Introduction

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Around the world, access to water has always been a key determinant of how and where human populations have flourished. Australia is no different. Both Indigenous people and European settlers were mainly drawn to those parts of the country with more abundant and reliable water supplies. Thus, in spite of being the driest inhabited continent, 80% of Australia's population inhabits a comparatively well-watered green fringe.

Water is essential to our economy and our way of life and its use has continued to increase due to population growth and expansion of agriculture and other industries. This increase in water use – significantly underpinned by investment in major water infrastructure – has helped fuel Australia's economic growth, but at an environmental cost.

Australia's water use is dominated by irrigated agriculture, industry, and households. The water is extracted from rivers, lakes, and groundwater. Nationally, Australia uses approximately 6% of the available renewable water (surface runoff and groundwater recharge), but use is focussed in a few areas, such as the Murray–Darling Basin and the catchments surrounding capital cities where the resources are fully allocated.

Australia faces challenges of a growing and urbanising population, of growing demand for water for food and fibre production, and of environmental sustainability, particularly in the face of climate change. These are not unique to this country, but, unlike other developed nations, Australia faces the added complications of high rainfall variability and general aridity. The scarcity of water in Australia depends as much on the variation between years as it does on the long-term average. The highly variable climate means proportionally more water has to be stored to provide the same reliability of supply compared with less variable climates. For example, Melbourne's water supply system has 10 times the per capita storage volume of London's water supply system.

In contrast to human populations, Australia's unique flora and fauna are well adapted to high variability in available water. Recognising this dependency on variable water supply is central to ensuring the protection of ecosystems and the services they provide. Australians highly value their rivers and estuaries for tourism, amenity, and commercial and recreational boating and fishing. These values can be considered as services provided by aquatic ecosystems. Other less obvious aquatic ecosystem services include waste treatment, flood mitigation, biodiversity, and weed and pest control. Increasing levels of water use and expansion of water infrastructure have, however, led to worrying levels of environmental degradation in some areas, affecting the provision of these natural services. In addition, many intrinsically valuable environmental assets,

Discussing water, Hillston, New South Wales. Photo: Bill van Aken, CSIRO.

including extensive floodplain wetlands and forests, and iconic species such as the Murray Cod, are in marked decline from water use and other threats such as pests and water quality.

The challenge for Australia is to not only to deal with the present problems, but to prepare for the future. Demand for water will continue to grow, to support a population that is anticipated to increase by at least 50% by 2050. Global demand for food is expected to double, and growth in the mining and industrial sectors will place even greater pressures on water resources. Competing demands will mean that returning over-allocated systems to sustainable levels of use will be even more difficult than at present. Securing reliable urban water supplies – especially for Australia's four major urban areas (Perth, Melbourne, Sydney, and South East Queensland), requires far-sighted planning and billions of dollars of infrastructure investment. To continue to increase agricultural productivity with limited water will require many innovations in policies, technology, and knowledge that enable smarter and more efficient delivery and application of irrigation water.

As well as increasing demands, there are clear signs of decreasing water availability in parts of the country. In South West of Western Australia, climate change observed since the mid 1970s has seen stream flow into Perth's reservoirs more than halved, compared with the earlier long-term average. Research has shown that the unprecedented 1997–2009 drought in south-eastern Australia included a climate-change signal: a signal consistent with climate change predictions for a future of global warming producing lower rainfall in southern Australia. Further research continues to better quantify these signals.

Traditionally, water resource planning and engineering design of major infrastructure, including dams, were guided by measurements of past rainfall, temperature, and river flows. Scientists, engineers, and policy makers now agree that water resource planning and investment should consider multiple plausible climate and hydrology futures, not just historical records. The road ahead is uncertain, but relying only on the rear-view mirror would be negligent.

In the face of increasing demand and dwindling supply in some regions, Australia has the difficult task of balancing the use of water for direct economic benefits against indirect benefits such as environmental water use of water for conservation and the provision of ecosystems services.

There is a water quality dimension, as well as quantity, that needs to be considered for the future. Water quality should be at a level fit for its intended use; pollution of water can prevent or diminish future use and make it harder to meet increased demands on the resource. This is particularly a challenge for groundwater, where over-use of fresh groundwater can lead to salinisation reducing or preventing future use and degrading freshwater ecosystems reliant on the groundwater resource.

Responding to the challenge

Australian Governments have been actively reforming water management in response to the evolving water challenge. Under Australia's constitution, water resources are the responsibility of state and territory governments, but the Australian Government is involved through national competition policy, national and international environment policy, and the management of water resources that cross state borders (mainly the Murray–Darling Basin, Great Artesian Basin, and Lake Eyre Basin), and associated funding programs.

Monoman Creek, Chowilla Floodplain, South Australia during the millennium drought showing dying red gums and a blue green algae bloom. Photo: Ian Overton, CSIRO.

Googong Reservoir, Murrumbidgee catchment, New South Wales. Photo: Greg Heath, CSIRO.

The reforms increasingly treat water as an economic good or service, including formal legal entitlements to access water, which enable entitlements and seasonal allocations of water to be traded among users. Water supply services have been privatised, including in cases where infrastructure is government-owned, and the roles of water supply and regulation of use have been separated. Water prices are changing to reflect the full costs of supply and disposal, including separate charges for separate services.

A second key objective of the reforms is to make water management more environmentally sustainable. Water resources are thought to be over allocated in many parts of Australia, in the sense that the amount of water used, or the way that it is used, has caused socially unacceptable levels of environmental decline. An important milestone in the reform process was the passing of the *Water Act 2007 (Commonwealth)*, which has a focus on achieving sustainable management of the water resources of the Murray–Darling Basin through implementation of a Basin Plan. The Act paves the way for more formal environmental water management by establishing the Commonwealth Environmental Water Holder, which will hold in excess of 1000 GL of water entitlements and associated seasonal allocations to be actively managed for environmental benefit, just as other entitlements are managed for economic uses.

The reforms show that water is becoming an increasingly valuable commodity, and they provide an incentive for greater investment in the technologies and knowledge base required for smarter and more efficient management. In a carbon-constrained world, the large amounts of energy required to pump and desalinate water will increasingly mean the water and energy footprints of economic development will be considered jointly. Opportunities will be sought to reuse and recycle water rather than just using it once and disposing of the wastewater.

Wivenhoe Dam, Brisbane, during a controlled release, October 2010. Photo: Mat Gilfedder, CSIRO.

The role of science and technology

In order to secure water for future generations, Australian governments, industries, and communities will want to understand current and future water availability and explore ways of meeting the demands on these water supplies. They will want to better understand how river systems and groundwater systems respond to a changing climate and to increasing water use, and they will want to be confident that water use will not unduly harm future water supplies through pollution, over-use or environmental degradation. Improvements in ecological understanding, and in understanding the human health and other implications of contaminants in water, can provide vital help in developing water plans and provide safe and reliable water for all uses, including environmental water.

With increasing demands on a limited resource, there are strong incentives for more efficient ways of using water in irrigation, in cities, and for the environment. This will stimulate innovation in ways of providing the same or greater production and service provision using less water. Solutions are likely to include greater efficiency of water use in food production, in mineral processing, and for domestic use, to reduce demand while maintaining outcomes. Other opportunities may emerge from how water is managed for multiple benefits such as through recycling and reuse. New supplies will be sought through more efficient desalination and recycling technologies or through better use of groundwater. In the future, it is likely that the management of dams and rivers will shift from a primary focus on supply for cities or for irrigation, to balancing urban, agricultural, and environmental uses of water. New technologies are emerging with the potential to better understand and manage water resources. For example, ground-based

Woronora Dam, Sydney. Photo: Greg Heath, CSIRO.

radar and satellite-based remote sensing technologies are providing improved measurements of rainfall that will improve forecasting skill across the continent.

The scientist's techniques for employing accurate measurements, experimentation, hypothesis testing, and critical analysis, will assist in making major strategic decisions with confidence, and adapting to unforeseen consequences in the future. For example, new sensors and information technology are allowing early detection and remediation of urban water pollution. Careful monitoring and evaluation can improve the uncertain outcomes of providing water to restore degraded ecosystems. Accurate projections of the impacts of future climate on water resources and future demands on resources will help ensure enduring value from major investments in infrastructure.

Water science and technology has evolved in tandem with the water resource management challenges over the years. Research on aquatic ecosystems directly contributed to policies to tackle over allocation of water resources and return water to the environment. Now research is focussing on predictive ecology, to maximise the ecological benefit from the increasing volumes of water being managed for the environment, just as water supplies for irrigation are being improved to increase food production.

Billions of dollars of expenditure on water infrastructure is occurring now and this level of expenditure is expected to continue into the future, and similar amounts are spent on operating and maintaining water treatment, supply, and wastewater systems. Research that reduces operating costs or delays capital costs can have significant economic value. The well-being of the nation may depend, in future, on the ability to deliver high-quality water supplies to the many competing users. Scientific research continues to find solutions that greatly improve the effectiveness of water supplies and the benefits gained from them for all users.