmented and nowhere near as comprehensive and integrated as the SRA.

Health Rating	River Valley
Good	Paroo
Moderate	Border Rivers, Condamine
Poor	Namoi, Ovens, Warrego, Gwydir, Darling, Murray Lower, Murray Central
Very Poor	Murray Upper, Wimmera, Avoca, Broken, Macquarie, Campaspe, Castlereagh, Kiewa, Lachlan, Mitta Mitta, Murrumbidgee, Goulburn

Table 1: *Sustainable River Audit 2008 (Davies et al. 2008)*

Despite the limitation of monitoring there were sufficient data for the 2016 Australian State of the Environment (SOE) report to provide an assessment grade of very poor and deteriorating for the “state and trends of inland water ecological processes and key species populations” (Argent 2016). The SOE report further observes that there is “widespread loss of ecosystem function” in the Basin. The SOE also notes that, in terms of the “state and trends of inland water flows and levels” in the MDB, there has been no Basin-wide improvement since 2011 and that “longer-term downwards trends in flows seen in nearly 50% of stations, with no change in trends evident since 2011” (Argent 2016).

With the SRA discontinued, we are now dependent on limited and fragmented monitoring to assess trends in river and groundwater condition into the future. Will we have evidence to judge the success of our public investment, or is it something we will have to leave to the future? The driver for the water reform was, however, based on reliable, comprehensive evidence that the Murray–Darling River system’s health was as set out

in Table 1. It was poor or very poor for most of the rivers on which there was substantial extraction.

The poor health was based on the condition in terms of:

- flow regime incorporating volumes, periodicity and variability,
- aquatic plants and invertebrates,
- fish and bird life, as well as
- floods and flow regimes that are necessary for groundwater recharge and particularly for transport of salt from the Basin to the ocean.

A key driver for the impact of water extraction on river health and function is to understand the nature of rainfall variability over the longer term and observe how it was during periods of relative plenty that coincided with the rapid expansion in irrigation and water extraction in the MDB.

In Figure 1, the rainfall anomaly data for the Darling illustrates there is a period pre-World War II and pre-development that is quite different in its pattern to post-World War II and the period of rapid development of the MDB water resources. These two periods are indicated by the horizontal arrows in Figure 1.

The vertical arrows indicate periods of drought in the last 112 years. There were at least four significant droughts pre-World War II and two (see larger arrows in Figure 1) significant droughts since, with quite long periods of wet years, as indicated by positive rainfall anomaly. It was during this post-World War II period with long intervals of positive rainfall anomaly that the expansion of irrigation and water extraction occurred. This is shown clearly in Figure 2, when the water extraction and water storage history is laid over the rainfall anomaly pattern for the same period.

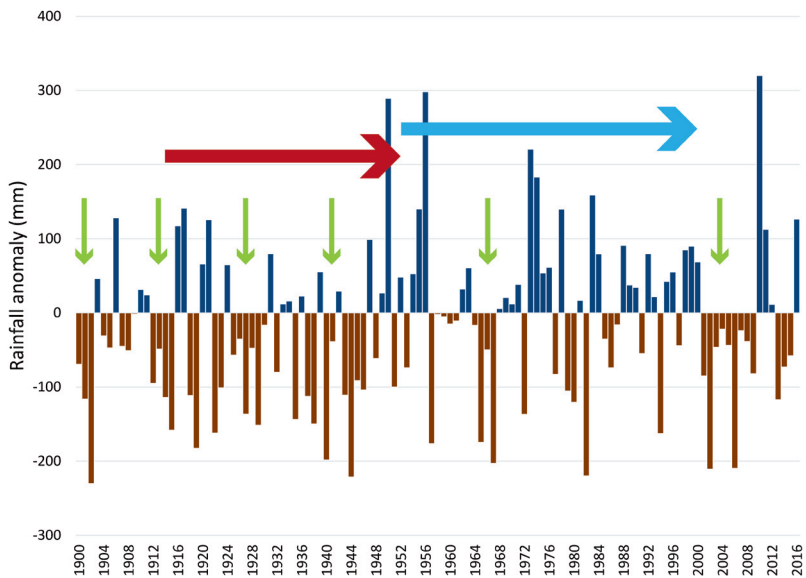


Figure 1: Annual rainfall anomaly in the Murray–Darling Basin, 1900–2012.

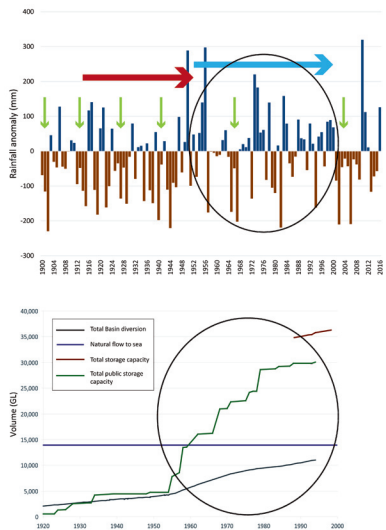


Figure 2: Rainfall anomaly in the Murray–Darling Basin set against the water extraction and water storage over 100 years of history.

Thus we seem to have set up our irrigation over a period that in general was considerably wetter than earlier periods of our history. It was not until 2000–2010 (when the Millennium Drought hit the MDB), that we

saw clearly the profound implications to the water security and environmental impact to the level and manner of water resource development. Figure 3 demonstrates the impact of water extraction on river flow regimes.

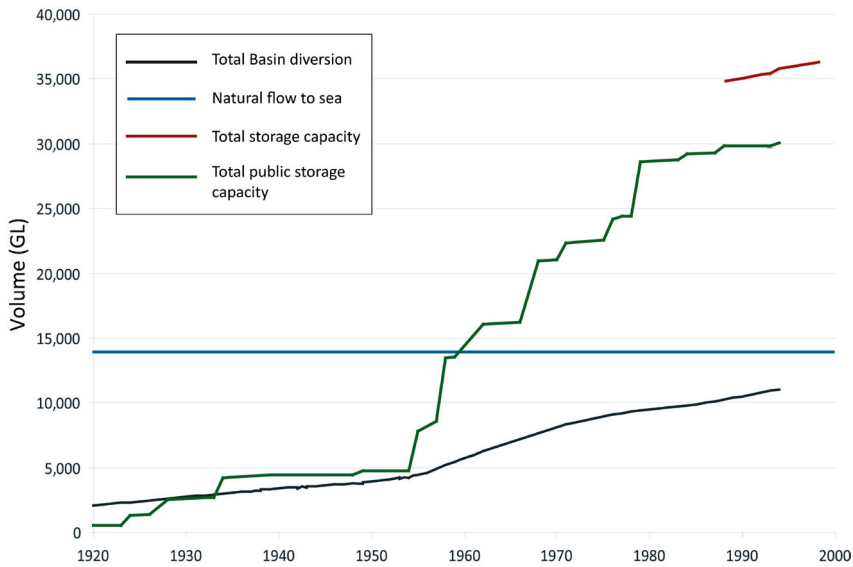


Figure 3: Storage capacity and diversions in the Murray–Darling Basin over time (Chartres and Williams 2006).

The long-term median natural flow from the MDB is about 14,000 GL/year. Since the 1960s, water extraction has steadily increased towards this level while built storage in dams and reservoirs increased rapidly to reach approximately 35,000 GL, or more than twice the annual volume that flowed to the ocean under natural conditions. As indicated earlier, this resulted in flows in the system equivalent to droughts that were now occurring in six out of ten years; compared to one in twenty years under natural flow conditions in which the ecological systems had evolved.

The key message is that to operate in this highly complex eco-hydrology under a highly variable climate, large storages are required. These large storages have a profound impact on the annual flow volumes but, more importantly, on the temporal patterns of floods and droughts within the floodplains, billabongs, wetlands and groundwater aquifers of the river system.

Growth in water use in the MDB since 1920 is set out in Figure 4 and highlights again the rapid increase in diversions from the late 1950s of around 4000 GL/year to over 11,000 GL by 1990. As discussed earlier, in the 1990s it was clear that the river system was stressed through over-extraction, and the evidence of declining ecological health was established.

The response was the historic intervention by the States, through the MDB Ministerial Council in 1994, to place a cap on further extraction beyond 11,600 GL/year. This courageous policy intervention caused enormous political conflict. It was strongly opposed in some quarters, resulting in a large campaign around the slogan “Zap the Cap” during the 1996 Federal election.

While generally Basin communities recognised that extraction had reached a limit, there remained a residual resentment and resistance to recognising that we had taken too much water from the system and we

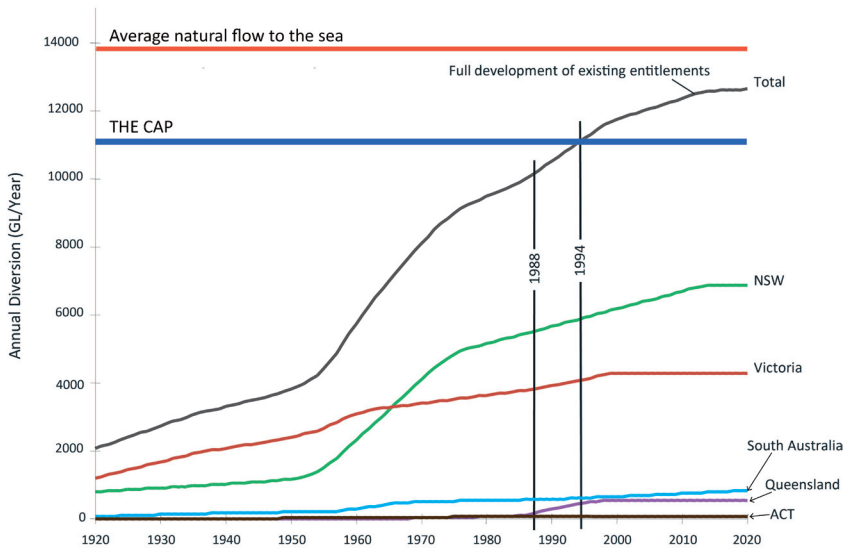


Figure 4: Growth in water use in the Murray–Darling Basin since 1920 (Chartres and Williams 2006).

needed to revisit how we operated. The facts were that available water was heavily used and this left a relatively small volume to service the ecological and hydrological functions of the river and groundwater system upon which healthy rivers derive their life.

It is important to realise that the surface water and the substantive groundwater systems that exist in the Basin are not separate—they are connected. Unless we have the large flows in the river channels and floods on the floodplains where the connections to the groundwater aquifers usually exist, we do not fill up the groundwater systems. Therefore, unless you have the Lachlan flowing and flooding in the north of the Lachlan, you do not have the groundwater in Hillston for our almonds. A flood in one place generates the groundwater and often the base flow in another place. It is a choice of where the water is used. If it is used so there is no flood, then it cannot be used in the connected groundwater. You can only

use it once! An Indigenous Elder once said to me: “When you think about water make sure you understand what it’s doing, where it is before you move it somewhere else.”

It is a critical, fundamental thing. Dams do not make more water—rainfall does. Further, having healthy rivers is not just so we have wetlands with rich fish and bird life. Healthy rivers are importantly about having flows and floods that replenish groundwater and have enough water movement to mobilise the salt that is always part of the Australian landscape, and move that salt to where it originally came from: back in the ocean. That is fundamental to the sustainability of irrigated agriculture in the MDB.

In Figure 5, at Wentworth, NSW, where the Darling River joins the Murray River, we have depicted the natural flows modelled and the observed flows under current water extraction over the 10-year period from 1998. It is clear that the flows are dramatically reduced, particularly in the

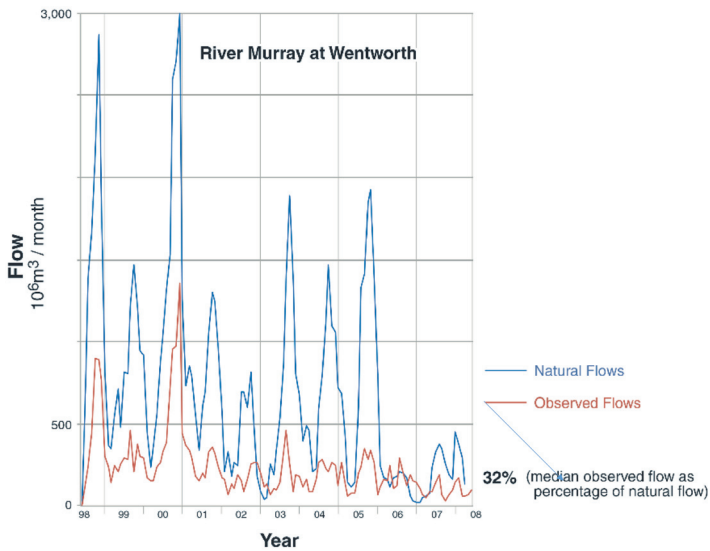


Figure 5: Murray–Darling River flow at Wentworth, NSW, over ten years from 1998 to 2008 (Grafton et al. 2014).

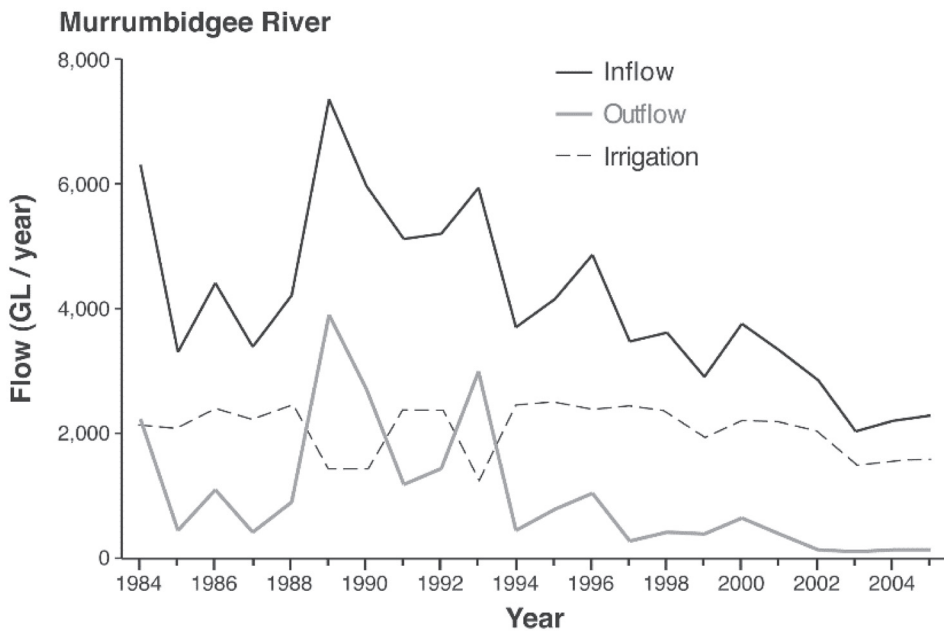


Figure 6: Murrumbidgee River at Balranald, NSW: inflow, outflow and water used for irrigation from 1984 to 2005 (Grafton et al. 2012).

higher-rainfall years. The large and moderate natural flows no longer occur. It is during the Millennium Drought that we see a most profound impact on the flow regimes of the MDB rivers. Severe and frequent droughts are imposed on the rivers and groundwater.

A similar story is told in Figure 6 for the Murrumbidgee system. The flow into the river system is compared to the irrigation usage and extraction with the river flow at Balranald, NSW. The profound impact on the river flow is clearly evident, while the

extraction for irrigation is maintained at a relatively constant level despite the high variability of inflow to the river and the overall declining trend during the Millennium Drought. The ecological and hydrological systems of the river bear the full burden of the drought conditions, to yield extreme drought impacts on the river function.

For an overview of the Basin as a whole, Figure 7 shows the mean long-term (115 years) inflows, extractions and the impact of the extractions on the end-of-Basin flows

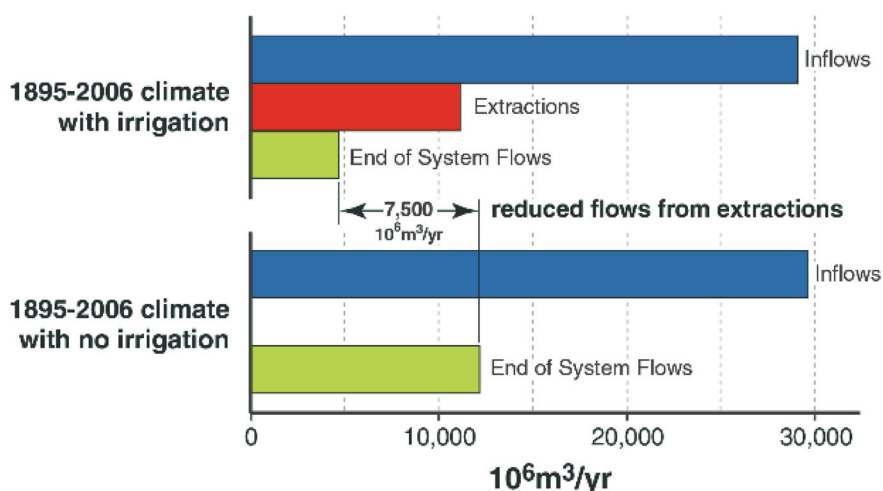


Figure 7: Inflows, end-of-system flows and extractions with and without irrigation for the Murray–Darling Basin from 1895 to 2006 (Grafton et al. 2014). Note: 1 GL = 10⁶ m³.

compared against modelled long-term natural flows where there is no extraction for irrigation. Overall, end-of-system flows are reduced by approximately 7500 GL. However, the consequence is not that simple. There are other factors (beside water flow) that determine river health: flooding, management of feral animals in the water (for example, Carp), and management of grazing systems on our floodplains.

While the graphical data of Figures 5, 6 and 7 tell the story of the profound impact on both the magnitude and pattern of flows in the MDB, Figure 8 attempts to visually show the magnitude of the extraction relative to the natural flow for the Murrumbidgee River. The left image is a supply channel in the Murrumbidgee Irrigation Area; and the right image is the Murrumbidgee River near Canberra during a high-flow event. The large

Clearly the major part of the Murray–Darling is the Murrumbidgee and the Murray rivers. Both are largely fed from snow melt and are located in a higher rainfall zone, dominated by winter rainfall. The southern system is more easily managed than the northern system based around the Darling River and its northern tributaries, which are fed by highly variable summer-dominant rainfall patterns where much of the variability is driven by the sub-tropical effects of the monsoon. The result is extensive flooding over large floodplains interspersed by low flows and drought.

The opportunity for dam and reservoir storage in the Darling system is relatively small at 4700 GL, compared to the southern rivers’ storage capacity of around 16,300 GL. This further adds to the complexity of management for sustainable irrigation.

The very shallow Menindee cluster of lakes represents the largest storage in the northern Basin of around 1760 GL with an annual evaporation of over 1300 GL per year. The annual variability in the north is very high coupled with a relatively small storage; whereas the south is also high but this is mitigated to some extent by the contribution of snow melt to the flow regime.

Not only is the MDB a complex biophysical system driven by temporally and spatially highly variable rainfall, which together have shaped the landscape topography in which ecosystems have evolved to accommodate these circumstances to produce a rich and diverse biodiversity that stands tall as a globally important natural heritage. It is also home to 35 endangered species of birds, 16 species of endangered mammals and over 35 different native fish species.

In the MDB, a river is much more than the main channel. Our river is a system of connected floodplains, billabongs, anabranches and nearly 30,000 wetlands. Figure 10 depicts in cross-section the nature and functions of the MDB river system.

Flooding is fundamental to the life of these river systems. Floods connect the main channel to the multiple levels of floodplains, the anabranches, the wetlands, billabongs and backwaters. It is here that water connects to the groundwater aquifers and replenishes them during floods, and in drought and dry times support the red gum forests and provide base flow to the main channel. It is these backwards and forwards flows that drive and nurture the ecological function and, ultimately, the river system health.

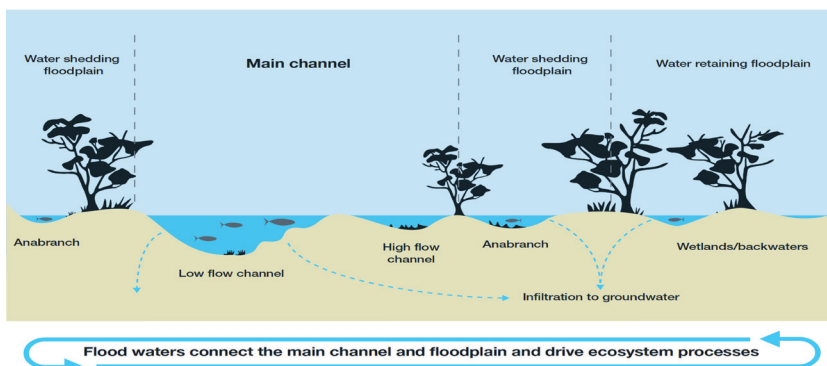


Figure 10: Cross-section of the ecological and hydrological functions in a riverine red gum forest in the MDB (Natural Resources Commission 2009).

Much of the Basin is flat, therefore rivers meander, and anabranches, billabongs and wetlands form. In this river geomorphology, for the river to function as it has evolved, flooding sequences are essential. In order to live, the river system needs to have water flowing out of those main channels into anabranches, billabongs and wetlands. This is where life cycles are re-ignited; food webs and a multitude of ecosystem functions are established. These are the places which drive the health of the river system. Where river metabolism kicks into life; where energy is captured as carbon and nutrients are fixed into emerging ecosystems; where algae, aquatic plants, small crustaceans generate a feed stock; and whole parts of the ecosystem then flow back into the main channel to nurture the aquatic ecology of a healthy main channel. This is the engine room—in some ways the stomach and in some ways the lungs of the river—and if you disconnect a river in the Murray–Darling from its stomach and its lungs, you can expect trouble. That is why over-extraction which significantly changes the flow regimes of the river system requires intervention to recover these functions. This is one of the key issues that we face.

Steps in Basin water reform: how much water is needed to return rivers to a healthy condition?

As outlined previously, in the 1990s, river health was in decline, the cap on extractions was introduced, data were collected, and the best science indicated that large volumes of water needed to be returned to the natural flows of the Basin rivers. Preliminary expert estimates suggested (Jones et al. 2002) at least 4000 GL/year needed to be removed from the volume extracted and that volume returned to the natural flow regime of the

rivers. This was a large amount of water when set against the cap of 11,600 GL/year, a reduction in extraction of 35%.

Toward the end of the 1990s, there developed between scientists, senior state and federal officials, and visionary politicians of the time a recognition that water reform was essential. New ideas and innovation would be needed to bring about the magnitude of reduction in water extraction required, as indicated by the emerging science. Following the fierce debates over the establishment of the cap on further water extraction, an accord emerged between the state and federal governments that has often been overlooked but which was fundamental to making the reform happen.

The accord was conceived where public water licences, after being separated from land, were to be converted by the State governments to a tradeable private property right. This water entitlement generated an allocation of water dependent on the seasonal rainfall patterns and storage capacities. In return for this exchange, water would be returned to the rivers by the government purchasing back from willing sellers the entitlement and their allocations to yield healthy working rivers. This was a huge reform and innovation in the development of water policy. It is the central principle behind the policy development within the National Water Initiative (NWI) designed to achieve sustainable water use in over-allocated or stressed water systems. In particular, the state and federal governments agreed:

... to implement this NWI in recognition of the continuing national imperative to increase the productivity and efficiency of Australia's water use, the need to service rural and urban communities, and to ensure the health of river and groundwa-

ter systems by establishing clear pathways to return all systems to environmentally sustainable levels of extraction” (NWI 2004).

This was the *quid pro quo*. The conversion of a water licence to a tradeable private property right meant transferring a huge amount of wealth from the public sector to the private sector. In fact, the property rights to water are now worth \$47 billion in 2012. This was done because it was seen as a just, fair, transparent and socially acceptable means to bring about a very large adjustment in the amount of water which could be extracted from the rivers. The NWI and the subsequent Water Act recognise this principle but it is often forgotten in the public discourse.

How much water is needed to return all stressed and over-extracted systems to environmentally sustainable levels of extraction? That is a challenging question scientifically because returning rivers to healthy conditions is not just about returning a volume of water. There is much complexity in how and when the volume is returned to generate the required flow regimes in both time and space, but, importantly, there are other factors in river and floodplain management which must be addressed, along with the return of water to move rivers back to a healthy condition. As previously indicated, the earliest attempts in 2002 to answer this question used expert panels and it was estimated for the Murray River alone that some 4000 GL/year was required to generate a return to good condition.

In 2008, using the best modelling available, the Wentworth Group (Wentworth Group 2008) concluded that approximately 4350 GL/year would be required. In 2010, the Wentworth Group (Wentworth Group 2010) indicated in more detail that 4400 GL/

year was the amount required to generate a good chance of returning the Basin rivers to healthy conditions.

The MDB Authority (MDBA 2010) then published in 2010 the *Guide to the proposed Basin Plan*, which was designed to give people a sense of the scope of the Basin plan. Their work indicated: that 3860 GL/year was the minimum (which had a low likelihood of success in achieving healthy rivers across all the Basin); and to achieve a high likelihood of success, the volume required to be returned to the river was as high as 7600 GL/year. When released, the magnitude of the reform shocked the irrigation communities in the Basin. These communities had never previously been exposed to the magnitude of the reform that was required.

Steps in Basin water reform: determination of a Sustainable Diversion Limit (SDL) for surface and groundwater

The political response to community concerns following the release of the *Guide to the proposed Basin Plan* caused a rethink in the development of the Basin Plan. Added to the biophysical complexity of determining a Sustainable Diversion Limit (SDL) was the complexity of incorporating social and economic analysis and negotiation in the determination. There was a clear recognition that water reform of the magnitude required to return the stressed rivers to healthy conditions had to urgently address the social, economic and community concerns (although it was clear the Water Act gave ultimate priority to the environmental sustainability of the river system).

The work to 2010 suggested that the volume of water sat around a 35% reduction in current levels of extraction and implied a SDL would be approximately 65% of the

current cap (11,600 GL) at approximately 7540 GL/year. The MDBA recognised the need to establish a consistent language and a process to move beyond the work of the *Guide to the proposed Basin Plan*. They adopted a process as set out in Figure 11 for determining a Sustainable Diversion Limit (SDL) in the Basin.

Key in this was the establishment of an Ecological Water Requirement (EWR) derived from the identification of the ecological and hydrological assets and their functions. The MDBA then set about determining the social and economic impacts of reducing current extraction by the EWR along with the legal and engineering/infrastructural constraints of delivering the EWR to the river systems. These are complex considerations and invariably resulted, as far as the published information allows, generally in a much larger SDL than indicated by the EWR.

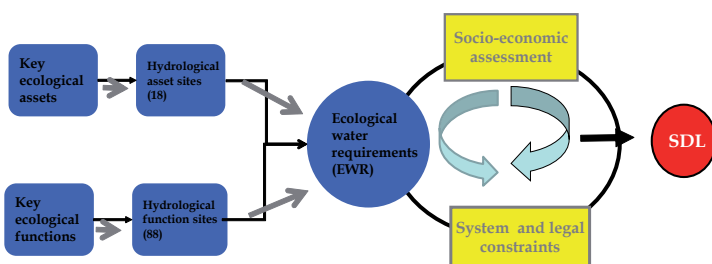
While the process outlined in Figure 11 is rational, it is an open question as to whether it complies with the intent and purpose of the NWI and the Water Act—both of which gave clear priority to returning rivers

to healthy conditions. Unfortunately, the process and analysis used to arrive at the SDL were opaque at best and certainly not open and published in a transparent manner.

The recommended reductions in extractions in the *Guide to the proposed Basin Plan* were revised downwards to 2750 GL/year when the Basin Plan was enacted in November 2012. The science to support this figure is a mystery to me. I do not understand the science, economics, social science or engineering used to arrive at this figure of 2750 GL/year. I have never yet seen the quantitative evaluation of this calculation. This is despite the fact that a study in 2011 by CSIRO (2011, p. vi) concluded that an increase in environmental flows of 3000 GL/year, based on long-term averages, would be insufficient “... to meet the South Australian environmental water requirements” and would also be insufficient to meet the salt export requirements specified by the MDBA.

In fact the lack of an open explanation of the basis for the recommended SDL in the Basin Plan led the Australian Senate Standing Committee on Rural and Regional

Balancing



Courtesy Professor Barry Hart, MDBA

Figure 11: The process and tasks required to establish a Sustainable Diversion Limit (SDL). Kindly supplied by Professor Barry Hart, member of the Murray–Darling Basin Authority.

Affairs and Transport Inquiry into the Management of the MDB in March 2013, to recommend the MDBA provide a “concise and non-technical explanation of the hydrological modelling and assumptions used to develop the 2750 GL/year return of surface water to the environment within the Basin Plan.”

The Senate findings (The Senate 2013) supported the disappointment and concerns I have on the size and nature of the SDL recommended and adopted in November 2012, when the Murray–Darling Basin Plan was enacted to give effect to the *Water Act 2007*. In December 2012, after further analysis and debate, it was negotiated that the 2750 GL return of environmental water to the river system should be increased by 450 GL to 3200 GL, provided funding of \$1.7 billion of new money could be found for this 450 GL of additional environmental water.

It is important, at this point, to appreciate that the SDL is computed by first ascertaining the Baseline Diversion Limit (BDL) established in the Basin Plan for the entire Basin. Then the SDL is equal to the BDL less the water to be returned to the environment, which is the 2750 GL/year, or, if funds allow, 3200 GL/year. The BDL was established at 13,623 GL/year (MDBA 2012, p. 28) and exceeds the annual total volume of surface water extracted in the Basin in any year from 2000 to 2001 through to 2014 to 2015, or in any year prior to setting of the cap (11,600 GL/year) in 1995. The BDL was calculated by adding to the traditional extractions of 10,636 GL/year and stream diversions of 267, the interception of plantation (2384) and farm dams (336) to yield 13,623 GL/year. Setting a BDL at such a high level has the net effect of increasing

the reliability of existing water entitlements in terms of their long-term average water allocations, but reducing the effectiveness of water recovery in terms of increasing environmental flows.

By increasing the Baseline Diversion Limit by 2720 GL/year (2384 + 336) above what it was, and then reduce this by 2750 GL/year would appear to be an exercise in smoke and mirrors. What have we really done?

Nevertheless, this is the situation. The planned reductions in extractions and returns to the environmental flows result in a planned SDL for the Basin of 10,873 GL/year. Recall that the cap in 1995 was set at 11,600 GL/year. Have we in reality only reduced the extraction beneath the cap by 727 GL/year? Now let us consider the groundwater story.

While the Basin Plan intended to reduce permissible surface water extractions by 2750 GL/year, it actually increases permissible groundwater extractions by 1548 GL/year (Pittock et al. 2015), from 1786 GL/year to 3334 GL/year based on long-term averages. This is despite the fact that surface and groundwater are highly connected in the Basin and that increased groundwater use lowers base flows to rivers (Evans 2004). The science and analysis to justify this very significant increase is not available for scrutiny and public explanation. It has not been subject to open, transparent peer review. Once again mystery surrounds another key plank in the Basin Plan. Therefore on paper we have reduced the surface extractions but we have increased the groundwater extractions.

At this point in time, the pattern of water reform in the Basin appears as follows.

As of June 2016, the Commonwealth Environmental Water Holder indicated that

approximately 1981 GL of the 2750 GL had been recovered for the environment, of which about 1165 GL of entitlement was purchased by tender from willing sellers, and approximately 602 GL has been calculated to arise from infrastructure and water use efficiency projects and from State Government assignments.

Issues arising from complexity at the interface of biophysical, social and economic systems

The diagram in Figure 12 should help to put this complexity into perspective. The task ahead is first to implement water policy reform which ensures the health of river and groundwater systems by establishing clear pathways to return all systems to environmentally sustainable levels of extraction. That is complex in itself, but the task must also include measures that achieve this whilst managing the economics and social impacts of the water reform. It is clear now — and it was to some in 2010 — that you cannot take 3200 GL of water (a 23.5% reduction) out of the irrigation system without social and economic consequences. No environmental reform can ever, in my view, be implemented without consideration of the tasks to manage the social and economic impacts

of change. The MDB is no different. Yet we have attempted a major water reform with little attention given to the management of the social and economic impacts (other than to back away from the objective of the water reform if there is an economic impact).

The complexity of the MDB can be visualised with at least three complex systems interacting together which will ultimately determine the environmentally sustainable level of extraction. First, the biophysical nature of the rivers, groundwater landscapes and their embedded ecosystems will interact to yield the EWR. Second, the Social and Economic Systems (SES) which have evolved to utilise and redistribute the water, land and ecological resource. Third, the natural and built infrastructure, collectively a complex system of engineering, policy, legal and management yielding Infrastructure System Constraints (ISC) to allow water to be delivered to the hydro-ecological assets.

The river system that has been designed for irrigation (built infrastructure of dams, reservoirs, weirs, channels, roads and bridges), will seriously constrain the delivery of water to floodplains, billabongs and wetlands as in natural flows. The built infrastructure on the floodplains are very significant constraints to returning natural flows and func-

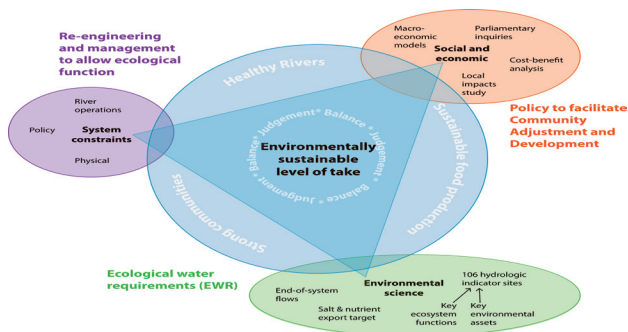


Figure 12: The complex system of the MDB into which the water reform task is cast. Kindly supplied by Professor Barry Hart, member of the MDBA.

tions essential to healthy river functions (see Figure 10).

A key task is the re-engineering and management to allow ecological function. For water reform policy to be effective, it must address the management of at least these three interacting complex systems. No wonder the struggle has a long history.

Given this understanding of the complex system, what progress has been made to date?

Since the publication of the *Guide to the proposed Basin Plan*, any evidence of a transparent scientific analysis and synthesis to provide a defensible prediction of the EWR as a means of determining the SDL has been abandoned. The science leading to the prediction and establishment of the EWR has, in my view, not been done in a way that is open to scrutiny. Obviously the political judgements will come as you put the three parts of the triangle together (see Figure 12), but first the science underpinning the EWR estimate and its likelihood of generating healthy ecological conditions for the rivers must be transparently provided. Let us get the science clear so we know what the risks are that we are working with in order to then make social and economic choices.

ISC are still to be resolved. How do we flood private land—and often public infrastructure—in order to have wetlands and billabongs begin to function again? Investment in re-engineering to minimise these constraints and maximise the re-establishment of natural flow patterns in the landscape has not received the attention it requires.

Social and economic analysis is required to inform policy development in order to assist communities to accommodate the Ecological Water Requirement. The volumes

of water required to be returned to the rivers are large, at approximately 25% of current extractions. Therefore economic adjustment and social impacts can be expected to be significant and require community development and adjustment interventions.

The 2010 Wentworth Group statement (Wentworth Group 2010), built on research conducted by The Australian National University, outlined the importance of recognising that regional and local community adjustment and development would be necessary if approximately 4000 GL/year was returned to the river system. Their report stated: “The scale of the water reform to restore the health of rivers, wetlands, floodplains and the estuary in the MDB is daunting. It can only be achieved by working with the communities of each catchment affected to bring about these reforms.” An environmental reform of this order must have a pathway to manage the actual social and economic impacts.

The economic impact of a 30% reduction in extraction was computed to be approximately 10% across the whole Basin. But in the Murray and Murrumbidgee rivers, which hold most of the water entitlements, the economic impact was computed to be approximately 12% and 25%, respectively. These are not economic impacts that can be accommodated without active policy and regional development programs to assist community adjustment.

Unfortunately, the Basin Plan did not have any policy or program of the magnitude and form appropriate for the task. However, the Wentworth Group (2010) did point to a policy option which focussed on water purchase to obtain water entitlements which were returned to the river. A large proportion of the “Water for the Future” program funds could be devoted to provide

financial assistance to the communities in the Murray–Darling catchments, such as investments in public infrastructure to help adjustment to a future with less water.

The School of Social and Policy Studies at Flinders University has developed the “Thriving Communities” model (Miller and Verity 2009; Miller 2011) based on an inclusive social and economic development approach. This model could provide the basis of this community development approach whereby the level of funding available to each affected community would be based on the economic impact resulting from the withdrawal of water for consumptive use in that district. In some of the worst affected communities, these amounts would need to be significant. With this financial support, some communities might decide to move out of irrigation and branch into new industries. Others might prefer to consolidate their irrigation industry and use the funds to invest in new water technology or to add value to their products. However, this decision would be made for the benefit of the whole community, not just individual irrigators.

In the current implementation of the Plan, funds flowing from the direct purchase of water entitlements are for much smaller amounts than where most funding is allocated, mainly for the refurbishment of principally on-farm infrastructure to increase Water Use Efficiency (WUE). The consequence is that practically all funds go to irrigators and thus to only one sector of the community which is confronted by the adjustment to the water reform impacts.

The complexity resulting from the interaction of the three systems depicted in Figure 12 makes water reform policy in the Basin a very demanding task indeed. My impression

is that the policy development as reflected in the Basin Plan and its resourcing and implementation through the “Water for the Future” program has struggled with this complexity and is yet to find the ways and means to bring it together.

The evidence at hand is that the understanding of the three systems has been less than adequate and neither have the systems been subject to open transparent analysis. The science underpinning the EWR has been disappointing; the clarity and transparency of the socio-economic examinations have lacked depth and consistency and have not adequately informed a policy to drive the significant regional and community adjustment and development required; and the attention to the legal operation management of ISC was not recognised early in policy development and has yet to be resourced adequately to drive effective delivery of the EWR.

The policy options for returning water for river and groundwater health

Two policy options to obtain water for return to the river and groundwater were: first, a direct purchase of entitlement and allocations from willing sellers; and, second, of water recovery through infrastructure subsidies and supply measures.

Until 2014, the Australian Government spent approximately A\$2.3 billion acquiring water entitlements from irrigators using reverse tenders, but such purchases have now been halted (Hunt et al. 2015). The average cost to the Australian Government of acquiring such water entitlement purchases has been about \$2000 per megalitre (and in some instances as low as \$884 per megalitre). This is much less than the costs from acquiring water through infrastructure subsidies (Grafton 2017).

Consequently, the cost to the Australian Government to acquire the 2750 GL/year required under the Basin Plan entirely from the purchase of water entitlements would have been approximately \$5.5 billion, while currently it is projected to spend \$8.9 billion to achieve the same volume of water recovered through the increased use of infrastructure subsidies and supply measures (Grafton 2017) operating both on- and off-farm, such as the Sustainable Rural Water Use and Infrastructure (SRWUI) initiative under the “Water for the Future” program.

As stated by Grafton (2017) it is now very clear “Notwithstanding the effectiveness of water recovery through infrastructure subsidies and supply measures, the economics of such an approach is highly questionable.” For instance, according to the Productivity Commission, the “... Australian government may pay up to four times as much as recovering environmental water through infrastructure upgrades than through water purchases. In other words, a premium of up to \$7,500/ML may be paid for recovering water through infrastructure upgrades...” (Productivity Commission 2010, p. 129).

Despite this evidence, the direct purchase of water entitlements by the Australian Government has been halted and “Water for the Future” funds are now used almost entirely for water recovery through infrastructure subsidies and supply measure programs. While many irrigators claim that such purchases negatively affect both irrigators and their communities, the evidence is contrary to these claims in that direct purchase of water entitlements by willing sellers increases, rather than decreases, the gross domestic product in the Basin (Wittwer and Dixon 2013).

As shown by Grafton and Jiang (2011), even with very large reductions in surface water extractions (30%), such buybacks from willing sellers impose very much smaller decreases (1–2%) in the gross value of irrigated agriculture and also irrigation profits. This is because water trading between regions in the Basin provides an effective way to mitigate reductions in surface water extractions (Grafton and Horne 2014; Kirby et al. 2014). The benefits of trade can be very large, approximating \$1.5 billion in 2007–08 during the worst year of the Millennium Drought (National Water Commission 2012, p. xii).

Figure 13 sets out the hydrological flows between the farm and the hydrology of the landscape. It demonstrates that gains in WUE cannot lead to increased water recovery unless the volume of water extracted is decreased by a greater amount than the reduction in water losses in surface and drainage past the root zone. Gains in WUE must result in a reduction in return flows to the landscape hydrology unless the subsequent reduction in extraction exceeds the losses or return flows. This is captured in Figure 13, where the numerical example for most irrigation is set out. If WUE is able to reduce return flows of 30 units to zero, under current agreements, then half of the return flows (30 units) are reduced in volume extracted from 100 to 85 units.

Overall, the consequence is that returned flow is halved, from 30 to 15 units. This is well-recognised in the literature (Batchelor et al. 2014; Adamson and Loch 2014; Qureshi et al. 2010) and noted by the Productivity Commission (2006, p. 171), “Capturing return flows that contribute to downstream allocations, for example, does not create overall system savings,” yet is not appreci-

ated or recognised in the water reform policy of the Basin Plan.

In short, the dependence in the Basin Plan on water recovery through infrastructure subsidies and supply measures to yield WUE improvement is fundamentally flawed. Not only is it more costly than direct pur-

chase of entitlements, it cannot deliver water recovery as advocated because it is based on fundamentally flawed hydrology.

However, it is more complex, as the surface drainage and drainage losses beneath the root zone from irrigation become increased

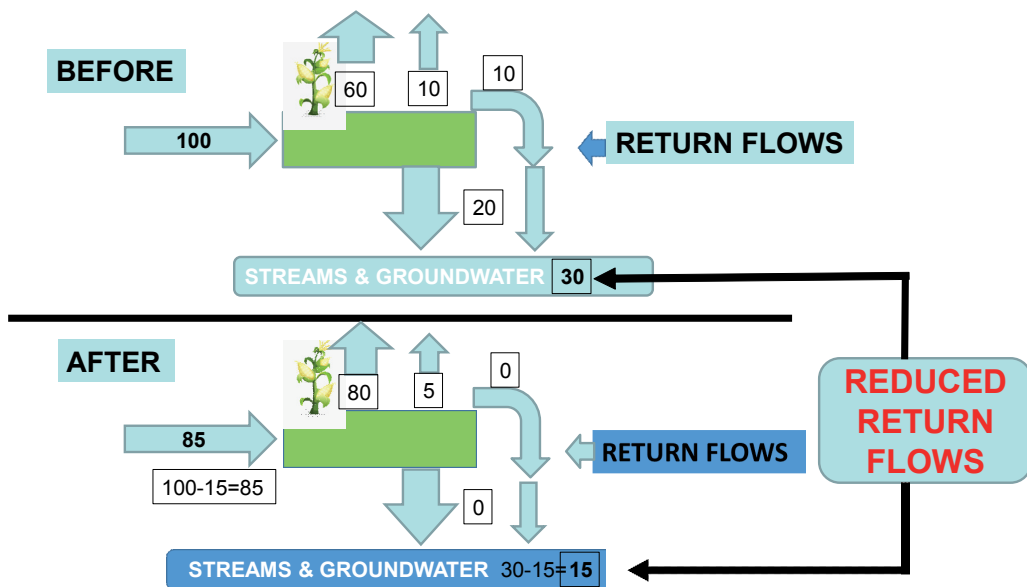


Figure 13: Water use efficiency gains, return flows and reductions in extractions.

return flow to rivers, streams and groundwater aquifers as depicted in Figure 13. These flows in some geological settings can be detrimental to the quantity and quality of environmental flows. Leakage and losses from irrigation water usually pick up salts, nutrients (especially nitrogen), and agrochemicals, which can drive salinisation and the pollution of water systems. Therefore, what is required for the future is the establishment of long-term water sustainability targets (ATSE 2017) for irrigation, recognising that farm and landscape hydrology is always connected and the whole-of-system must be examined.

Impact on Murray River mouth and environmental outcomes

Evidence of lack of progress to date, in terms of environmental benefits in the Basin, is provided in the 2016 Australian State of the Environment (SOE) Report that was published in March 2017, and which includes a specific report on inland water. Its findings on the MDB are for the period since 2011 and deliver an assessment grade of very poor and deteriorating for the “state and trends of inland water ecological processes and key species populations”.

The SOE Report further observes that there is “widespread loss of ecosystem function” in the Basin. The SOE Report also

notes that, in terms of the “state and trends of inland water flows and levels” in the MDB, there has been no Basin-wide improvement since 2011 and that “Longer-term downwards trends in flows seen in nearly 50% of stations, with no change in trends evident since 2011.” Further, Grafton (2017, Figure 3) provides evidence that there is, as yet, no discernible change in surface water diversions within the Basin despite the fact that there have been expenditures, to date, of more than \$5 billion under the “Water for the Future” program, and the Australian Government is more than 60% towards achieving its target of reducing extractions by 2750 GL/year.

The evidence at hand is that water application rates also follow a similar pattern, such that the average volume of water applied per hectare was the same in 2014–2015 as it was in 2002–2003 at the onset of the Millennium Drought (Grafton 2017). However, Roth et al. (2013) report that for cotton, the whole-farm irrigation efficiency index improved from 57% to 70%.

Despite the very large expenditure by the Australian Government on water recovery (A\$5.3 billion), the failure to see Basin-level reductions in surface water diversions is a matter of serious concern and one that needs investigation. It appears we have a huge failure in public policy.

In Figure 14, the mouth and estuary of the Murray River are pictured: in 2003, in the midst of the Millennium Drought; and in 2016 after several years of above average inflows to the Murray–Darling Basin (see Grafton 2017, Figure 3). In two very wet years (2012/13) the Murray River mouth did not remain open without an intervention of dredging at the mouth.

The Basin Plan seeks to ensure that the mouth remains open without the need for dredging 95% of the time under the 3200 GL water recovery scenario, which is expected to be achieved by 2019. The mouth was again facing the risk of closure during the summer of 2014/15.

In 2014, the MDB Ministerial Council provided \$4 million for a dredging program. The Australian and South Australian Governments are currently dredging sand out of the Murray Mouth to ensure it remains open. This process has been underway since January 2015, and will continue for at least another year in order to maintain the opening, and subsequently, the health of the mouth.

By mid-April 2016, almost 1.2 million cubic metres of sand had been dredged. This has resulted in a net reduction of sand at the mouth of 241,000 cubic metres. Recent barrage releases have scoured a modest amount of sand, but sufficient to improve connectivity of the Murray Mouth in the short term. Towards the end of 2016 (see image taken on 2 November 2016 in Figure 14), dredging was halted and the Murray River actually was flowing to the sea in what was a very wet year. At best it is an open question as to the environmental benefits of the huge public investments.

Conclusions and some ways forward

The MDB is a biophysical system driven by a highly variable climate that is in itself complex enough. However, within it exist social, economic and governance systems that regulate the built infrastructure and the legal and operational management of the rivers and groundwater. Together these three intersecting systems yield a highly complex system that is the MDB.



Figure 14: The Murray River mouth in 2003 and 2016 (Department of Environment, Water and Natural Resources 2015). Source: <http://www.naturalresources.sa.gov.au/samurraydarlingbasin/projects/all-projects-map/keeping-the-murray-mouth-open>

The first step into the future is to recognise and seek to understand the complexity of the Basin.

For public policy in water reform to succeed into the future, the interconnection and interactions of at least these three systems will need to be managed in an integrated manner.

For water policy to achieve the vision of the NWI and the Water Act, all three must receive active attention in policy development and implementation.

The magnitude of the reduction in water extraction is large at 3200 GL/year, and if the science we do have is correct, the volume required appears to approach 4000 GL/year. This reduction in extraction will require a rethink of funding allocations so that regional and community development towards “thriving resilient communities” is adequately resourced to adjust and build new futures. Funding needs to be re-allocated from subsidies for on-farm water use efficiency and supply measures to the direct purchase of entitlements. This will release funds within current budgets to be put towards programs that facilitate and underpin community adjustment, redevelopment and new enterprise. The level of funding available to

each affected community would be based on the economic impact resulting from the withdrawal of water for consumptive use in the district. In some of the worst case communities, these sums would be very significant (Wentworth Group 2010).

The governance and implementation has been top-down, and while consultation has been significant there has been resistance, particularly from central agencies, to empowering regional, local and community bodies—such as Catchment Management Authorities and Regional Development Agencies. Such agencies could take responsibility for driving the social and economic adjustment, together with the development and implementation of the water-sharing plans directed to return rivers and groundwater to healthy conditions.

Connell and Grafton (2011) argue that empowerment and engagement with stakeholders, other than irrigators, have been inadequate. They maintain that meaningful participation by Basin communities should include elected regional bodies which would make the decisions about how and when to use the publicly owned environmental water, based on long-term averages, for the purpose of increasing environmental flows and

to generate healthy working rivers. There is evidence that integrated catchment planning, building on resilience principles, can work to empower people to own and manage regional and local environmental assets (Natural Resources Commission 2012; Williams 2012). Such participation, as argued for by Connell and Grafton (2011), would be consistent with “citizen power” rather than “tokenism” (Arnstein 1969) that typified many of the interactions in the processes leading to the Basin Plan (Mulligan 2011).

There are ways of providing empowerment and support to assist people in building new, thriving communities, enterprise and social wellbeing. There are towns in the Murray–Darling which, through their own initiatives, have shown how to be more economically thriving and not so dependent on a water system that is as climatically-driven as this one.

For public policy in water reform to succeed into the future, we must address what has evolved in the MDB. Essentially we encouraged people in the Murray–Darling to adopt irrigated agriculture in one of the most highly variable climates on the planet, dependent on that water, and, at the same time, producing commodities which are subject to the large fluctuation in price on global markets with declining terms of trade. That is a tough gig. It is an example of the very complex systems in which water reform is critical to the long-term sustainability. Yet its success is dependent on policy, governance, and implementation to manage not only the water, but to resource and facilitate the communities to build new and better futures that draw on the multiplicity of uses for the water in rivers and groundwater that support a very diverse array of ecosystem services.

Australians are spending over \$11 billion on the Basin Plan. It is a complex system in public policy and we are only in the middle of it. We must rebuild and radically adjust the Basin Plan.

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