

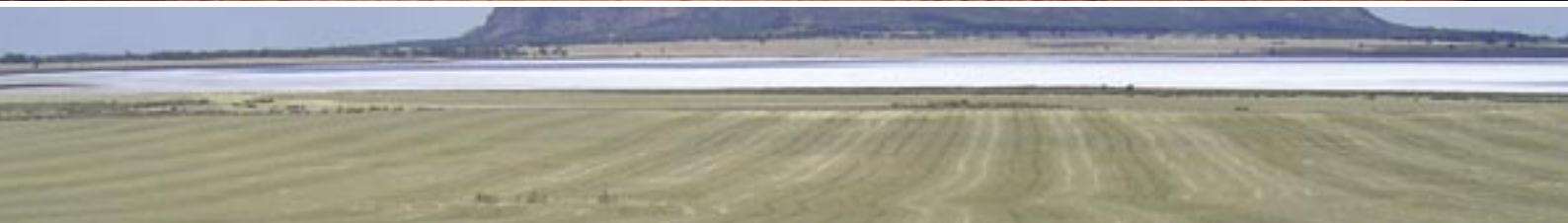


Australian Government
Land & Water Australia



The Impact of Groundwater Use on Australia's Rivers

Exploring the technical, management and policy challenges



Based on the Land & Water Australia
Senior Research Fellowship Report by
Dr Richard Evans, Principal Hydrogeologist,
Sinclair Knight Merz

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*Former Deputy Prime Minister
the Hon. John Anderson MP
presenting Dr Richard Evans with
his Senior Research Fellowship
award supported by Sinclair Knight
Merz Catchment Planning Manager
Dr Michael Shirley.*



In late 2004 Dr Rick Evans, a Principal Hydrogeologist with leading consulting firm Sinclair Knight Merz, was awarded one of the inaugural Land & Water Australia Senior Research Fellowships.

Land & Water Australia specialises in funding research for the sustainable management of the resources that underpin our primary industries and rural and regional communities.

Land & Water Australia's Senior Research Fellowships are an exciting initiative that works at the intersection of two of the Australian Government's key priorities:

- ▶ innovation and scientific excellence, and
- ▶ improved management of Australia's natural resources.

This document summarises Dr Evans' report and will be of relevance to water managers and planners, policy makers, industry and industry peak bodies. This document is intended to be used in conjunction with the technical report.

Land & Water Australia would like to thank Sinclair Knight Merz for supporting and releasing Dr Evans to undertake this work.

About Dr Rick Evans

Dr Evans has more than 25 years experience in water resource management and has worked on numerous water resource projects throughout Australia and Asia both at a technical and management level. He has extensive experience in dealing with complex groundwater management issues. He is the author of several authoritative national policy documents, including the COAG National Groundwater Management Policy, and is also a member of the World Bank Groundwater Management Advisory Team.

One of Dr Evans' research interests is on the interaction between surface water and groundwater, he has written many reports and papers on this issue. He regularly addresses community organisations on a broad range of groundwater management topics.

The internationally peer-reviewed technical report is available electronically or in hard copy through Land & Water Australia's website at www.lwa.gov.au

What are the Senior Research Fellowships?

During the peak of a researcher's career their most precious commodity is time. Many of our best scientific brains spend too much of their time on activities other than research—administration, management, writing research proposals, wrestling with budgets and so on. In a new approach to funding science, the Land & Water Australia Fellowships are expressly designed to “free up” the time of a select few leading researchers each year, to give them some time and space free from the constraints of everyday work. The intent is to sponsor reflective, synthesis research by people at the top of their fields—in mid-career, rather than in retirement.

The Senior Research Fellowships are designed to advance the way Australians think about, interact with and manage our natural resources. Each of the Fellows produces a major work, in written form, lectures and all forms of media, which outlines their thinking, findings and recommendations. Land & Water Australia expects these works will be thought-provoking and challenging, representing leading-edge thinking within their respective field.

Each year the Fellows are selected by the Land & Water Australia Board. The Fellowships are also made possible by the support of the Fellows' employers. Land & Water Australia thanks these organisations for their foresight and willingness to participate in this initiative.

Summary

Groundwater and surface water resources are often closely linked. This has particular implications for Australia and how we manage our water. As a result of this connectivity it is possible to allocate the same resource twice, to surface water users and to groundwater users. This double allocation of the same water has reduced the flow in our rivers and streams.

There has never been a nationwide review of surface water and groundwater interaction in Australia and consequently the extent of double allocation is unknown. There is also no national approach to managing our groundwater, nor an agreed method for assessing its links to surface water.

The lack of understanding of the links between groundwater and surface water has contributed to the nation's present water shortage. This has been exacerbated by dry conditions over the last decade and by rising demands for water.

It is suggested that tackling the impacts of surface water and groundwater interaction requires a national approach on three fronts - technical, managerial and educational.

Several approaches are proposed for assessing and managing our groundwater resources, and recommendations made for their adoption.

It is also argued that remedying the over-allocation of surface water and groundwater should be borne equitably by all users, with cuts and restrictions applied generally rather than to groundwater users alone.

How do groundwater and surface water link?

Groundwater contributes to, and increases stream flow when the water table is higher than the level of the stream. The quantity of groundwater contributing to stream flow is called baseflow (Figure 1).

If an aquifer's water table is below the level of the stream, the stream water will tend to recharge (replenish) the groundwater (Figure 2).

If aquifer and stream are separated by a semi-permeable layer (e.g. clay) this will slow the water flow in either direction creating a lag. How closely a stream and groundwater are connected depends on the extent and nature of the saturated material between them (permeability).

If the groundwater table and stream level are the same, any change in the groundwater table will affect the level of the stream so that it either gains or loses flow.

Groundwater and surface water are regarded as being poorly connected if they constantly differ in water level and are separated by a layer of material with low permeability. Research however shows that over time, all streams are connected with groundwater.

Groundwater is recharged in three ways:

- ▶ by rainfall or irrigation
- ▶ by leakage from streams, lakes and reservoirs, or
- ▶ by water rising from aquifers underneath.

And it can discharge in three ways:

- ▶ by evapotranspiration (water lost through the combined effects of evaporation from the grounds surface and transpiration from the vegetation)
- ▶ by flowing into surface water, or
- ▶ by leaking into a deeper aquifer.

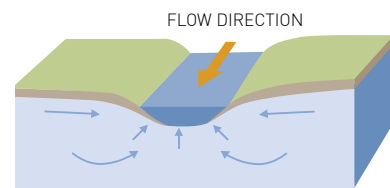


Figure 1 - Gaining stream

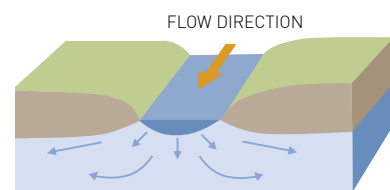


Figure 2 - Losing stream

Impacts of pumping on surface water and groundwater resources

Under normal climatic conditions, groundwater reaches a “steady state” where the volume of recharge is balanced by discharge, within a pattern of seasonal fluctuation. If pumping is significant, this lowers the water table which will, in time, reach a new “steady state”.

Groundwater pumping lowers the flow of groundwater into the stream unless there is a proportionate addition of water from some other source.

Groundwater pumping also increases the rate at which surface water leaks into the groundwater and drains the stream.

Even if the stream is gaining flow from other sources pumping still reduces baseflow as the groundwater table sinks relative to the stream level and draws water out of the stream. Heavy pumping over time may mean the river actually loses flow. (Figure 3)

Thus, pumping groundwater can reduce stream flow in Australia’s rivers in two ways:

- by decreasing baseflow in streams (or recharge into the stream by groundwater), and
- by increasing leakage of the stream into a deeper or adjacent aquifer.

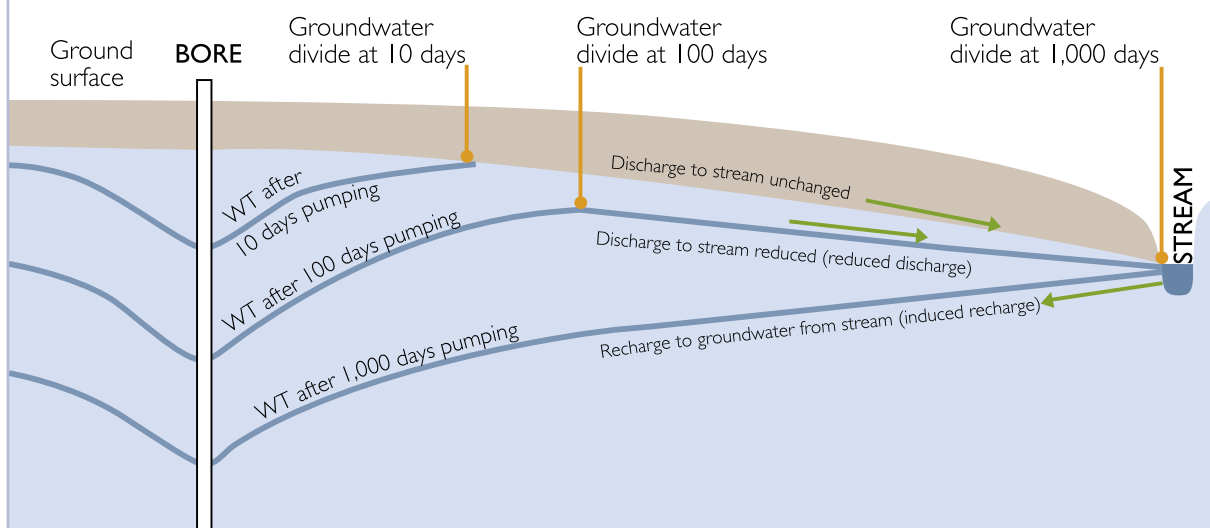


Figure 3 ~ Effect of groundwater pumping on a gaining stream [Note: induced stream leakage after 1,000 days is labelled as 'induced recharge']

Estimating stream flow impacts

Due to the complexity and variability of the natural environment there is no single robust and technically simple tool for predicting the impact of groundwater pumping on stream flow.

Over the last 20 years various attempts have been made to link surface water models with groundwater models to calculate stream flow impacts. These attempts have had mixed success because of the different scales and variability in time periods used in the analysis.

Choosing the right model for each situation requires judgment and must be tailored to local circumstances. All models however show that:

- ▶ the relationship between groundwater pumping and stream flow is complex, with a range of time lags depending on local geology.
- ▶ the distance from the river is less of an issue than the nature of the material the groundwater must flow through to reach the river.

Recent developments in techniques for estimating stream flow impacts involve use of chemical methods for tracing the links between groundwater and stream water such as comparing the natural chemical composition of the surface and ground waters, comparing their physical properties, and using dyes and tracers to track flow.

Understanding responses to pumping

Time lags

Time lags are a vital part of understanding the links between groundwater and surface water. Between the start of pumping and an impact in the stream, the lag can be hours, weeks, years, or even centuries. When pumping ceases, it may take decades before stream flow returns to its previous norm.

In situations where lags are short and impacts large, stream flow monitoring alone can be used to measure the impact of pumping. This is far less effective when bores are distant, lags long or extraction of groundwater is small relative to streamflow. Where groundwater has been subject to prolonged periods of extraction (i.e. decades), reductions in streamflow can be a result of current and past groundwater extraction.



Response ratios

One way to understand the relationship between groundwater and surface water is to calculate the response ratio. Response ratios are useful for catchments where similar management approaches can be used to control groundwater and surface water extraction. For example, pumping at 10 megalitres (ML) a day is found to deplete a stream by 3 ML a day after 10 years—a response ratio of 0.3 is attained. If pumping doubles to 20ML a day, the stream is depleted by 6ML after another 10 years.

Geological variability

Australia's wide geological variability makes monitoring the impact of groundwater pumping a real challenge. The two most common geological situations are:

- ▶ alluvial settings where groundwater exists in material that has been deposited by water such as sand, silt and gravel. Here water flows freely between river and aquifer and lags between pumping and observable effects are usually short, and
- ▶ broad plains with varying geology, where bores may be sited long distances from streams and time lags may be very long.

Most Australian studies have focused on the first setting, where aquifer and river are closely interlinked and bores cause a gradual drawdown in streamflow. However on flat plains with shallow water tables, a significant amount of groundwater is lost through evaporation from soil and transpiration by vegetation. The amount of water lost to groundwater evapotranspiration is vital in calculating the water balance for a catchment.

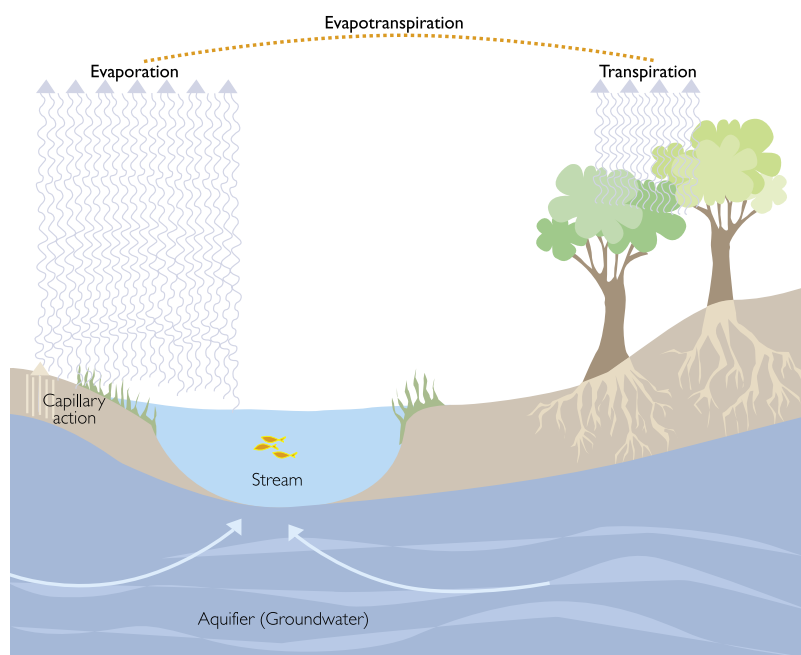


Figure 4 – Evapotranspiration

Evapotranspiration

Groundwater is an important source of water for vegetation and is subsequently significant for environmental health. Groundwater pumping can have the effect of lowering the water table, limiting the water available for vegetation and hence reducing evapotranspiration. In some settings the effect of pumping reduces stream flow by as much as 1:1, which can have a significant impact on the health of the surrounding landscape and vegetation. In many instances vegetation is the first to feel the impacts of groundwater extraction before it is reflected in streamflow (Figure 4).

Other impacts

In the case of Australia's rivers that only flow for short times, it is sometimes argued that groundwater pumping has little or no effect on them. However by decreasing the amount of water stored below the stream bed, pumping increases the time it takes for the river to fill and flow. This makes flow events even more short lived.

Where groundwater pumping occurs close to the coast this usually has little effect on stream flow in the region although it does have an impact on sub marine groundwater discharge.

Understanding baseflow

Baseflow holds the key to understanding how surface water and groundwater interact in streams that are fed by groundwater (gaining streams). Baseflow occurs when the groundwater table is higher than the level of the surface water and the groundwater drains into the stream. Further detail about baseflow is available in Chapter 5 of the technical report.

Baseflow has several sources:

- ▶ groundwater discharge
- ▶ flow through soil
- ▶ bank storage
- ▶ delayed surface water from lakes and wetlands, or
- ▶ delayed groundwater from perched aquifers.

Calculating baseflow can be tricky

Streamflow can be measured by gauging stations placed at various locations along a river. The accuracy of a baseflow estimate in a stream is firstly dependent upon the accuracy of the streamflow gauge recording the data. Methods for baseflow separation analysis are complex and are described in detail in Appendix A of the technical report.

In reality, only parts of the upstream river may receive baseflow, while other parts may lose water to groundwater. The baseflow observed at a streamflow gauge is the combined result of these processes.

In cases where the water table is shallow and soils are highly transmissive, groundwater discharge to streams increases rapidly after rainfall. This process can make it difficult to interpret the distinction between baseflow and streamflow.

In many situations the amount of groundwater lost to evapotranspiration may be significant. Baseflow is then calculated as:

► $\text{baseflow} = \text{recharge quantity} - \text{evapotranspiration}$.

It is important to note that in most catchments baseflow volume cannot be used as a surrogate for recharge. This is because baseflow may have multiple sources.

In cases where water tables are deep and there is effectively no evapotranspiration, baseflow is approximately equivalent to recharge across the catchment.

Baseflow Index

The Baseflow Index (BFI) is an indicator of the hydrogeological conditions in a particular catchment. Long-term average BFI is defined as the baseflow divided by the total streamflow over the same period. This indicates the relative contribution of baseflow to total streamflow. BFI can be used to compare sites along a river or even different catchments.

While annual BFI results indicate how much groundwater is contributing to streamflow on average and are useful for regional and long-term studies, they can disguise the marked seasonal variation in many rivers. Monthly or seasonal BFIs are a better indicator.

There has so far been no comprehensive analysis of the baseflow of Australian rivers although some studies have been carried out at the regional level on streams in the Murray-Darling Basin.

Catchment managers usually rely on models to estimate likely streamflow response to changes in baseflow. Their accuracy subsequently relies on how well the model reproduces the historical behavior of the river.

With some caveats, baseflow analysis provides a valuable source of information on groundwater processes and a way to deduce a whole-of-catchment water balance. This in turn can greatly help to understanding how groundwater pumping affects our rivers.



Case studies

Case studies in managing groundwater/surface water interaction hold valuable lessons for Australia. Some experiences in the United States where the issue has long been recognised, are of particular relevance for Australia. Two cases, the Eastern Snake River in Idaho and the Republican River in Kansas, are detailed in Chapter 6 of the technical report.

Useful findings from these cases include:

- ▶ any agreement to use river water must also take into account groundwater use
- ▶ a combined groundwater/surface water plan provides greater certainty for all users
- ▶ groundwater modeling is essential to assess the effectiveness of various mitigation options
- ▶ although the impact of a single bore may seem small, the combined effect of many bores may be large
- ▶ the water quantity impact on the stream is often the same regardless of its distance from the bore however the time lag may vary significantly
- ▶ there is nearly always a need for close monitoring and strong compliance
- ▶ it may be necessary to retire both surface and ground water licences
- ▶ a domestic water use policy may be necessary if there are many household bores,
- ▶ there must be open and transparent agreement among technical people on the scientific method used to model water flows
- ▶ a good model can lead to better community understanding of the real issues
- ▶ the scientific basis for water planning should be complete before the management plan is developed
- ▶ management plans must be flexible to allow for changing conditions, and
- ▶ zoning groundwater use enables the area with the heaviest impact on the river to be managed first.

Australian context

In the Murray-Darling Basin it is estimated that groundwater extraction, mainly for irrigation, rose by 310 gigalitres (GL) a year (equal to 310,000 Olympic sized swimming pools a year) in the seven years since the cap on surface water extraction was introduced in 1993/94. This is about two per cent of the total cap (10,000GL) each year.



If extractions continue to grow, by 2050 the loss to the Murray River will be around 711 GL. This does not include groundwater extraction prior to 1993, some effects of which are yet to be felt.

Scientific studies reveal a clear relationship between the geology of the Murray-Darling Basin and the connections between its groundwater and surface waters. Stream losses in the mid-section of the Murray are thought to be closely related to groundwater extraction and subsequently have rapid response times.

The sustainable yield of groundwater in the Murray-Darling Basin is uncertain because not enough is known about the extent of the connection between its groundwater and surface water. The best estimate is that extraction of both is causing a net reduction in the Murray's flow of 275-500 GL a year. High risk areas exist in Queensland such as the Condamine, in NSW on the Lower Gwydir, Upper Namoi, Upper Macquarie, Upper Lachlan, Murrumbidgee and in some groundwater management units in Victoria.

One study documenting the drying out of Maules Creek on the Namoi River over a 20-year time frame shows that groundwater pumping has impacted on surface water flows, causing a decline in baseflow over time. Another example is from Geelong, where the predicted drying up of Boundary Creek by Barwon Downs bore field five kilometres away occurred after a lag of about one year.

A major challenge is to assess the risks and benefits of pumping in areas where the lag between extracting groundwater and in-stream impact is long, requiring a better understanding of the fundamental processes.



National implications

In the decade from 1985 to 1996 groundwater use in Australia grew from 2600 gigalitres (GL) to 4200 GL—an increase of 58 per cent. This compares with surface water use of 19,100 GL, making groundwater about 18 per cent of the nation's total water use.

It is generally agreed that groundwater consumption increases in times of drought due to limited availability of surface water supplies. Despite there being few records of groundwater consumption, let alone records of consumption during drought, it is probable that in 2007 national groundwater use will be between 6000-8000 GL.

Two major reviews of Australia's water resources (1985 and 2000) assessed surface and groundwater separately. Consequently they may have double-accounted the same water in many catchments.

Double accounting occurs when water in a catchment is counted once as surface water and again as groundwater and no allowance is made for interaction between the two. This leads to an overestimate of the total water resource.

This is a headache for water planners, but only becomes a serious problem when it leads to double allocation of the same water. This reduces river flow, lowers security of supply for surface water users, harms landscapes and can dry out rivers.

The extent of double allocation of water in Australia is unknown.

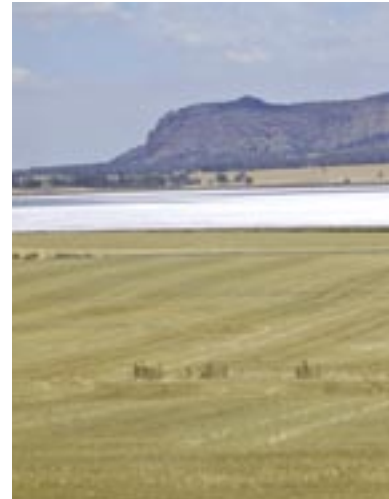
It is comparatively straightforward to estimate surface water resources using stream gauge data. In comparison, Australia has no agreed method for assessing the sustainable yield of groundwater. Unfortunately most estimates of groundwater sustainability today are based on imperfect methods which do not account for the many ways it can discharge.

Boundaries between bodies of groundwater do not always coincide precisely with surface catchment boundaries as groundwater management units may embrace several catchments. This means that groundwater pumping in one catchment can sometimes reduce water availability in other catchments.

In catchments where most bores are within about five kilometres of rivers their effects are likely to be felt quickly and may be factored into surface water yield estimates. However persistent drought can disguise the full impact of pumping. Heavy surface irrigation may also disguise or offset the effects of groundwater removal and make establishing a water balance difficult.

The technical report presents a possible national methodology for assessing groundwater/surface water interaction detailed in Chapter 8. This has three steps:

- ▶ define the degree of connectivity
- ▶ define the impact of interaction, and
- ▶ define the combined surface/groundwater yield.



Management options

The current draft national policy on groundwater proposes that all jurisdictions should assess the impact of groundwater pumping on streams. All states are currently considering how to do this.

OBJECTIVE	Total Water Resource Sustainability	Stream Management Plans (maintain environmental flows)
MANAGEMENT TOOLS	<ol style="list-style-type: none"> 1 Whole of Catchment Water Balance 2 Zonal Management 3 Connectivity Risk Assessment 	<ol style="list-style-type: none"> 1 Zonal Management 2 Connectivity Risk Assessment
COMMON MANAGEMENT OPTIONS	<ol style="list-style-type: none"> 1 "Capping" (i.e. in the case of new entitlement applications) 2 Cancellation or buy back of licenses 3 Restriction on pumping volumes (including Annual Announced Allocations) 	<ol style="list-style-type: none"> 1 Cancellation or buy back of licenses 2 Restriction on pumping times 3 Transfer of surface water entitlements to groundwater entitlements 4 Groundwater trading away from streams 5 Surface water to groundwater trading
TRIGGERS	<ul style="list-style-type: none"> ▸ Regional groundwater level decline ▸ Declining stream flows over the long term 	<ul style="list-style-type: none"> ▸ Environmental flow targets reached at critical times

The chart above shows a range of tools and responses available to water and natural resource managers for controlling, mitigating or administering groundwater extraction.

In the case of short term impacts and bores close to streams this is relatively straightforward. But when large time lags are involved the issue is far more complex.

Management tools

1 Catchment water balances

A good way to identify double accounting of water is to undertake a **whole-of-catchment water balance**. This gives a realistic idea of the volume of water available for use.

A catchment water balance is arrived at by calculating:

- i** opening stocks of water in on-river reservoirs, farm dams, aquifers, soil, river channels and wetlands and snow (if relevant)
- ii** inflows from rainfall, surface flow from other catchments and from aquifers outside the catchment
- iii** interchange between water types within the catchment (e.g. rainfall to surface water, rainfall to soil water, soil water to groundwater etc), extraction for consumptive use and returns for consumptive use within the catchment

- iv outflow, including evapotranspiration, evaporative loss from water bodies, city water use, aquifers flowing out of the catchment, other consumptive uses outside the catchment, and
- v closing water balance, consisting of the volume of water in aquifers which is recharged over a given period of time and the volume of water which is not replaced and leads to depletion.

Catchment water balances should be made over a long enough period of time to allow for slow movement of groundwater. The extraction of both surface and ground water affects the total balance, as will the environmental needs of the catchment.

2 Zonal management

Catchment water balances can be supplemented by **zonal management**. This maps groundwater pumping zones based on their impact on the river in the short term and is particularly useful in managing the impact of groundwater pumping on the landscape and on environmental flows. Zones are classified as having a very short, short, medium and long time lag between pumping and the effects being seen in the river (Figure 5).

Each zone requires a different management response, for example:

- i *very short* – apply the same rules as for surface water extraction
- ii *short* – restrict pumping volumes, duration, period and timing to particular times of the year
- iii *medium* – limit extraction to sustainable yield, based on a catchment water balance, and
- iv *long* – no active management.

This does not mean the impacts will necessarily be severe or mild but that in a low connectivity setting, they will be much slower to emerge.

Edge of Surface Water Catchment

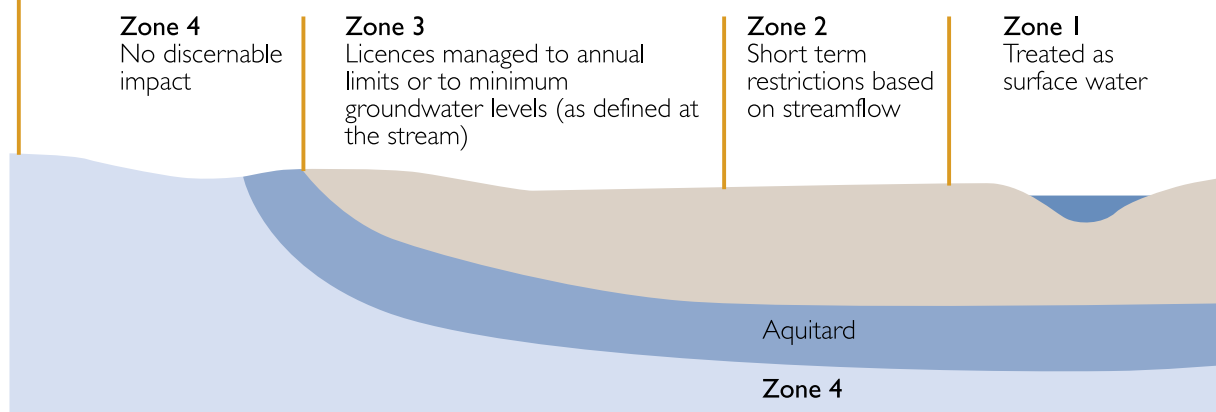


Figure 5 ~ Proposed zonal concept for managing new and existing water access entitlements

3 Connectivity risk assessment

Connectivity risk assessment can be used to assess the connectivity between groundwater and surface water on a case-by-case or stream reach basis. This can be seen as a risk-based approach:

- i** *Low connectivity* – cases where groundwater abstraction impacts on surface water resources by 10 per cent or less, over a 50 year period
- ii** *Moderate connectivity* – cases where groundwater abstraction impacts upon surface water resources by 10-50 per cent, over a 50 year time period, or
- iii** *High connectivity* – in cases where groundwater abstraction impacts upon surface water resources by greater than 50 per cent, over a 50 year time period.

A 50-year plus time period is used as it is the long term effects which the connectivity categorisation is aimed at addressing and is also consistent with the notion of sustainable surface water and groundwater yields. Also 50 years plus is a sensible timeframe for water resource planning to occur.

Sustainable yield

The current definition of sustainable yield for groundwater is “*the extraction regime, measured over a specific planning timeframe that allows acceptable levels of stress and protects dependent economic, social and environmental values*”.

There is currently no agreed way to determine sustainable yield, although some states use an Annual Announced Allocation as a surrogate, and this can be based on concepts such as reliability of supply.

Curbing double accounting and double allocation

Managers have three main options for curbing the impact of double accounting and double allocation of groundwater and surface water, these options must apply to all water users, not only groundwater users:

- ▶ to issue no new licences
- ▶ to cancel or buy back existing licences, or
- ▶ to restrict pumping volumes.

Whatever the preferred option, it needs to be technically defensible in the context of the particular catchment. Groundwater monitoring close to where it is pumped will usually, over time, identify regional trends in resource use.

Trading of groundwater and surface water entitlements can help to achieve a smooth transition to a more sustainable water management regime. The use of a zonal system will help to determine where and how trading can take place.



Conclusions

The key technical, management and education conclusions are:

1 Technical

- ▶ The magnitude and timing of the interactions between surface water and groundwater in Australia have not been defined and broad understanding of the issue is lacking.
- ▶ There is often a significant time lag between the start of groundwater pumping and its visible impact on rivers.
- ▶ Caution should be exercised in using baseflow analysis as it generally overestimates groundwater discharge. A hydrogeological model should be used to modify the results of baseflow analysis to provide a more accurate estimate of groundwater discharge. More case studies, field measurements and a clearer understanding of the role of climate are needed.
- ▶ The use of whole-of-catchment water balances will give greater confidence in defining the impacts of groundwater pumping on streams.
- ▶ Many long-established bores are located close to streams. Therefore in many catchments, the effects of groundwater pumping on streamflow have already been felt. Depending on how surface water resources are calculated, this may have already been factored into the (reduced) surface water yield.
- ▶ In large flat catchments evapotranspiration of groundwater is an important factor reducing the impact of groundwater pumping on stream flow. Groundwater evapotranspiration is vital to the health of native landscapes.
- ▶ The impacts of groundwater pumping on reducing stream flow can vary from nil to 100 per cent depending upon the local hydrogeology. In situations where the bore is close to the stream and aquifers are unconfined the impact will be close to 100 per cent in a steady state. As groundwater levels fall across the catchment due to continued pumping, the importance of groundwater evapotranspiration decreases and pumping has a bigger impact on the stream.

2 Management

- ▶ Australia has no agreed national approach on how to manage the interaction between groundwater and surface water.
- ▶ The extent of double allocation of groundwater and surface water resources across the continent is unknown.
- ▶ Current water management does not generally focus on longer-term impacts of groundwater pumping.
- ▶ Applying a total catchment water balance and zonal management approach will help achieve sustainable water management.

3 Education

- ▶ Community understanding and goodwill are essential to integrating the management of groundwater and surface water in Australia and to avoid conflict between users.

The way forward

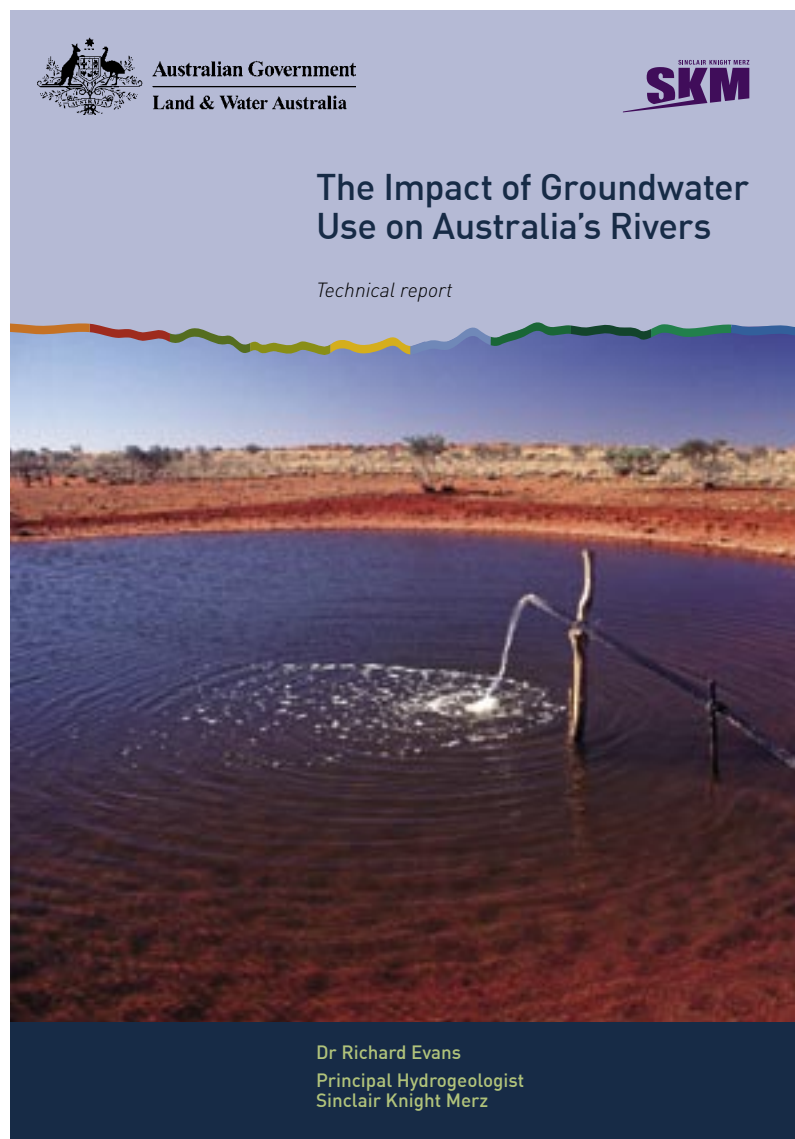
The following steps are considered necessary to take Australia into a new era of integrated water management:

- ▶ A national assessment of the extent of double accounting of Australia's water resources.
- ▶ A national approach to managing our groundwater, and an agreed method for assessing its links to surface water.
- ▶ The development of integrated surface water and groundwater management plans in every catchment (except in catchments where the hydraulic interaction is extremely small).
- ▶ Whole-of-catchment water balances to identify double accounting at the catchment level.
- ▶ More studies that "close the water balance" to build confidence in the use of the methods described in the technical report.
- ▶ Further studies to define how much pumped groundwater is intercepted discharge to streams and how much comes from other sources.
- ▶ A national toolbox of assessment methods agreed to by the states and territories that would help managers define the interactions between groundwater and surface water and the degree of connectivity and the extent of double accounting.
- ▶ Identification of groundwater management units where boundaries need to be modified to better allow for surface water/groundwater interaction across jurisdictions.
- ▶ Investigation of the impact of climate change on baseflow to streams and rivers.
- ▶ Adoption of integrated management measures that treat all water users equally, especially where licences are withdrawn or reduced.
- ▶ A public education program on the links between groundwater and surface water to help achieve national cultural change in water management.

For further information please see 'The Impact of Groundwater Use on Australia's Rivers. Technical Report.'

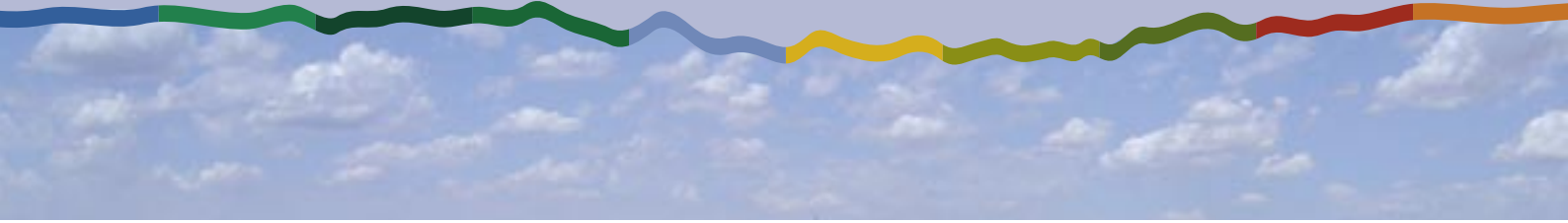
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