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Managing Connected Surface Water and Groundwater Resources

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Science for Decision Makers is a series published by the Bureau of Rural Sciences. It describes the latest developments in scientific advice, assessments or tools relating to agricultural, fisheries and forestry industries, including their supporting communities.

Its purpose is to make rural science more accessible to those needing to quickly understand the benefits and implications of the most recent research as a basis for decision-making.

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Key Points

1. Groundwater represents around 20% of the water harvested in Australia and is an essential component of the supply for some major population centres, including the Perth metropolitan area. For many regions, particularly in the arid zone, it is the only reliable water available to communities and to support economic activity.

2. Increasing demand for water and a decline in the availability of surface water has seen significant growth in abstraction of Australian groundwater resources.

3. Connectivity refers to flows between water resources located above ground and below ground; understanding the connections helps to anticipate how management of one resource will impact on the other over time.

4. Our present knowledge of the implications of connections between surface water and groundwater is limited.

5. Past management has typically failed to account adequately for these connections.

6. The risks of managing connected water resources independently include allocating the same water twice and exacerbating salinity problems as groundwater flows change in response to the water being extracted from bores.

7. These risks will become more significant as pressure on groundwater resources grows with economic development and the anticipated changes in climate.

8. A better understanding of the connectivity between surface water and groundwater and management of the combined resource as a single unit is required, if Australia's water resources are to be sustainably managed.

DEPARTMENT OF AGRICULTURE, FISHERIES AND FORESTRY

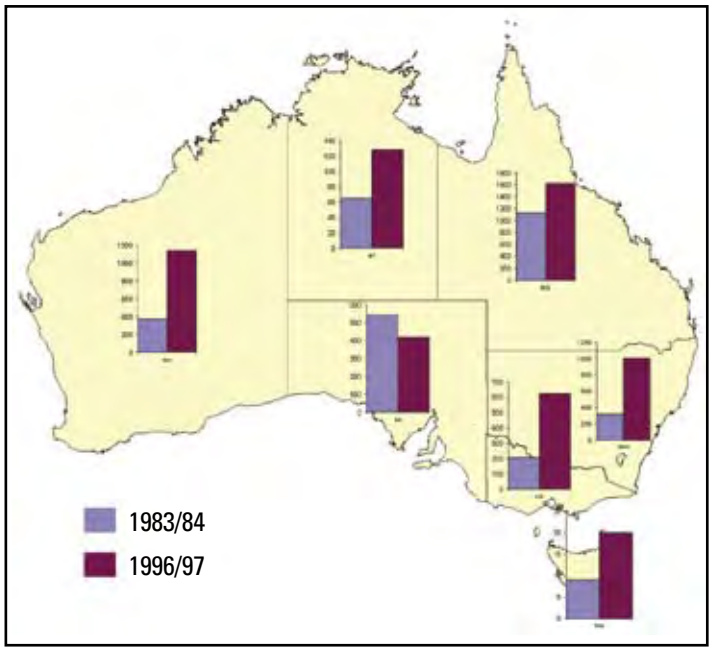
Introduction

On average, around 24,000 GL of Australia's water is harvested per year. Of this, 5,000 GL is groundwater (NLWRA, 2000).

The most recent data available show that total water use increased by 9 400 GL/yr or 65% between 1983/84 and 1996/97. This was mostly due to increases in irrigated agriculture, while urban centres have shown either low increases or net decreases in water consumption over the same period. Over the same period, groundwater use across Australia increased by 88%, and by over 200% in each of New South Wales, Victoria and Western Australia (Figure 1).

Between 1983/84 and 1996/97 groundwater abstractions increased by over 200% in each of NSW, Victoria and WA.

FIGURE 1 Groundwater extractions by region, 1983-84 and 1996-97



Much of the growth in groundwater use in the South East is attributed to irrigation in the Murray Darling Basin. In recognition of the socio-economic and ecological pressure on surface water resources, from 1 July 1997, the volume of surface water diverted from the Murray Darling river system in New South Wales, Victoria and South Australia was capped by agreement at around 1993/94 levels. Groundwater use in the Basin was not capped and has continued to increase steeply since that time. Groundwater impacts on stream flow are now recongnised as an immediate priority in the Murray Darling Basin (Craik, 2005). This increase in groundwater use will be reflected in reduced surface water flows, although uncertainty surrounds the volume and timing of the reduction.

The pressure on Australia's water resources is expected to increase with continuing economic growth. On the supply side, most climate models suggest a decline in rainfall over much of the continent, with significant declines already experienced in the south west corner over the past 25 years (IOCI). Such reductions in water availability have the potential to magnify the shortages already evident.

Declines in water availability will impact on all sectors of the Australian economy, with agriculture being particularly affected. The Australian Bureau of Statistics (ABS) estimated that in 2000-01 agriculture was the largest Australian consumer of water, using 16,660GL (67%), households used 2,181GL (8.8%), water supply, sewerage and drainage services used 1,794GL (7.2%), electricity and gas supply 1,688GL (6.8%), manufacturing and mining 1,267 (5.1%) with all other users accounting for around 5% of consumption (ABS 2004).

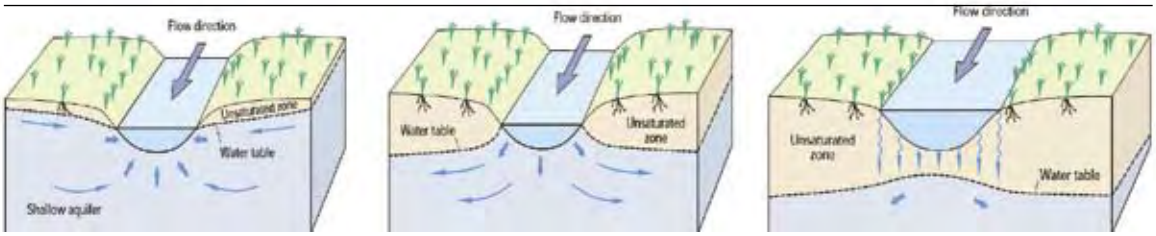
What is Connectivity?

Connectivity refers to flows between water resources located above ground (surface water) and below ground (groundwater). While there are aquifers within Australia that appear to be disconnected from present surface water flows, State and Territory groundwater managers and groundwater scientists (Fullagar, 2005) recommend that allocation regimes should assume connectivity between surface water (including overland flows) and groundwater unless proven otherwise.

Across much of Australia, rainfall is highly variable and flows between surface water and groundwater can vary greatly over time. Water from significant rainfall events filters down into sub-surface aquifers to emerge as a contribution to surface flows (see Figure 2), as a spring elsewhere in a basin or to be drawn from the aquifer via bores.

Connectivity between groundwater and surface water resources can be categorised as gaining, losing or indirectly connected water resources (Figure 2).

FIGURE 2 Gaining, losing, and indirectly connected surface and groundwater resources.



Gaining stream | Losing stream | Indirectly connected stream

Figures adapted from Winter *et al.* 1998

Why is Connectivity Important?

As groundwater is abstracted from bores the water table around the bore will decline. Water is drawn from within the aquifer towards the bore, reducing the flow moving through to streams, natural springs or other bores (Figure 3). More generally, any groundwater abstracted can be expected to result in reduced surface water flows at some time in the future.

Similarly, a change in the way in which surface water is managed (for example, by the construction of additional surface water storage capacity) can alter groundwater dynamics through increasing or reducing recharge.

FIGURE 3 Bore interception of stream baseflow and bore induced aquifer recharge.

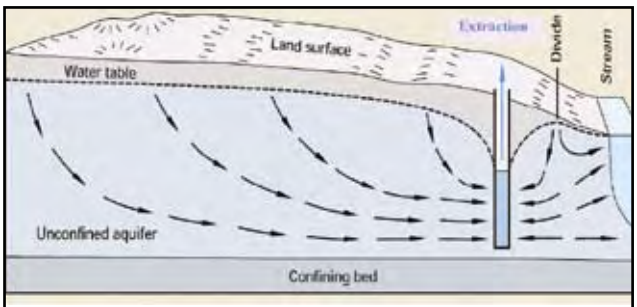


Figure adapted from Winter *et al.* 1998

Where large abstractions are made from bores close to streams, bores will not only intercept water that would otherwise have entered streams, but may also reverse groundwater flows, so that water flows out of the stream to replace water taken from the aquifer.

Assessing Connectivity

There is a range of measurement and mapping techniques for assessing the connectivity between surface water and groundwater. Some techniques employ chemical or physical tracers such as water temperature, pressure, water chemistry or introduced chemicals to infer the direction and, in many circumstances, the volume of flow. Other techniques include mapping the landscape and geological characteristics to define the hydrogeological setting and identify possible paths through which groundwater will flow.

The methodology chosen will depend on the purpose for which the measure is required. The most cost-effective strategies will usually involve a combination of coarse, broad scale mapping to identify sites where interaction is likely, followed by site specific work to trace and quantify the flows (Box 1).

The choice of method should also recognise:

- limitations of scale and the data already available;
- natural variability of connectivity (e.g. seasonal variations and flow responses to drought versus flood situations);
- time delays between impact and flow response, including long term changes in climate, and changed management or extraction regimes; and
- land use practices (e.g. water tables underlying an irrigated landscape may not directly respond to changes in river height).

BOX 1

BORDER RIVERS AND LOWER RICHMOND CATCHMENTS

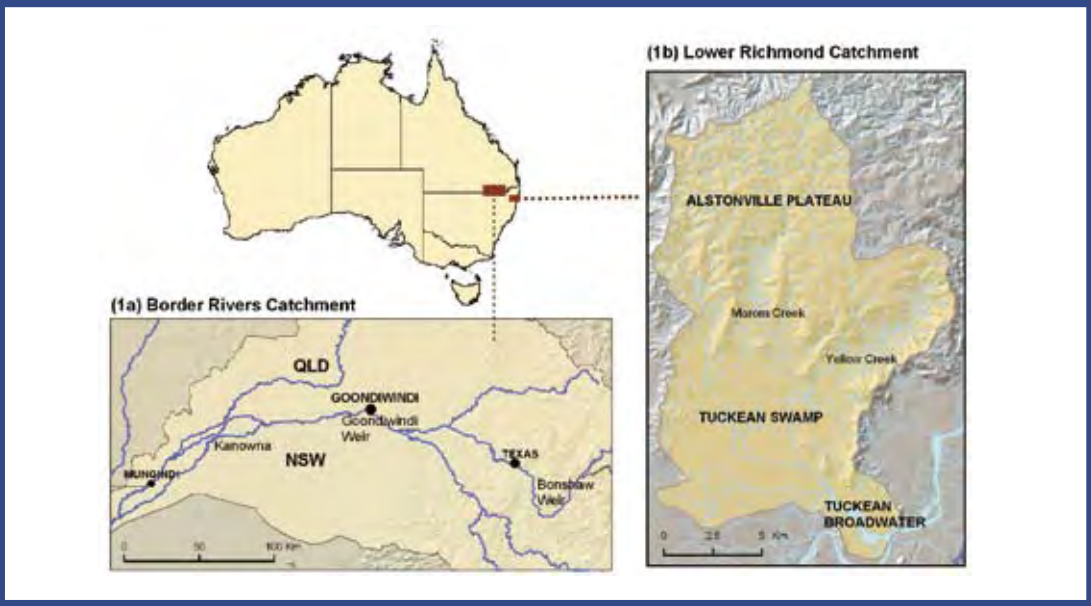
The prolonged drought over much of the 1990s, rapid growth in groundwater abstractions and a concern that groundwater use could undermine efforts to improve the environmental condition of key river systems has been behind several projects designed to understand groundwater and surface water interactions.

The Bureau of Rural Sciences (BRS) is part of a joint project in the Border Rivers and the Lower Richmond catchments (Figure 4) to develop and test assessment tools to understand and manage the region's surface water and groundwater resources in a coordinated way.

Desktop analysis using available information on river and groundwater was used to develop a schedule of field investigations. Site investigations involved the use of seepage meters to directly measure seepage flux, mini-piezometers to measure head gradients between the stream and shallow aquifer, and multi-level temperature logging to infer the dominant seepage direction, as well as geophysical surveys and field sampling for hydrochemistry and environmental tracers.

The study has provided a better understanding of the connectivity between streams and aquifers that is being used to develop a water management plan for the region. In particular, the study has identified important links between natural wetlands and groundwater flows. A full account of assessment of groundwater-surface water interactions in the Border Rivers and Lower Richmond catchment can be found in Baskaran *et al* (2005) and Brodie *et al* (2005).

FIGURE 4 Location of the field trial sites in the (1a) Border Rivers and (1b) Lower Richmond catchment.



Identifying Locations Where Connectivity may be Important

There is a growing concern that the increase in groundwater use over the 1980s and 1990s has yet to be reflected in stream flows. In New South Wales, Victoria and Western Australia, groundwater use has increased by over 200% between 1983-84 and 1996-97. While estimates of the impact of this growth in groundwater use on surface flows vary considerably, there is concern that future flows in the Murray Darling Basin for example, could be reduced significantly as a consequence of past groundwater diversions.

Relatively little is known about the connectivity between groundwater and surface water in Australia

Without further work, it is difficult to predict when and how these impacts will be realised. In Australia, the development of the Barwon Downs bore-field in south western Victoria resulted in the drying up of Boundary Creek within a year. In the United States, irrigation developments on the Republican River in Colorado, Nebraska and Kansas in the 1960s were not reflected in reductions in river flows until the 1990s. Developments in Western Kansas in the 1950s saw streams dry up by the 1990s.

The delayed response of stream flows to changes in groundwater abstraction is an impediment to understanding the hydraulic connection between surface water flows and groundwater. In particular, these time lags make it difficult to gain community and official acceptance that surface water and groundwater are commonly the same water resource.

New water management plans to reduce water allocations to sustainable levels could be ineffective unless the plans allow for the potential for changes to groundwater recharge and groundwater leakage to surface water systems

The problem is made more difficult with surface water and groundwater typically the responsibility of separate agencies or different branches of the same agency. Relatively little is known about the connectivity between groundwater and surface water in Australia and the extent to which accounting for the same water twice in separate management plans may have affected its rate of use.

The importance of connectivity between water resources can be prioritised on the basis of current or foreseeable resource management objectives. In particular, where there is known to be socio-economic and ecological pressure on available water resources — such as in many parts of the Murray Darling Basin — it will be important to identify and measure connectivity. Understanding connectivity is also important for the protection of groundwater dependent ecosystems, even in areas where double accounting is not a major issue.

Indicators for assessing the significance of connectivity could include:

- where over-allocation of a common local flow system is known or suspected. The long term development implications of stream leakage induced by increased groundwater abstractions, interception of future stream base flows, and loss of rainfall events providing aquifer recharge need to be identified as risks to successful restoration of over-allocated systems.
- where decay in the quality of groundwater or surface water is recognised. Salt mobilisation is one of the possible consequences of unmanaged connectivity.
- where environmental assets such as wetlands or streams have been identified for conservation. The local (surface and/or ground) water supplies supporting these environments may be affected by connectivity; management of these connectivity dynamics may be critical to conservation of identified assets.
- where management of the total water resource can offer an overall improvement in the efficiency of water use – such as using local connectivity characteristics to 'bank' water (See Box 2 and Hostetler 2006).

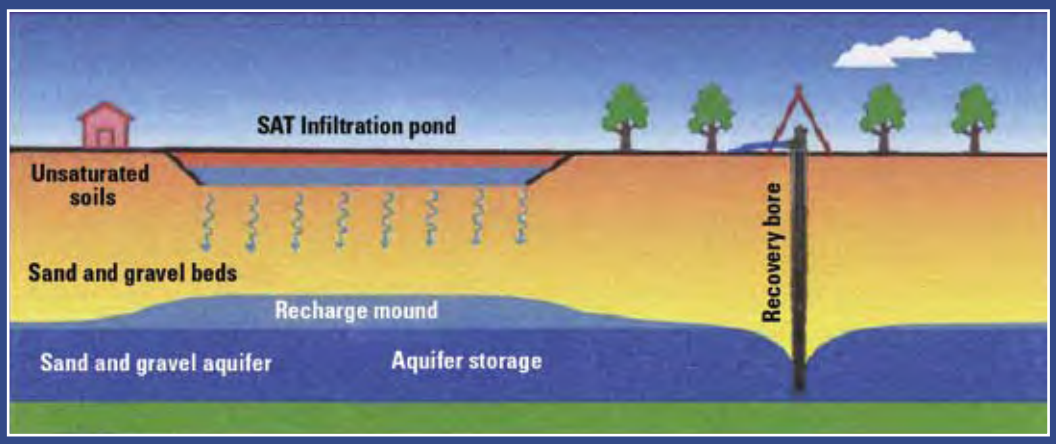
The time lags that are typically experienced between groundwater abstraction and impacts on surface flows raise the opportunity to use groundwater as a buffer in times of low rainfall and scarce surface water. *Water Banking* (Hostetler, 2006) discusses the possibility of using underground aquifers to store water.

BOX 2

MANAGING CONNECTIVITY TO IMPROVE WATER AVAILABILITY AND QUALITY

In Alice Springs, work is under way to store waste water in an underground aquifer to be pumped to the surface for irrigation and horticulture use (see Box 3). (http://www.powerwater.com.au). This is known as Management Aquifer Recharge (MAR). The scheme is expected to increase the supply of water available to the Alice Springs community, reduce mosquito breeding areas and mitigate an emerging problem with rising saline groundwater. Similarly, Adelaide has a scheme to capture, store in underground aquifers and use urban storm water. Perth has also commenced a Managed Aquifer Recharge trial to offset declining groundwater supplies.

After primary treatment, the recycled water is pumped to soil aquifer treatment (SAT) basins. The water infiltrates through the basin to a naturally formed aquifer, chosen so that it will not affect other town water supplies. The recycled water is thus 'banked' for future use in horticulture, agriculture, irrigation of playing fields and other open areas. It can also be used in other non-potable applications such as toilet flushing and garden watering.



As shown in *NT Power and Water PER*, prepared by HLA Envirosciences P/L, 2005, page 7

Policy and Management Implications

Surface water harvesting has been capped in many parts of Australia and many groundwater resources have had allocation limits applied to them in water management plans. However, a legacy of the history of separate management of these resources is that the same water may have been allocated twice, once as surface water and separately as groundwater.

Dealing with this double accounting of our water resources seems likely to emerge as a major policy challenge

Dealing with this double accounting of our water resources seems likely to emerge as a major policy challenge in the immediate future. The National Water Initiative is the most recent step in a series of agreements by Australian Governments to manage both surface water and groundwater holistically and move towards more sustainable water use (Box 3).

The *Rivers and Aquifers: Towards conjunctive water management* workshop (Adelaide, May 2004; Fullagar 2005) brought together water scientists, planners and managers to discuss risks and opportunities in managing surface water and groundwater resources in an integrated way. Workshop participants identified a range of challenges, including:

- development of methods to assess connectivity as a basis for resource management decisions and to demonstrate the significance of connectivity for water management;
- streamlining existing surface water and groundwater management. This could include integrating reporting processes and measures to bridge differences in infrastructure ownership and trading markets; and
- development of accounting, planning and institutional arrangements to integrate groundwater and surface water management across state borders.

The BRS is collaborating in a project to test the application of existing groundwater management and assessment tools in Australian conditions (Baskaran *et al* (2005)).

BOX 3

KEY COMPONENTS OF THE INTER-GOVERNMENTAL AGREEMENT ON THE NATIONAL WATER INITIATIVE RELATING TO CONNECTIVITY

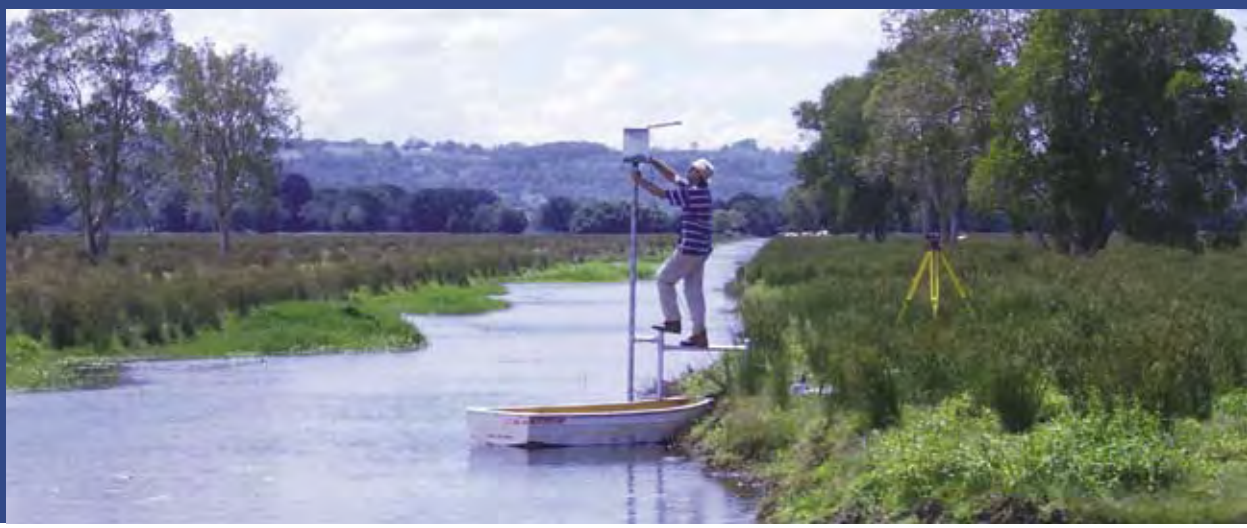
All clauses in the National Water Initiative are written to include both surface water and groundwater, unless stated otherwise. The Initiative's objectives (Clause 23) state that:

'Full implementation of this agreement will result in a nationally-compatible, market, regulatory and planning based system of managing ***surface and groundwater*** *resources for rural and urban use that optimises economic social and environmental outcomes by achieving the following:*

(x) recognition of the connectivity between surface and groundwater resources and connected systems managed as single resource.'

This agreement to manage surface water and groundwater as a single resource is then reflected in the National Water Initiative Agreement's water access entitlements and planning framework, the management of water for the environment, water resource accounting, including an agreement by the signatory states and territories to:

"identify by end 2005 situations where close interaction between groundwater aquifers and stream flow exist and implement by 2008 systems to integrate the accounting of groundwater and surface water use" (Clause 83).



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CONCLUSIONS

Australian water resources are under pressure with recent strong growth in the demand for water and the possibility of decline in rainfall in some areas. The concern that groundwater abstractions over the past several decades has yet to be fully reflected in reduced stream flows has heightened interest in the connectivity between groundwater and surface water.

Historically, Australia's surface water and groundwater resources have been managed as separate resources, with insufficient regard to the impact that depletion of groundwater resources is likely to have on future stream flows. While there are some regions where groundwater may constitute a separate resource, it is more reliable to assume that future surface water flows will be reduced as a consequence of any groundwater extraction.

The National Water Initiative has recognised the importance of this connectivity and proposes that both resources should be managed as one. However, there is much that we have yet to understand about the connection between groundwater and surface water in Australia, and much more to be done to manage the connections effectively.

A range of assessment tools are being tested for measuring and monitoring the connection between surface water and groundwater in the Australian context. These tools will provide the basis for planning and managing our valuable water resources and are vital if we are to realise the opportunities associated with connectivity and use our scarce water resources for the greatest benefit of the Australian community.

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