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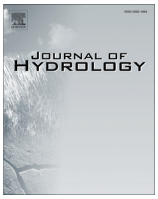

# Banking for the future: Prospects for integrated cyclical water management

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SUMMARY

Integrated management of surface water and groundwater can provide efficient and flexible use of water by making the best use of the properties of different types of water resources. Integrated cyclical water management can help adaptation to climate variation and uncertainty by varying the proportion of surface water and groundwater allocations over time in response to changing water availability. Water use entitlements and rules specify conditions for the use, storage and exchange of surface water and groundwater. These entitlements and rules provide certainty for water users, investors and managers. Entitlements and rules also need to be flexible to enable users and managers to respond to changing water availability and knowledge. Arrangements to provide certainty and flexibility can conflict. For example guarantees of specific long-term allocations of water, or shares of allocations can conflict with arrangements to bank water underground during wet periods and then to use an increased amount of groundwater in dry periods. Systems of water entitlements and rules need to achieve a balance between certainty and flexibility. This article explores the effect of water entitlements and rules, and arrangements to provide certainty and flexibility for the integration of surface water and groundwater management over time. The analysis draws on case studies from the Namoi River basin in New South Wales and the South Platte River basin in Colorado. Integrated cyclical water management requires a comprehensive, flexible and balanced system of water entitlements and rules that allow extended water carryover, water banking, aquifer storage and recovery over the wet and dry climate cycle. Opportunities for extended carryover and aquifer storage and recovery over the wet and dry climate cycle merit further consideration in New South Wales, Colorado and other jurisdictions.

## 1. Introduction

Water is an essential resource required for sustaining life and livelihoods: clean water is needed for drinking and hygiene. Adequate water supplies are needed to produce food and energy and to support economic activities such as industry and transportation. Global water supplies are under pressure, in particular from increasing population growth and demand for food (UNESCO, 2012). By 2050 2.3 billion more people are projected to be living in river basins experiencing severe water stress (OECD, 2012). Therefore it is important to make the best possible use of available water resources by integrating the use and management of surface water and groundwater.

Integrated surface water and groundwater management can be defined broadly to mean the joint or coordinated use and management of surface water and groundwater resources, whether these resources are physically connected or unconnected. Integrated management of surface water and groundwater can provide efficient and flexible use of water by making the best use of the properties of different types of water resources. Surface water is visible and relatively accessible, but supplies can be highly variable, whereas groundwater is less visible and accessible but provides a more stable source of supply (Evans and Evans, 2011).

Integrated cyclical water management can increase the efficiency of water use and also help adaptation to climate variation and uncertainty by varying the proportion of surface water and groundwater used over time in response to changing water availability. Integrated cyclical water management involves storing surface water underground and recharging aquifers during wet periods, and using an increased proportion of groundwater in dry periods (Blomquist, 1992; Blomquist et al., 2004a). This practice can be applied on a seasonal or inter-annual time scale.

The benefits of integrated cyclical water management and underground water banking have been well documented (National Research Council, 2008). Firstly, integrated cyclical water

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management reverses groundwater depletion and enables rivers to continue to receive flows of water from aquifers (Winter et al., 1998; Evans, 2007). Secondly, integrated cyclical water management helps farmers and communities adjust to climate variability and uncertainty by diversifying sources of water supply and establishing underground water reserves that can be used to increase the stability of water supplies (Agrawal, 2008). Thirdly, underground water banking avoids the substantial evaporative losses from surface water storages. For example, in the Murray-Darling Basin in Australia up to 3000 gigalitres (GL or million cubic metres) of water a year evaporates from surface water storages,[1] leakage from underground storage occurs at a much smaller rate. Fourthly, underground water banking can cost less than building new surface storage reservoirs, and the environmental impacts can usually be expected to be less. Fifthly, storing water in aquifers can leach out pollutants and improve water quality (Dillon et al., 2009) although the impact of adding excess water on the quality of water in an aquifer needs to be carefully managed.

Although the case for integrated cyclical water management has been established in theory and demonstrated in practice, and the basic physical requirements for underground water banking exist in many regions of the world, the global uptake of water banking is relatively slow and unevenly distributed. For example, there are over 100 commercial aquifer storage and recovery operations in California (Hanak and Stryjewski, 2012), whereas there are only about 30 operating in Australia many of which are at the prefeasibility or pilot stage (Dillon et al., 2009). This suggests that social and institutional factors have a major influence on regional differences in the design and implementation of integrated water management.

The remainder of this article explores the influence of institutional design and settings on the integrated use and management of surface water and groundwater, and including mechanisms to provide certainty and flexibility in water entitlements, water management rules and water allocations. The article draws on case studies from the Namoi region in New South Wales and the South Platte region in Colorado. The article contains four parts. The next section of the article provides a further explanation of physical and institutional prerequisites for integrated cyclical water management, including arrangements to provide certainty and flexibility. This is followed by a brief introduction to the comparative case study of institutional factors affecting integrated cyclical water management. The following section includes a comparison of the effects on the integration of surface water and groundwater management in New South Wales and Colorado of water entitlements, water management rules and related mechanisms to promote certainty and flexibility. This is followed by a discussion of experience in New South Wales and Colorado and a short concluding section.

## 2. Requirements for integrated cyclical water management through time

A hypothetical illustration of integrated cyclical water management using underground water banking is shown in Fig. 1. Surplus water is banked in wet periods (the areas above the upper dotted line) and extracted for use in dry periods (the area below the lower dotted line). The area between the dotted lines reflects the acceptable amount of variation in water available for use. Water banking enables greater certainty for water users and managers by stabilising water use in a range between the dotted lines.

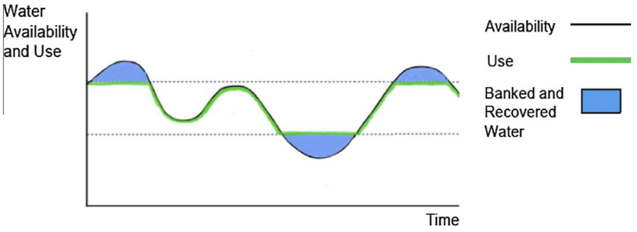

**Fig. 1.** Graphical illustration of integrated cyclical water management.

### 2.1. Physical requirements

There are several physical and institutional prerequisites for integrated cyclical water management and underground water banking. The key physical requirements are:

- access to surplus water for banking. Sources of surplus water can include reservoir surpluses, dam spills, floodwater, recycled stormwater and wastewater and purchased water entitlements. In fully allocated basins underground storage effectively provides a supplementary source of water by avoiding evaporative losses (Thomas, 2001; Rawluk et al., 2013); and
- a suitable aquifer[2] where water can be stored and recovered. The best aquifers for underground water storage have a high storage capacity, high percolation rates and high well yields. However, strong surface water groundwater connections and leaky aquifers can complicate aquifer storage (Purkey and Mansfield, 2002).

In addition, in many cases infrastructure is required to move water from its origin to an underground storage area, and from there to its place of use. These physical requirements are available in many regions of the world. For example, in Australia much of the highly populated areas on the eastern and south-western parts of the continent is suitable for water banking (Hostetler, 2008).

Underground water banking methods can be divided into two broad categories.

- Non-infrastructure based methods rely on natural recharge. They are usually based on varying surface and groundwater allocation and use, or surface water–groundwater substitution over time. Changes in land use can also play a part (Ross, 2012).
- Infrastructure based methods include in stream and off stream infiltration facilities and injection wells. Infrastructure based methods are more expensive but offer a wider range of benefits. The development of infrastructure based water banking projects requires detailed site-specific knowledge (Dillon et al., 2012).

### 2.2. Institutional requirements

Comprehensive, well defined, secure legal entitlements provide incentives for investment in water management (Ostrom, 2005; Bruns et al., 2005; Young and McColl, 2005). Schlager and Ostrom (1992) distinguish five elements of a bundle of entitlements for common pool resources; access, use; management; exclusion and transfer.[3] Specific entitlements to store water in a surface water storage or an aquifer, and then to extract it for use or transfer are required to provide incentives for underground storage of water (Ward and Dillon, 2011).

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[1] This number is derived from estimates by the Australian Bureau of Meteorology and CSIRO of evaporation from major storages http://www.bom.gov.au/water/nwa/2010/mdb/14.html accessed 30 September 2013, and evaporation from on farm storages estimated in SKM (2010).

[2] Aquifer suitability depends on a range of factors including the rates at which water can be infiltrated into and recovered from the aquifer, lateral flows and aquifer leakage rates.

[3] Transfer includes selling or leasing a water entitlement.