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# ON THE CHARGE FOR ARTIFICIAL RECHARGE

***One solution to water supply problems lies hidden in the rocks. By Mike Wills.***

The security and quality of the water supply is a major issue facing every South African community. From tiny dorps to big cities the demands for potable and industrial or agricultural usage water are ever increasing.

Some areas are fortunate to have either or both consistent rainfall and sufficient river and dam capacity but many municipalities are subject to seasonally distorted rainfall patterns and some face radical demand spikes (e.g. Plettenberg Bay which has a huge jump in usage in the peak of summer).

In the past the solution provided by consulting engineers in bigger communities has been to build dams and in smaller towns to extract groundwater via boreholes. Both these approaches are now problematic. Most potential major dam sites have been utilised and there is growing awareness of the massive environmental damage and subsequent hidden cost in dam construction. And the over-use of boreholes has caused an alarming drop in the water table in many areas and a subsequent decline in water quality.

Increasingly the answer for engineers engaged in water projects is to explore the possibility of managed artificial recharging of aquifers. Artificial recharge (AR), as the technique is widely known, involves transferring river or dam water underground by means of infiltration basins or by borehole injection to boost the water table and "bank" the water for later usage. Buried in the rocks there is no evaporation loss – which can amount to a drop in water levels up to 3m per annum in dams – and the dangers of contamination are markedly reduced. Unless a scheme is poorly designed virtually all recharged water can be recovered and techniques can be used to reverse hydraulic gradients causing even "lost" water to flow back into the wellfield.

The water usually needs to be treated before it is sent below to prevent clogging of the surface of the basins or the boreholes although in many European countries the process itself is used for water treatment purposes with the sandy aquifers serving as giant natural filters.

Artificial recharge is a widely used concept in other parts of the world.

The Indian government recently produced a Master Plan for Artificial Recharge and is committing R33bn to the concept over ten years in an effort to capture over 36000 Mm $^3$ of water across 450000 km $^2$.

Amsterdam receives 60% of its drinking water from a scheme that involves spreading treated river water over 40 recharge ponds covering 86ha which have an infiltration rate of 20cm/day and an average sub-surface travel time of 90 days. The water is then recaptured through drains and open canals situated about 60m from the infiltration basins.

Mt Gambier in South Australia is an isolated city in an arid region and channels all of its stormwater into an underlying karst aquifer using more than 300 drainage wells producing an annual recharge of up to 6.2 $Mm^3$.

Unsurprisingly the Israeli's have also pioneered artificial recharge - the biggest of their schemes in the Dan Region uses the aquifer media to supply irrigation needs from Tel Aviv's treated reclaimed wastewater – but it's the United States that has the most extensive history in the technique and there has been a noticeable increase in usage in the past twenty years. The largest existing operation is in the Las Vegas Valley which has a recovery capacity of 0.59 $Mm^3$/day but the Florida Everglades, New York City and San Antonio all run AR schemes.

An American Water Works Association survey shows that most schemes are used primarily for municipal supplies and for seasonal storage but secondary benefits are also often cited like recovery of groundwater levels, prevention of saltwater intrusion, protection of habitats and improvements in groundwater quality. Although most schemes use surface water as their sole source of injection, a number involve transferring water from one aquifer to another.

The Department of Water Affairs and Forestry (DWAF) has recently finalised a strategy on artificial recharge to encourage its expanded usage locally and also to provide a regulatory framework for implementation. The strategy is being implemented by DWAF's Directorate: Water Resource Planning Systems.

Dr Ricky Murray, a hydrogeologist engaged by DWAF to implement their strategy, says "many of our local geological formations contain appropriate aquifers that could be used to enhance the water supply at far cheaper and more efficient rates than dams". The capital cost of a typical AR scheme is often well under half that incurred in more conventional surface storage schemes and artificial recharge offers considerable benefits in terms of any quantifiable costs of climate change. The local authorities in Plettenberg Bay are planning borehole injection tests into the local aquifer and if the results are positive they will be able to save on the cost of constructing an off-channel storage dam from the Keurbooms River.

The relatively limited number of South African AR schemes are all detailed in the DWAF strategy which can be downloaded from their website http://www.dwaf.gov.za (go to "Documents" and two-thirds down the long list of DWAF documents, you'll find the strategy under "Other: Integrated water resource planning – National Documents").

Polokwane, Atlantis and Karkams in Namaqualand have successfully implemented AR and, as well as Plettenberg Bay, Prince Albert and Langebaan are actively investigating projects at the moment.

The Namibians have been far more active in this area. The Omaruru Delta aquifer is recharged via infiltration basins for the supply of Swakopmund and Walvis Bay, reversing decades of a declining water table because of over-abstraction, and the capital Windhoek uses AR extensively to ensure the security of its supply. It opted for a groundwater solution from the nearby mountainous aquifer rather a surface water transfer system from the distant Okavango basin. The estimated savings amount to R1.3bn. Currently ten percent of the city's supply is achieved through groundwater but an ambitious expansion scheme that includes AR is in place to increase that percentage. An additional ten injection/abstraction boreholes are currently being added to the existing five and the target capacity is 8 $Mm^3$/annum or ~250 L/s of continuous injection. This is equivalent to 40% of the city's annual water requirements.

Windhoek's aquifer of quartzites and schists is highly fractured and complex with intense faulting and folding but extensive testing that included 6-month long borehole injection tests and even longer abstraction tests established the viability of rapid replenishment and large scale abstraction.

Dr Murray says there are several "success factors" which determine the likely value of any AR scheme:

- water used must be of a consistently high quality with low turbidity and borehole injection methods demand higher quality than infiltration basins.

- the surface water (which is usually saturated with oxygen) must be chemically compatible with the groundwater which may be more anoxic and even anaerobic.

- the aquifer geochemistry is important as some rock types might cause health problems in underground water.

- the hydraulic conductivity of the rock or soil is critical. It needs to be sufficient both at the point of recharge and further afield – in hard rock environments the fractures need to be reasonably extensive and interconnected.

- the hydraulic gradient will determine where the water flows once it has entered the sub-surface. In some cases it will be possible and cost effective to recover water at the point of recharge but in others it will be preferable to abstract the water down-gradient.

Murray also points out that artificial recharge systems can range from the very simple to the highly sophisticated but they all present management challenges.

In particular the issue of clogging or plugging has to be watched carefully. This can apply to the reduction of the permeability of the filtration surface of the recharge facility (the basin or the borehole) or it can apply to the aquifer itself. The former is reasonably easy to monitor and remedy, the latter is more gradual and can become irreversible especially in a borehole-fed system. Various forms of clogging have been identified including suspended solids, microbial growth, chemical precipitation, clay swelling and dispersion, air entrapment, gas binding and the mechanical jamming and mobilisation of aquifer sediments.

Furthermore, some potentially negative environmental impacts of AR schemes need to be monitored closely. A raised water table becomes more vulnerable to pollution and might exacerbate flooding, it can also cause vegetation dieback and could destabilise roads and buildings. On the other hand, lower groundwater levels can impact on river flow regimes and wetland eco-systems as well as damaging on tree root systems and can cause land subsidence and the drying up of existing boreholes.

Murray however is convinced that where aquifers are well understood and well monitored the potential for AR is substantial in South Africa especially given the high evaporation rates for surface-stored water caused by the hot and windy conditions that prevail across most of the country.

Smaller, more isolated communities which suffer from long, dry spells are the obvious immediate candidates but with the proper application of DWAF's strategy, careful testing and competent management, artificial recharge could play a far bigger role than that.

Some really ambitious thinking includes the possibility of transforming dry Northern Cape areas into fertile agricultural land through AR as has happened in both Israel and the Burdekin River Scheme in Australia. The extensive Table Mountain Group Aquifer also represents a potentially gigantic underground reservoir to meet the long-term needs of the entire region. Interfering so radically and on such a huge scale in environmentally sensitive areas is obviously at best a very distant prospect and requires considerable research but more immediate priorities can be met almost immediately with artificial recharge at a great cost saving to ratepayers.