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Water recycling in Australia – during and after the drought

John C. Radcliffe

Australia is a dry continent. Its governments initiated a visionary process of water reform in 1994, when water resource management and water supply services began to be progressively separated. The subsequent *Intergovernmental Agreement on the National Water Initiative* (2004) separated entitlements for water from ownership of land, allowing water to be traded. The agreement provided a nationwide framework for management of water for the environment, agriculture and urban use, including water recycling. Also included was a commitment to full cost recovery. From about 2000, Australia had entered a prolonged period of what came to be known as the "millennium drought". This encouraged the urgent adoption of alternative water sources and the development of recycled potable water guidelines. However, rains returned to eastern Australia from 2008 and in January 2011, much of it was flooded. After their proving phases were completed, newly-built eastern states desalination plants were put on standby and the Brisbane Advanced Water Treatment Plants were closed without ever having been used for their principal purpose of potable supply. By contrast, Western Australia has remained dry, thought to be early evidence of global warming, with its desalination plants supporting Perth's base water supply. An indirect potable water recycling plant using managed aquifer recharge is being built with wide community acceptance. Nationally, following much of the major water infrastructural investment now seeing little use, attention has turned to economic regulation, the evaluation of those capital investments and their impact on prices and charges to water consumers. It has been argued that insufficient attention was paid earlier to the continuing role, economics, on-going technological resilience and in some cases public acceptance of the water recycling and desalination after the drought abated. After the end of the drought in eastern Australia, national policy priorities have turned elsewhere. Intergovernmental and statutory institutional structures have been abolished. Water policy complacency is evident and reform impetus is at risk of being lost. Water research funds are reducing. Australia must ensure that a long term policy reform commitment is maintained while dealing with immediate, short term issues. Policy-makers and the community must ensure that recycled water and desalination are seen as valuable resources within the framework of the entire hydrological cycle where economically viable – all water is ultimately recycled.

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Water impact

The introduction of Australian environmental protection agencies with effluent disposal standards followed by the millennium drought led to coordinated national water reforms in the 1990s and the 2004 *Intergovernmental Agreement on the National Water Initiative*. Investments followed in potable and non-potable water recycling. After 2010 eastern Australian floods, four new desalination plants have been placed on standby and three advanced water treatment plants for indirect potable use closed, seeing little significant use. Western Australian desalination and indirect potable water development continues, but national policy attention has turned elsewhere. The Ministerial Council on Environment and Water has been abolished and the National Water Commission closed, leading to loss of coordinated national policy impetus for water reform and likely reduced uptake.

Background

That urban waste water in Australia might be recycled for further use was first suggested in 1977 for Melbourne, but without response. However, at about the time of publication of the *Ecologically Sustainable Development Report* in 1991, the Australia states began establishing environment protection agencies and authorities. The potential damage from inadequately treated sewage effluent being discharged to oceans, rivers and estuaries was recognised. Regulations were brought in setting standards for discharges. Sewage

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Treatment Plant operators were increasingly required to come up with environmental management strategies for their discharges.

A number of major initiatives were implemented in the 1990s, including the *National Water Quality Management Strategy Guidelines*, the NSW *Guidelines for Urban and Residential Use of Reclaimed Water*, the planning for dual reticulation of both drinking water and recycled water in the new Rouse Hill (Sydney) subdivision, initiation of an integrated approach to sewage effluent and stormwater management at the site chosen for Sydney's 2000 Olympic Games, the upgrading and provision of recycled water from Adelaide's Bolivar Waste Water Treatment Plant (WWTP) for vegetable growing on the Northern Adelaide Plains and the building of a microfiltration – reverse osmosis water recycling plant at Luggage Point in Brisbane to produce very high quality water for industrial use. The primary driver for initiating these projects was environmental protection.[1]

Australia's water reform

A strategic framework for the reform of the Australian water industry was agreed in 1994 at the Council of Australian Governments (COAG) comprising the Prime Minister, State Premiers and Territory Chief Ministers and a representative of the Australian Local Government Association.[2] Land titles were separated from rights to water, with both becoming separately tradable. Water resource management was separated from the water supply functions which were to be transferred to identifiably separate commercial corporatised entities, albeit mostly still government-owned.

From around 2000, the east coast of Australia began to dry out. Most of Australia's capital cities except Hobart began to find their water resources progressively depleting as a result of drought, a condition which continued across the country for most of the decade, and came to be known as the "millennium drought". The demand management policies and water restrictions introduced resulted in the Australian community becoming increasingly concerned that they would run out of water. Urban water issues were front and centre daily in the newspapers and discussed regularly on talk back radio.[3]

Further water reforms followed in 2004–2006 when the Commonwealth and the States and Territories progressively signed a 108 clause *Intergovernmental Agreement on the National Water Initiative* (NWI). The agreement[4] encompassed clauses on water entitlements, water markets and trading, water pricing, management of environmental water, water accounting, urban water, community partnerships and adjustment, and knowledge and skills. It had objectives of ensuring healthy, safe and reliable water supplies; increased domestic and commercial water use efficiency; facilitating water trading between and within the urban and rural sectors; encouraging innovation in water supply sourcing, treatment, storage and discharge; and achieving improved pricing for metropolitan water. The National Water Commission (NWC) was established in March 2005, initially attached to the Office of the Prime Minister, though later transferred to the portfolio of the Minister responsible for water resources. The NWC was an independent statutory body created to drive the national reform agenda and assist with the effective implementation of the NWI. The Commission undertook two-yearly evaluations of progress.

Investments in desalination and water recycling

In 2004, the major Water Smart Australia program was announced. This provided for investment in the conservation and more effective utilisation of water resources. "Diversity of supply" through the provision of alternative water sources became the new driver. The Commonwealth government contributed financially to recycling and desalination initiatives to *accelerate the development and uptake of smart technologies and practices in water use across Australia*. Within two years, 48% of the investment had been directed towards for water recycling projects. Some projects were developed in "near emergency conditions". Ultimately, the program ran until June 2012 and provided funding of $1.48 billion towards 78 projects with total costs of $4.96 billion.[5] The NWC also developed a $200 million Raising National Water Standards program of 177 projects to *support the better management of Australia's water resources and by securing practical outcomes consistent with the implementation of the National Water Initiative*, the overall Program investment being over $244m.[6] Subsequently, the Commonwealth government introduced the National Water Security Plan for Cities and Towns (2007) which predominantly funded projects in towns with populations of less than 50 000. This was followed by the National Urban Water and Desalination Plan to *reduce reliance on rainfall dependent sources by supporting infrastructure projects and research in desalination, water recycling and stormwater harvesting and reuse*.[7] This program included funding of research over five years for the Australian Water Recycling Centre of Excellence (AWRCoE) in Brisbane[8] and the National Centre for Excellence in Desalination (NCED) in Perth,[9] each supported with $20 million.

Australian guidelines for water recycling

Meanwhile, under the auspices of Ministerial Councils involving Commonwealth, States/Territories and New Zealand Ministers responsible for environment, agriculture and health portfolios, led by the Environment Protection and Heritage Council (later retitled the Standing Council on Environment and Water [SCEW]) and the National Health and Medical Research Council (NHMRC), development was initiated of a series of National Water Quality Management Strategy Guidelines for water recycling. The *Australian Guidelines for Water Recycling* were released after extensive international refereeing as *(Phase 1) Managing health and environmental risks* (2006); *(Phase 2) – Augmentation of drinking water supplies* (2008); *Stormwater harvesting and reuse* (2009); and *Managed*

aquifer recharge (2009).[10] In 2011 the *Australian Drinking Water Guidelines* were re-developed by the NHMRC in collaboration with the Natural Resource Management Ministerial Council.[11] All these guidelines are based on Hazard Analysis and Critical Control Point (HACCP) principles. Since the States/Territories have responsibility for water resources under the Australian Constitution, the guidelines can be incorporated into their regulatory systems.

Responses to the drought

The drought continued. There were considerable differences in the water storage provisions for the different cities. Brisbane could store six years' water supply, principally in its Wivenhoe Dam which also served as a flood control dam. Sydney could store four years' supply, Melbourne that for three years, while Adelaide could store only about ten months' supply as it had since the 1940s been taking much of its urban water from Australia's longest river system, the River Murray.[12] Water supplies were at risk. For example, the City of Brisbane saw its water supply decline markedly, hitting a low point of less than 17% of storage capacity in August 2007. The mean annual run-off from Perth's catchments in 2001–2008 was 49% of what it had been in 1980–1999, and 30% of what it had been between 1911 and 1979.[13] A statistically significant reduction in rainfall was recorded in Melbourne, the extended drought period being the worst on record with a probability of occurrence of cumulative inflow (1997–2006) being less than 0.002. It was concluded that the 39 percent reduction in long term average stream flows that had occurred since 1996 could represent a new planning base for Melbourne – a step change that was similar to (but not as big) as had occurred in Perth 30 years earlier.[14] The River Murray ceased to flow through its mouth to the ocean and the water salinity increased, making it unsuitable for drinking. Following unprecedented water restrictions having been introduced in all mainland capital cities during the middle of the decade, seawater desalination plants were urgently developed for Perth, Sydney, Adelaide, Brisbane's Gold Coast and Melbourne. These plants involved a variety of design, funding, and technical development methods, but all were fundamentally dependent on reverse osmosis. Perth completed its desalination plant at Kwinana first, and then built a second plant at Binningup, 150 km south of the city. Both the Adelaide and Perth's Binningup plant were originally designed as 50 Gl per annum installations, but then doubled in size. In addition, a major north–south pipeline was built to bring purchased irrigation water from the River Murray system to Melbourne.

Meanwhile, the city of Toowoomba in Queensland had generated a proposal for an indirect potable recycled water supply.[15] But to secure Commonwealth government co-funding, a community plebiscite of the proposal was required and subsequently lost. A review identified biases in information processing, with supporters and opponents selectively attending to information aligned with their own values.[16] Despite that referendum outcome, the Queensland government cancelled a proposed Brisbane plebiscite on potable recycling for March 2007 and proceeded to directly develop Advanced Water Recycling Plants adjacent to Waste Water Treatment Plants at Bundamba, Luggage Point and Gibson Island. The scheme, known as the Western Corridor Scheme, was based on the manufacture (as it was described) of purified recycled water by microfiltration, reverse osmosis and advanced oxidation. The recycled water was to be pumped to the Wivenhoe Dam. Portion of the flow was to be used at two power stations which were then using 10% of Brisbane's daily drinking water consumption. Brisbane's water resources were linked together with the Gold Coast desalination plant to form a newly constructed water grid. The whole project was completed urgently within 2 years.[17]

The resultant alternative urban water sources are summarised in Table 1.

Melbourne took a different approach for one of its projects when in 2006, it initiated an upgrade of the Melbourne Water Eastern Sewage Plant which handles 40% of Melbourne's waste water. There was a need for environmental improvement surrounding the treated effluent discharge point at Boags Rocks, but also to increase the use of high quality recycled water for non-potable purposes. A pilot plant was built to test alternative treatment trains, including membrane separation and media filtration.[20] The upgrade chosen for the Advanced Tertiary Treatment Plant, completed in 2012, treats secondary effluent uses a pre-ozone – biological media filtration – post-ozone – UV – chlorine process train. While the treatment includes filtration, this does not contribute to the microbial treatment objectives at this stage, the required log reduction values (LRVs) being achieved through inactivation by the post-ozone, UV and chlorine treatment.[21]

Independently of the development of these major urban schemes, by 2008, "fit-for-purpose" recycled water in various forms had progressively evolved across in Australia for use in third pipe reticulation systems to new housing developments in Adelaide, Melbourne Sydney and Brisbane. Recycled water was also being adopted for urban amenities, industries, environmental flow substitution, and to achieve discharge standards to receiving waters now required of wastewater treatment plants. Some proposals included well conducted community consultations, a prime example being the developing 7000 hectare Pimpama-Coomera area, served by Gold Coast Water, a Directorate of the Gold Coast City Council. All houses built after August 2005 were to have Class A+ recycled water in third pipe systems. *De facto* indirect potable recycling from the discharges of wastewater treatment plants into receiving waters which downstream were used as a source for water treatment plants was also more widely recognised, albeit discreetly.[22] By 2009–2010, urban water utilities were supplying a total of 245 GL of recycled water *per annum*, an increase of 34% since 2005–2006.[23] The Australian Bureau of Meteorology has established a public database of Climate Resilient Water Sources (www.bom.gov.au/water/crews) which provides for viewing, downloading and

Table 1 Details of the desalination and advanced water treatment plants in Australia, December 2014 (ref. 17–19)

City/location/(state)	Capacity (GL per annum)	% Current demand	Contractor	Delivery method	Owner	Contract (years)	Status (2014)
Desalination							
Sydney-Kurnell (NSW)	90	15	Veolia Water (Veolia & John Holland Industries)	Design, build, operate for Sydney water, then lease	Long term lease to Sydney Desalination Plant Pty Ltd	50	Standby
Melbourne-Wonthaggi (Vic)	150	33	Aquasure (Dégremont, Thiess, Macquarie Capital)	Build, own, operate under public private partnership	Private owner – Aquasure	30	Standby
Gold Coast/Brisbane-Tugun (Q)	45	18	WaterSecure [now Seqwater] (John Holland, Veolia Water, SKM, Cardno)	Alliance – design, build, operate	Seqwater	10	Standby
Adelaide-Port Stanvac (SA)	100	Up to 50%	Adelaide Aqua (Acciona Agua, United Utilities, McConnell Dowell, Abigroup)	Alliance – design, build, operate, maintain	SA government	20	Standby (10% production in 2015 for optimising study)
Perth-Kwinana (WA)	45	17–25	Dégremont (Multiplex-Dégremont)	Competitive alliances	Water corporation	25	Full capacity
Perth-Southern Binningup (WA)	100	18–25	Southern Sea Water Alliance (Technicas Reunidas, Valoriza Agua, Lucas, Worley Parson, Water Corp.)	Design, construction and operation	Water corporation	25	50–80 GL per annum, 100 GL per annum in drought
Advanced water treatment – potable recycling (excluding pipelines)							
Brisbane-Bundamba (Q)	24	30	Thiess, Black & Veatch	Alliances – three treatment plant alliances, plus two other transfer system (pipelines) alliances	Queensland manufactured water authority (WaterSecure) to the Queensland bulk water supply Authority (Seqwater from 1 July 2011)	10	Closed
Brisbane-Gibson Island (Q)	36		MWH, Worley Parsons, Baulderstone Hornibrook, United Group Infrastructure			10	Closed
Brisbane-Luggage Point (Q)	24		CH2MHill, Lang O'Rourke. Connell Wagner, Hatch			10	Closed

contributing data on Australia's alternative water sources including recycled and desalinated water. It currently records 165 water recycling plants with a total capacity of 467 GL and a 2013 production of 151 GL, and 78 desalination plants with a capacity of 351 GL and a production of 37 GL in 2013.

The rains returned

But towards the end of 2008, the rains had returned to eastern Australia. As Brisbane's Wivenhoe dam was filling, there seemed no need to top it up. With the lake standing at 70% full, the Queensland government determined that recycled water would be added in the future only if the Wivenhoe storage fell below 40% of capacity. This was seen by some as both a failure of political nerve and a distinct setback to the progress of indirect potable recycling within and outside Australia.[24]

The period from late November 2010 to mid-January 2011 was extremely wet through much of eastern Australia. There was widespread flooding on many rivers, culminating in severe flooding (including river and flash flooding) in Brisbane and nearby areas of south-east Queensland, northern New South Wales, large parts of northern and western Victoria and northern Tasmania. The flooding, in terms of extent, impact and severity, was amongst the most significant in Australia's recorded history – many catchments were already wet before the flooding rains.[25] Brisbane's Wivenhoe dam, which also served as a flood attenuation dam, filled to 200% of its maximum water storage capacity, and water had to be released from it at relatively high rates to protect the

structure, resulting in exacerbation of flooding in large areas of low lying Brisbane. Attention turned from water resource deficits to flood mitigation.

Addressing production economics including the debts

Most States/Territories have in recent years introduced independent economic regulators, though in Western Australia and the Northern Territory, prices remain set by governments, and in Queensland and rural New South Wales by the water utilities, many operated by local government.[26] Considerable criticism has developed of how urban water supplies were secured and the extent of investment in alternative water sources. The costs to consumers and the community have been large. Water restrictions were likely to have cost the nation in excess of a billion dollars per year from the lost value of consumption alone. Inefficient supply augmentation in Melbourne and Perth, for example, could cost consumers and communities up to $4.2 billion over 20 years. Large government grants for infrastructure may have led to perverse outcomes.

All of the east coast desalination plants and advanced water recycling plants were virtually taken out of service once their validation and contract proving stages were completed, although the Gold Coast Tugan plant was fleetingly reactivated when Cyclone Oswald in 2013 dumped huge rainfalls on the Wivenhoe catchment, the subsequent massive silt load causing major problems for Brisbane's Mount Crosby water treatment plant. From the perspective of governments, attention turned to economics, particularly the debt loads that these plants had generated, and the impact of perceptions and increased costs and prices on water consumers. Having signed the *Intergovernmental Agreement on the National Water Initiative*, governments had committed themselves to full cost recovery, including debt servicing. This has required the development of price paths to accommodate water customers. For example, in 2008, the Queensland government decided to phase in bulk water price increases to cover the costs associated with the recently-completed investment in the bulk water supply system for desalination, advanced water recycling and pipeline infrastructure by implementing a 'price path' that provides for annual price increases over a 10 year period, during which water prices will not recover the full costs of supplying bulk water. This means selling bulk water at a loss, being funded by further debt.[27] Excluding capital costs, the actual operating cost of producing manufactured water from the Gold Coast desalination plant in 2011–2012 was $959 per ML, from the Advanced Water Treatment plants of the Western Corridor scheme $834 per ML, while that harvested from the catchment base, which constituted 96% of Brisbane's water, cost $67 per ML.[28] One assumes, however, that the cost of maintaining the catchment environment or income foregone from alternative catchment uses was not encompassed.

One alternative approach is to purchase water from agricultural users for urban supply. A small amount of water for agricultural use can represent a relatively large amount of water for urban users. The South Australian Water Corporation did so in 2009 and 2010. In Victoria, scope was provided for a substantial transfer of irrigation water with the Sugarloaf Pipeline, completed in 2010 for $750 million. It connects the Goulburn River to Sugarloaf Reservoir and was expected to supply 75 GL of water to Melbourne each year when used. However, following considerable disquiet expressed by irrigators in the form of a "plug the pipe" campaign, the Victorian Government imposed a policy ban, determining that the pipeline is not to be used except in the case of critical human need for water in metropolitan Melbourne.[29]

The Australian National Audit Office concluded that when considered against Commonwealth program guidelines, neither of the two grants for the Adelaide Desalination Plant demonstrably satisfied the program's merit criteria.[30] There were considerable differences in the capital costs and operating costs between each of the desalination plants and with the Western Corridor Advanced Water Treatment plants. When the plants are not in use, the costs of debt servicing and care and maintenance may still exceed half the operating costs at full production.[31] Regulated prices have been established for the privately leased Sydney desalination plant including for various periods of non-production and for start-up costs after a period of closure.[32] The technologies required to maintain membrane plants when they are not being used are still unclear. Submissions to a Queensland Parliamentary inquiry (now lapsed) suggested that the Western Corridor scheme would be much more economically effective if recycled water were piped directly as potable water to the Mount Crosby Water Treatment Plant rather than being pumped a considerable distance as a form of indirect potable recycling to the Wivenhoe Dam.[33]

In 2011, Sydney Water confirmed that it had no intention of building any further recycled water plants to serve domestic third pipe systems because they were too costly.[34] However, the City of Sydney has been pursuing recycled waste water and stormwater opportunities in new developments by encouraging private sector decentralised systems for non-drinking purposes. A key legislative instrument guiding arrangements for water and sewerage services in Sydney is the *Water Industry Competition Act 2006 (NSW)* which aims to encourage competition in water supply and sewage services in NSW and to facilitate the development of infrastructure supporting production and reticulation of recycled water.[35]

Declaring that the cost of the scheme outweighs the value to the community, the Gold Coast Council is staging the closure by December 2016 of the Pimpama Coomera Class A+ recycled water scheme which provides recycled water to 5650 houses approved and built since August 2005.[36]

Many of the alternative water source plants initiated in Australia during the drought appear to have been based on decisions made mostly through central planning processes rather than markets, and by assuming continuous operation.

South west Western Australia is different

The position in Western Australia contrasts with that of eastern Australia. The Perth catchments continue to have low yield. The city now secures 60% of its water from groundwater and the two desalination plants have been in full operation since completion. A three year research project completed in December 2012 by the Western Australian Water Corporation evaluated managed aquifer recharge of advanced recycled water from the Beenyup Wastewater Treatment Plant. The trial's regulators, the Department of Environment and Conservation, Department of Health and Department of Water indicated that the trial had met all of the project objectives and that groundwater replenishment was feasible. An associated communications approach with tours and an interpretive centre, proved successful with the 2012 Annual Community Survey indicating that community support for a full scale groundwater replenishment scheme remained steady at around 76 percent.[37] In consequence, Thiess and CH2M Hill Australia (KEP Recharge Alliance) have been contracted to design, construct and commission a full-scale advanced water recycling plant of capacity 14 GL per annum by 2016 for managed aquifer recharge, with potential to expand to 28 GL per annum.[38]

The future for water research

During the post-drought period, water recycling research has continued, but opportunities for new funding have diminished. The Queensland Urban Water Security Research Alliance, a partnership between the Queensland Government, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Griffith University and the University of Queensland, was established in 2007 with $50 million invested in cash or in-kind over five years until it closed on 30 June 2012, to address South East Queensland's urban water issues. Those covered included stormwater harvesting, advanced water treatment technologies, the water energy nexus and South-East Queensland's water security.[39]

The National Centre of Excellence in Desalination, comprising CSIRO and 13 participating universities, has come to the end of its initial Commonwealth funding. It has been researching pre-treatment, reverse osmosis desalting, novel desalting, concentrate management, and social, economic and environmental issues from a base in the Rockingham campus of Murdoch University in Western Australia.

The Goyder Institute for Water Research is a partnership between the South Australian Government through the Department of Environment, Water and Natural Resources, CSIRO, Flinders University, the University of Adelaide and the University of South Australia. Establishing in July 2010 with the development of a $50 million, 5 year strategic research plan covering four key themes of environmental water, water for industry, urban water and climate change, its initial term is drawing to a close. Among many other reports it has issued, the Goyder Institute has released reports on 'Managed Aquifer Recharge and Urban Stormwater Use Options: Summary of Research Findings; Satellite Sites' 'Stormwater Quality Monitoring and Treatment Requirements for Potable Supplies' and 'Investigation of stormwater impact on water quality and distribution infrastructure'.[40]

The National Centre for Groundwater Research and Training (NCGRT) was established in 2009 by the Australian Government as a Centre of Excellence co-funded for five years by the Australian Research Council and the National Water Commission until 2014. Based at Flinders University, with 12 partner universities and more than 10 industry partners, it now has interim base funding from Flinders University and a project grant from the Murray Darling Basin Authority. Research had been grouped into five major research programs which contributed to the potential for recycled water to be used in conjunction with managed aquifer recharge.[41]

The Australian Water Recycling Centre of Excellence (AWRCoE), funded until 2015, has been undertaking projects encompassing the social, economic and environmental value of water recycling by developing and demonstrating new technologies; establishing a National Validation Framework for water recycling to simplify future approval processes; developing programs and products that will facilitate reclaimed water being viewed as an acceptable 'alternative water' for augmenting drinking water supplies; and establishing a national knowledge, training and education program for water recycling. Being aware of the 2012 US National Research Council report on Water Reuse,[42] AWRCoE commissioned an independent report from the Australian Academy of Technological Sciences and Engineering (ATSE) on the benefits and costs of supplying recycled water directly to the distribution system. The report concluded that advanced water treatment plants are complex but direct potable recycling (DPR) is technically feasible and can safely supply drinking water directly into the water distribution system, noting that current Australian regulatory arrangements can already accommodate soundly designed and operated DPR systems.[43] Increasingly, AWRCoE research has been coordinated with the United States WateReuse Research Foundation (WRRF) which is responding to protracted drought in south-western USA, particularly California.

Water Research Australia Limited (WaterRA) can be traced back nearly 20 years to the Cooperative Research Centre for Water Quality and Treatment (1995–2008). Re-established as Water Quality Research Australia in 2008, it became Water Research Australia in 2013. It is a not-for-profit entity, with 43 members including 17 urban and regional water corporations, 17 universities, 5 industry groups and the Departments of Health of New South Wales and Victoria. It can anticipate some funding continuity, albeit reduced by winding down of sources from the Victorian Smart Water Fund and the Commonwealth government through the National Water Commission.[44]

Changing policy priorities

The end of the drought in eastern Australia has distanced community, industry and government policy focus from strengthening the security of water supply (at almost any cost) to one of pursuing economic efficiency and containing consumers' water charges and prices.

On 13 December 2013, COAG replaced its 22 Standing Ministerial Councils, Select Councils and governance fora with a set of eight Councils. The decision saw the revocation of the Standing Council on Environment and Water which had been responsible for coordinating Commonwealth/States/Territories water policies.[45] This has created uncertainty in how national cooperation on water reform will be achieved and advanced in future.

As a result of provisions in the 2014 Commonwealth budget papers, the office of the National Water Commission, responsible for driving water reform in Australia, was closed on 24 December 2014.[46]

The 2014 assessment

The final report of the Commission was its *Triennial reform assessment 2014*. It observed that the recent abolition of the COAG Ministerial Council dealing with national water issues, combined with the lack of an organisational champion for water reform, may undermine shared understandings into the future. Although all jurisdictions now have in place some form of economic regulation, for urban water there are rising concerns about pricing for service efficiency and customer value. Worries about affordability are also emerging. Transparent information on the pricing of water charges is lacking in several jurisdictions. As governments emerge from the wave of capital investment in urban water supply and wastewater systems they have been confronted with new challenges relating to service delivery, institutional and regulatory alignment and community demands for sustainable and affordable supplies. Capital constraints, debt levels, asset renewals and an increasingly market-orientated sector are adding to the efficiency challenge. More effort is needed to address costs and regulation of environmental externalities. Decisions made under conditions of water scarcity were perceived to have resulted in several large-scale investments that were not subject to the same rigorous approaches undertaken through economic regulation of water utilities. Different facets of the urban water cycle including water supply, drainage, water pollution control, groundwater, water recycling and water conservation and land use planning are often managed by different departments, making it difficult to plan and implement urban water systems holistically.

Australia's performance in providing safe drinking water remains high and drinking water is consistently safe and of a high quality. In 2012–2013, all but three water utilities across Australia with 10 000 or more connections reported 100 percent compliance with relevant microbiological standards. But while the supply diversity measures have ensured cities have secure water supplies, this has come at a cost. Government decisions about major recycling and desalination infrastructure investment were not always well communicated in terms of the costs and benefits of the alternative options considered. This has undermined community confidence that it is receiving value-for-money services. Large-scale augmentation decisions taken in Victoria and South East Queensland were considered particularly contentious because of a perceived lack of transparency in decision-making. Changes in organisational structures are being suggested. Governments and communities are starting to discuss ways that increased private sector investment can enable existing public capital investments to be released for further use in the water or other infrastructure sectors. Successful national reforms typically involve leadership, coordination and facilitation. The Commission called on Australia's state and territory governments to work together to deliver better outcomes for their constituents as well as the national economy.[47]

Conclusion

Other jurisdictions can learn from what followed Australia entering the 1990s with a long term vision for its water. It generated an excellent policy framework for water reform by intergovernmental consensus. It recognised that water was a crucial and finite resource, needing to be equitably managed. Those accessing water for productive purposes needed to be able to do so securely and with confidence and efficiency. The importance of being able to reuse it for other purposes was recognised. A Federal commitment to encourage 30% reuse of urban wastewater was adopted. Widely respected guidelines for water recycling were developed. Innovative technologies in water management and treatment were introduced. But as the drought worsened, storages continued to decline and water quality deteriorated, capital was urgently diverted, sometimes in near "panic", to new infrastructure to provide diversity of supply though recycling, desalination and interconnecting grid pipelines. Using a variety of delivery and financing approaches, it was demonstrated that recycling and desalination plants could be built quickly when necessary. Validation in pilot plants were generally a critical part of establishing the preferred process trains. However, though technically sound, several projects were built with overcapacity in responses to offers of additional funding without regard to clarifying how the additional production capacity would be integrated into the long term likely base supply requirements, even in the face of potential climate change. There were alternative interpretations of how and when to achieve the commitment to full cost recovery. Historically, long term water infrastructure investment had been treated as a "sunk cost" with loans potentially serviced from taxation revenue. There have been difficulties in whether and how to assign environmental costs of alternative water proposals. Issues which were not always well confronted in responding to the potential crisis of drought included how to convey to

consumers the value of security of supply, the cost of achieving it and the transparency of the decision-making processes required. Greenhouse gas issues have been debated but not widely communicated. Australia has yet to effectively address the issue of acceptance of potable recycling with the notable exception of Western Australia. Rains brought a reduced policy priority to water issues and a reduced strength of policy governance frameworks and commitment. Following the breaking of the drought, a level of water policy exhaustion appears to have set in.

Droughts will return. Australia has developed most of the policy framework and infrastructure to face them. Yet there is more to be done. A National Water Quality Management Strategy Guideline on the economic regulation of water utilities would be valuable. Research capacity should be maintained. New urban, industrial and agricultural approaches to planning and design, integrated with water and wastewater services should be encouraged, increasingly incorporating recycled water as appropriate and economic "fit for purpose" technologies are advanced. Policy collaboration between levels of government should be reinforced. Continuing reform and innovation must be maintained.

References

1 J. C. Radcliffe, *Water Recycling in Australia*, Australian Academy of Technological Sciences and Engineering, Melbourne, 2004, http://www.atse.org.au/Documents/Publications/Reports/Water/ATSE%20Water%20Recycling%20in%20Australia%202004.pdf (accessed 4 February 2015).

2 *Compendium of National Competition Policy Agreements*, 2nd edn, National Competition Council, Melbourne, June 1998 http://ncp.ncc.gov.au/docs/PIAg-002.pdf (accessed 4 February 2015).

3 R. Young, The risks of urban water management In: *The Australian Water Project - Crisis and opportunity: Lessons of Australian water reform*, CEDA – the Committee for Economic Development of Australia, November 2011, http://adminpanel.ceda.com.au/FOLDERS/Service/Files/Documents/15335~waterprojectdigital.pdf (accessed 4 February 2015).

4 *Intergovernmental Agreement on the National Water Initiative*, 2004, http://nwc.gov.au/__data/assets/pdf_file/0008/24749/Intergovernmental-Agreement-on-a-national-water-initiative.pdf (accessed 4 February 2015).

5 GHD. Review of Water Smart Australia, July 2012., http://www.environment.gov.au/resource/water-smart-australia-program-review-and-lessons-learnt-report 3-2-2015 (accessed 3 February 2015).

6 Inovact Consulting Pty Ltd Raising National Water Standards Program: Stage 2 Evaluation Report, July 2011. http://archive.nwc.gov.au/rnws/stage-2-evaluation (accessed 4 February 2015).

7 Department of Environment – Water in Cities and Towns http://www.environment.gov.au/topics/water/water-cities-and-towns (accessed 3 February 2015).

8 Australian Water Recycling Centre of Excellence http://www.australianwaterrecycling.com.au/ (accessed 4 February 2015).

9 National Centre for Excellence in Desalination http://desalination.edu.au/ (accessed 4 February 2015).

10 National Water Quality Management Strategy, http://www.environment.gov.au/water/quality/national-water-quality-management-strategy (accessed 4 February 2015).

11 Australian Drinking Water guidelines http://www.nhmrc.gov.au/guidelines-publications/eh52 (accessed 4 February 2015).

12 J. Marsden and P. Pickering, *Securing Australia's Urban Water Supplies: Opportunities and Impediments - A discussion paper prepared for the Department of the Prime Minister and Cabinet* (November 2006) http://www.environment.gov.au/system/files/resources/a4c27c83-6edd-4fc5-84a2-70e38b183fc4/files/urban-water-report.pdf (Accessed 10 February 2015).

13 Sue Murphy, Water Forever – Towards climate resilience – Water Corporation, Western Australia, October 2009, https://watercorporation.com.au/-/media/files/about%20us/planning%20for%20the%20future/water-forever-50-year-plan.pdf.

14 R. Skinner, Whole of water life cycle innovations. In: *The Australian Water Project - Crisis and opportunity: Lessons of Australian water reform*, CEDA – the Committee for Economic Development of Australia, November 2011, http://adminpanel.ceda.com.au/FOLDERS/Service/Files/Documents/15335~waterprojectdigital.pdf (accessed 4 February 2015).

15 P. Selmes, R. Bain, A. Domanti, W. Zillmann and I. Cameron, *Water, Journal of the Australian Water Association*, 2004, **33**(6), 64–66.

16 J. Price, K. Fielding and Z. Leviston, *Soc Nat Resour*, 2012, **25**(10), 980–995, DOI: 10.1080/08941920.2012.656185.

17 W. Traves and K. Davies, *Water, Journal of the Australian Water Association*, 2008, **35**(4), 65–69.

18 Water Services Association of Australia – Seawater desalination Information Pack https://www.wsaa.asn.au/WSAAPublications/Documents/WSAA%20Seawater%20Desalination%20Information%20Pack.pdf (accessed 5 February 2015).

19 Seqwater Western Corridor Scheme (2015) http://www.seqwater.com.au/water-supply/water-treatment/purified-recycled-water (accessed 5 February 2015).

20 C. McAuliffe, J. Mieog, C. Williams and J. Currie, Planning for Advanced Tertiary Treatment: Melbourne's ETP, *Water, Journal of the Australian Water Association*, 2009, **36**(6), 46–55.

21 J. Mieog and A. McNeil, *Recycled Water Treatment on a Large Scale using Multiple Disinfection Barriers at Melbourne Water's Eastern Treatment Plant*, July 2013, AWA Asia Pacific Water Recycling Conference, Brisbane.

22 J. C. Radcliffe, *Water Sci. Technol.*, 2010, **62**(4), 792–798.

23 National Water Commission National Performance Report 2009–10: Urban water utilities, April 2011, http://archive.nwc.gov.au/library/topic/npr (accessed 5 February 2015).

24 B. McCann, *Water21* – International Water Association, December 2009, pp. 62–64.

25 Bureau of Meteorology – Special Climate Statement 24 http://www.bom.gov.au/climate/current/statements/scs24c.pdf (accessed 5 February 2015).

26 M. Black, *Water, Journal of the Australian Water Association*, 2014, **44**(8), 68–71.
27 Queensland Department of Energy and Water Supply. 2014 https://www.dews.qld.gov.au/policies-initiatives/water-sector-reform/water-pricing/bulk-water-prices (accessed 3 February 2015).
28 S. Warner, *Maintenance of water infrastructure assets*, SEQ Catchments 2013, http://www.parliament.qld.gov.au/documents/committees/SDIIC/2013/12-WaterInfraAssets/submissions/008.pdf (accessed 7 February 2015).
29 Productivity Commission 2011, Australia's Urban Water Sector, Report No. 55, Final Inquiry Report, Canberra. http://www.pc.gov.au/inquiries/completed/urban-water/report/urban-water-volume1.pdf (accessed 6 February 2015).
30 ANAO. 2013. Grants for the Construction of the Adelaide Desalination Plant. http://www.anao.gov.au/Publications/Audit-Reports/2012-2013/Grants-for-the-Construction-of-the-Adelaide-Desalination-Plant/Audit-summary.
31 Queensland Audit. Office Report to Parliament 14 for 2012–13: Maintenance of water infrastructure assets - https://www.qao.qld.gov.au/files/file/RTP14.pdf (accessed 6 February 2015).
32 New South Wales Independent Pricing and Regulatory Tribunal. Review of water prices for Sydney Desalination Plant Pty Limited, December 2012, http://www.ipart.nsw.gov.au/Home/Industries/Water/Reviews/Metro_Pricing/Review_of_Sydney_Desalination_Plant_Pty_Ltds_prices (accessed 6 February 2015).
33 Australian Water Recycling Centre of Excellence/Australian Water Assoc./Water Services Assoc. of Australia (2013) http://www.parliament.qld.gov.au/documents/committees/SDIIC/2013/12-WaterInfraAssets/submissions/018.pdf (accessed 6 February 2015).
34 Sydney Water. Recycling in Retreat Daily Telegraph 27 October 2011, p. 15.
35 GHD. Report for City of Sydney- Recycled Water Plan, http://www.cityofsydney.nsw.gov.au/__data/assets/pdf_file/0007/151198/Recycled-Water-Plan.pdf (accessed 10 February 2015).
36 Gold Coast Council Pimpama Coomera Report 2014 http://www.goldcoast.qld.gov.au/pimpama-coomera-recycled-water-master-plan-public-reports-8063.html (accessed 6 February 2015).
37 V. Moscovis, Groundwater Replenishment Trial Final Report, http://www.watercorporation.com.au/-/media/files/residential/water%20supply%20and%20services/gwrt/gwrt-final-report.pdf (accessed 7 February 2015).
38 Water Corporation (WA) 2015 http://www.watercorporation.com.au/water-supply-and-services/ongoing-works/groundwater-replenishment-scheme (accessed 7 February 2015).
39 Urban Water Security Research Alliance - 5 Years of Urban Water Research in South East Queensland – 2007–2012 (2012) http://www.urbanwateralliance.org.au/publications/UWSRA-final-synthesis-report.pdf (accessed 7 February 2015).
40 The Goyder Institute 2015. http://goyderinstitute.org/ (accessed 7 February 2015).
41 National Centre for Groundwater Research and Training (2015), http://www.groundwater.com.au/research_programs/surface-water-groundwater-interactions (accessed 7 February 2015).
42 National Research Council, Water Reuse: Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater, 2012, National Academies Press, Washington, D.C.
43 Australian Academy of Technological Sciences and Engineering. Drinking Water Through Recycling – The benefits and costs of supplying direct to the distribution system, 2013, ATSE, Melbourne, http://www.atse.org.au/content/publications/reports/natural-resources/drinking-water-through-recycling.aspx (accessed 8 February 2015).
44 Water Research Australia – Annual Report 2013–2014 http://www.waterra.com.au/publications/annual-reports/ (accessed 7 February 2015).
45 Department of Environment, http://www.scew.gov.au/about-us/senior-officials-group (accessed 3 February 2015).
46 K. Maywald – E-mail message from Chair, National Water Commission, 22 December 2014.
47 National Water Commission – Australia's water blueprint: National Reform Assessment 2014 http://www.nwc.gov.au/publications/topic/assessments/australias-water-blueprint-national-reform-assessment-2014 (accessed 8 February 2015).

