10.1071_ISSN0311–4546EC110p28

# Water alchemy

## Aquifer injection is shaping up as smart water conservation. **Steve Davidson** reports.

Urban stormwater and treated sewage effluent carry a cocktail of contaminants into our lakes, rivers and oceans, and planning for their disposal is costly and complicated for governments and management authorities. Yet, following some lateral thinking, scientists have found a simple but effective way to store and recondition this precious water and recover it for re-use.

Working initially in South Australia, hydrogeologists from CSIRO and the South Australian Department for Water Resources have pioneered the use, in this country, of wells to store undrinkable water in aquifers – underground bodies of water – for later reclamation.

**Below: Aquifer storage and recovery in Australia was first evaluated at Andrews Farm, a suburban development in Adelaide.**

SA Dept for Water Resources

Remarkably, the process of underground storage reconditions the water, even though it often has been injected into brackish (salty) aquifers. In fact, the reclaimed water is good enough for irrigating urban landscapes or crops. An added bonus is that urban stormwater vitalises brackish aquifers by reducing their salt content.

Aquifer storage and recovery (ASR) has other advantages too.

In arid or semi-arid areas or monsoonal regions, aquifers can be recharged with surplus in wet periods and recovered in dry periods, when the demand for water is high.

This usually is cheaper than storing the water in dams on a flat landscape. It also prevents evaporative losses, and reduces the run-off of nutrient-rich, possibly polluted water to estuaries and oceans.

### Simple idea, complex processes

So what are the unseen processes that make all this happen? What are the problems and risks of ASR and how can these be overcome or minimised? How much water can be stored? Does it really work?

Dr Peter Dillon, of CSIRO Land and Water, and his CSIRO and Department for Water Resources colleagues have been seeking answers to these questions for the past eight years.

They've reviewed previous studies, consulted with the community, and conducted bench-top experiments and computer modelling exercises. Pilot studies have taken place in Australia, the United States and the Netherlands.

'The work of our consortium on the research and practicality of water reclamation is conceptually simple,' Dillon says. 'Basically, we put in a well, inject the otherwise-wasted water, and later take it out again!

'But, it has required a lot of innovation to overcome problems such as clogging of injection wells due to turbid or nutrient-rich water, and to develop measuring methods for monitoring aquifers so that ASR with low-quality water can be managed sustainably.'

Clogging of wells can have many causes, including suspended solids or organic matter, precipitation of minerals, and growth of microorganisms.

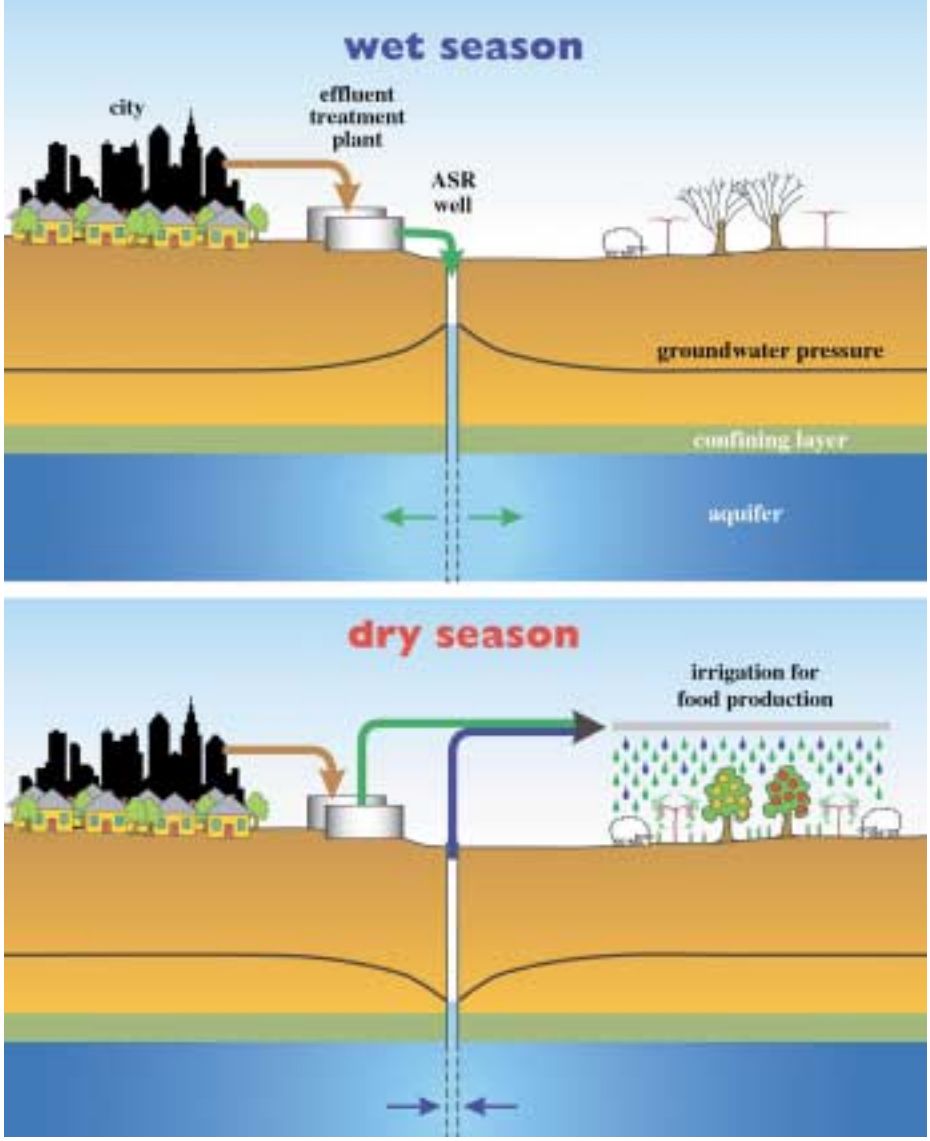
The problem led many to conclude that injection wells were not viable, but tests by the ASR research team found that clogging could be reversed by periodic redevelopment of the well, by better well design, and by pre-treating the water to be injected.

What about the risk of pathogens (disease-causing organisms), especially when effluent from wastewater treatment plants is being injected?

**Far left: SA Department of Water Resources technician Herb Videka collects groundwater samples for physico-chemical and isotopic analyses.**

**Centre left: Sampling the backwash water during well redevelopment at the Andrews Farm site. Backwashing is by airlift, and is used to unclog the well.**

**Left: CSIRO's Karen Barry and work experience student Peta Teague collect a water quality profile at an observation well.**




**In aquifer storage and recovery, a well is used to inject stormwater from a holding pond or other constructed wetland into the aquifer, for later recovery. Alternatively, reclaimed water derived from a sewage treatments works can be injected and reconditioned during underground storage.**

Local communities are understandably concerned about the health and environmental implications.

In an ASR project at Bolivar, Adelaide's main sewage treatment works, the recycled water is filtered and chlorinated. As a consequence, pathogen presence in the water is very low.

But what if pathogens entered the aquifer due to a process failure at the treatment plant, or through recontamination of some sort?

The number of microorganisms in aquifers tends to decline rapidly over time. In fact, it declines at an exponential rate, analogous to radioactive decay.

For example, Dr Simon Toze, of CSIRO Land and Water, found that the bacterium, *E. coli*, had removal times (time to decline to 10%) of 3–20 days. Two species of *Giardia* had removal times ranging from 7–23 days.

The removal rate mostly depends on the presence of antagonistic organisms and on temperature, with higher temperatures accelerating inactivation of pathogens.

The trick is to keep injected water underground for long enough to exceed microbe removal times several times over, so that the risk of exposure to pathogens in recovered water is infinitesimally small.

Other problems have been addressed or are being investigated. These include the risk of leaky wells, aquifer instability due to injection, presence of organic compounds, brackishness of recovered water, and the possibility of inadequate storage capacity.

Aquifers can be huge, but may have a finite capacity for additional water. In consultation with others, national guidelines for use of stormwater and treated wastewater in Australian ASR installations have been produced.

## Aquifer projects

The technical viability and environmental sustainability of ASR in Australia was first evaluated in a pilot study, initiated in 1993, in a new suburban development in Adelaide, known as Andrews Farm.

Here the water source for injection was stormwater run-off from a catchment with both residential and sheep grazing land use. It provided the scientists with much useful data and met its goal of providing water suitable for irrigation.

Russell Martin, of the South Australian Department for Water Resources, says his department has set up six stormwater ASR projects in Adelaide with a view to reducing demand on the Murray River and Mt Lofty Ranges water supply catchments.

'Future projects being planned are larger, better integrated with urban water management, more widespread and cover a wider range of aquifer types,' Martin says.

In each case, wetlands and detention ponds have been installed as part of urban stormwater flood management plans. Supplies of 30 000–150 000 cubic metres of water have been produced at about half the cost of mains water, using aquifers that previously were too salty for irrigation purposes.

Following the success of stormwater projects, the group extended the concept to treated sewage effluent that has been reclaimed through an additional treatment plant.

Unlike stormwater, reclaimed water flows at a relatively uniform rate throughout the year and inevitably expands as the municipal population grows.

The ASR field trial at the Bolivar treatment works initially ran into clogging problems, but these have now been resolved. The site contains 16 observation wells in addition to the injection well.

Bolivar, Adelaide's main sewage treatment works.

The Bolivar trial looks promising and another similar pilot project is under way at a second sewage treatment plant.

At both sites, expansion of irrigated viticulture and horticulture has caused groundwater pressures to drop and the project leaders expect that ASR with reclaimed water will counter this to the tune of 10 000 and 3000 megalitres of water per year respectively.

## Clayton's good drop

The researchers have now turned their attention to the improvement in water quality that occurs during aquifer storage, particularly for supply of drinking water.

The Department for Water Resources established a site at Clayton, a small town on the lower Murray River system, where a lake that supplies the town's drinking water is threatened by toxic algal blooms that occur in some summers.

An ASR scheme recharges water in an aquifer in winter, for recovery as an emergency supply in summer. The outcomes have been remarkably positive. In spite of the injection of lake water into an aquifer that was nearly as salty as seawater, a suitable quantity of good quality water is recovered.

The townspeople actually prefer the recovered drinking water as it has lower turbidity (less cloudiness) than the lake water and the chlorine dose can be lowered, improving the taste. Similar projects are under way in Western Australia and on a Northern Territory island.

So innovative harvesting of stormwater and reclaimed water for storage and recovery in underground water bodies shows great promise. Projects using highly treated waters have been running for 25 years in the US, and it has recently been recognised that the newer Australian approach, using lower quality water, will have wide applications in water-sparse, developing countries.

Late last year, CSIRO Land and Water and the SA Department of Water Resources were jointly awarded a UNESCO prize, with the impressive title of 'The Great Man-Made River International Water Prize for Innovation in Water Resources Management in Arid and Semi-Arid Areas', for their ASR work.

In accepting the prize on behalf of the group, Dillon emphasised the urgent need for smart water conservation in dry regions of the world, and the magnitude of the task.

For their part, the scientists in the group intend to extend their research, education and training activities.

Considering the demands on our water resources, one feels we have not heard the last of underground storage and recovery of water in dry lands like ours.

In September this year, the group will host the Fourth International Symposium on Artificial Recharge of Groundwater and delegates will see some of the field research sites that led to the award (see: www.groundwater.com.au/conf/ISAR4.htm.)

## More about aquifer storage


Dillon P Pavelic P Toze P Ragusa S Wright M Peter P Martin R Gerges N and Rinck-Pfeiffer S (1999) Storing recycled water in an aquifer: benefits and risks. AWWA *Journal of Water,* 26:21–29.

Dillon P Pavelic P Sibenaler X Gerges N and Clark R (1997) Aquifer storage and recovery of stormwater runoff. *AWWA Journal of Water,* 24:7–11.

Toze S Dillon P Pavelic P Nicholson B and Gilbert M (2001) Aquifer storage and recovery: Removal of contaminants from stored waters. *Aust. Water and Wastewater Association Journal of Water,* 28:41–44.


On the web: www.clw.csiro.au/research/-catchment/reclamation/.


**Abstract:** Scientists at CSIRO are piloting the use of aquifers to store and recover urban stormwater and treated sewage effluent. The reclaimed water is good enough to irrigate urban landscapes or crops and the stormwater vitalises brackish aquifers by reducing their salt content. Aquifers can be recharged in wet periods and the water recovered in dry periods. This usually is cheaper than storing the water in dams. Clogging of injection wells and monitoring aquifers so that low-quality water can be managed sustainably have been addressed Pilot projects have taken place in Adelaide, supported by the South Australian Department for Water Resources. Future projects will be integrated with urban water management.



**Keywords:** aquifer injection, aquifer storage and recovery (ASR), water storage, waste water reuse.


**The quality of water reclaimed using aquifer storage and recharge is good enough to irrigate urban landscapes or crops.**