# Artificial Recharge Schemes - A Novel Method to "Bank" Water

by Sue Matthews

**At first glance, Windhoek – Namibia's capital city inhabited by more than 200 000 people – would appear to have little in common with Karkams, a rural village in Namaqualand with a population of less than 2 000. Yet both have adopted a novel method of 'banking' water to tide them over dry periods. Surplus surface water is injected into hard-rock, fractured aquifers to 'recharge' groundwater and take advantage of natural storage space underground. These artificial recharge schemes were the subject of a recent WRC-funded study by Ricky Murray and Gideon Tredoux of the CSIR in Stellenbosch.**

"The main benefit of artificial recharge in southern Africa is that it allows the available water resources and storage space to be used to maximum capacity," explains Dr Murray. "We can effectively overutilise a resource – normally considered completely unacceptable – if we know there's a dependable source of water to replenish it rapidly."

This is particularly applicable in Windhoek, where a fractured aquifer has been used as a municipal water source since the early 1920s. Highly productive boreholes are located along faults in the underlying quartzites, and groundwater was the main source of water for the city until the completion of the Von Bach Dam in 1970.

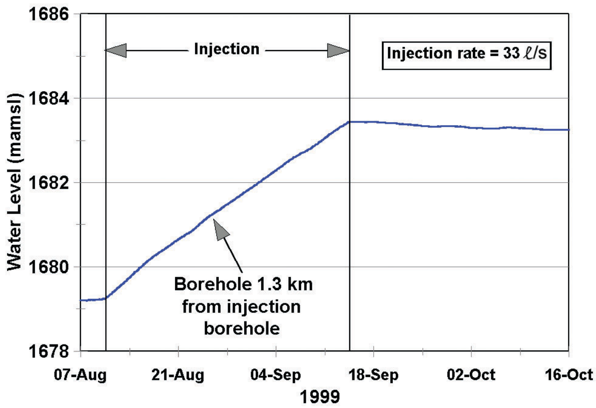
Since the 1950s, more than 100 Mm$^3$ has been pumped from the aquifer. This abstraction rate has evidently been over and above the sustainable yield – exceeding the natural recharge rate – as groundwater levels have declined drastically, resulting in a cone of depression in the southern wellfields. The overutilisation is believed to have caused water to be drawn from natural storage in the Auas Mountains.

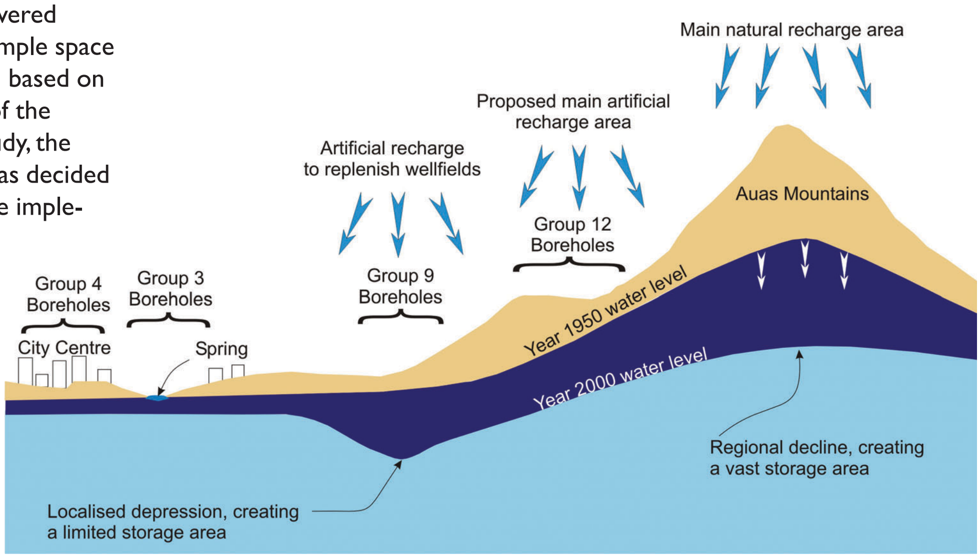
At the same time, the lowered water level has created ample space for artificial recharge, and based on the encouraging results of the CSIR-supervised pilot study, the Windhoek Municipality has decided to go ahead with full-scale implementation.

"The city of Windhoek is fast outgrowing the water resources available to it, and pumping water from other sources 400-500 km away would increase the cost of supply significantly," says Piet du Pisani, the Municipality's head of Infrastructure, Water and Technical Services. "An economic feasibility study has indicated that artificial recharge is the most viable option available to us. We see it as a way of optimising the available resources in the area, whereby we will take excess water in the three surface reservoirs and inject it into the aquifer so that it can be used in times of short supply. In other words, we'll have water in storage when the dams are low."

*Erecting the carbon filter at one of Windhoek's injection boreholes*

*Water level response in one of the Windhoek boreholes after injection*




*Schematic diagram showing the change in groundwater levels since abstraction began, and the vast storage area under the Auas Mountains that has been reduced as a result of pumping*

*The simple sand filter in the bed of the river, which flows through a valley carved from granite.*

*Sieving sand for rehabilitation of the sand filter. In the background is the pumphouse of the abstraction borehole.*

Water from the dams will be filtered through activated carbon and chlorinated before being injected into the boreholes, because the CSIR team recommended that only high-quality water be used. This is to prevent particulate matter from entering the aquifer and to ensure that the injected water is chemically compatible with the natural groundwater, minimising the risk of negative hydrochemical reactions with it or the surrounding rock.

They also recommended a phased approach for full-scale implementation - initially making use of existing infrastructure and production boreholes, and later drilling special injection boreholes and installing the additional infrastructure needed for injecting water closer to the mountains, to make use of their vast storage area. Modifications required for Phase 1, which will focus on filling the main cone of depression in the southern wellfields, are due to be complete by July 2003. Ultimately, the full-scale scheme – with a planned injection rate of 200 ℓ/s - will secure 25-30 $Mm^3$ in Windhoek's 'water bank', representing a couple of years' supply for the burgeoning city.

## KARKAMS

On the other end of the scale, the Karkams artificial recharge scheme has a maximum injection rate of only 1 ℓ/s, but is no less important to the people living in this remote, arid area. The mean annual rainfall here amounts to only 250 mm, and the community is entirely dependent on groundwater, pumped from the Municipality's three abstraction boreholes. The lowest-yielding of these lies close to a small seasonal river in a valley about 15 km east of Karkams, providing a ready source of water for injection purposes.

Artificial recharge was initially conducted at the site in 1995, but some problems were experienced and the system fell into disrepair. The CSIR team made some modifications to the design, and DWAF drilled four new monitoring boreholes, one of which became the new injection borehole.

The scheme is ingenious in its simplicity.

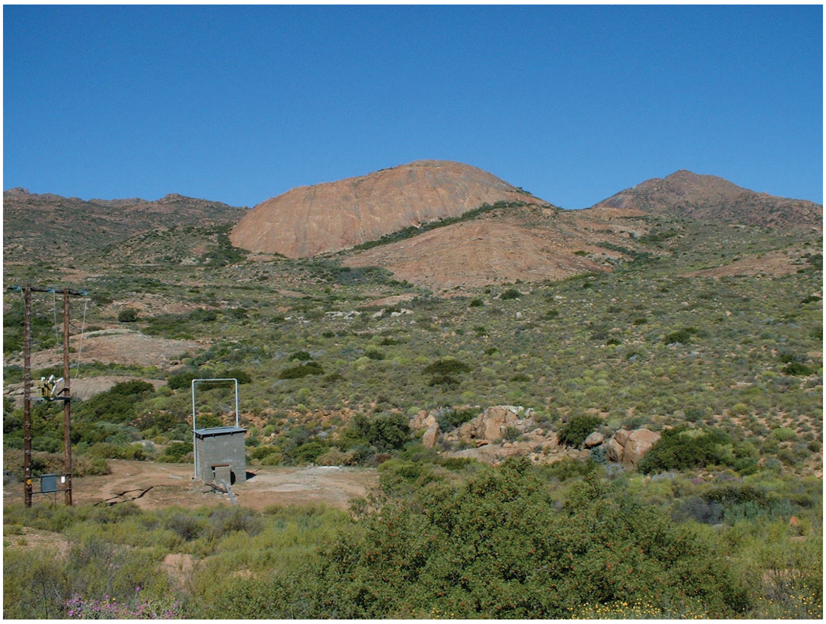
"All it involves is taking some of the river flow when it rains, draining it through a sand filter in the river bed, and then gravity-feeding it into a borehole," says Dr Murray. "There are no pumping costs, and the maintenance costs – merely removing debris and clay from the sand filter between injection runs – are insignificant. It's almost crazy not to do it, because it's so cheap and simple."

Cheap and simple it may be, but the recharge is potentially enough to double the sustainable yield of the borehole. An added advantage is that it improves water quality significantly.

"Groundwater in Namaqualand is generally quite saline, and the injection of freshwater dilutes it," explains Dr Murray. "We got feedback from the residents of Karkams that this is the best water they've ever had!"

Asked whether the study team had encountered any resistance to the concept of artificial recharge, Dr Murray responds, "The biggest concern that people expressed was of losing water – putting it in and not being able to recover it. But you don't go into these types of studies blindly – you have to do your homework and get an indication of groundwater flow paths, so you can design the system properly. And even water that appears to be 'lost' can be recovered by reversing the hydraulic gradient and pulling it back again."

*The sand filter where river water is filtered before it gravitates into the injection borehole. In the background is the pumphouse of the abstraction borehole.*

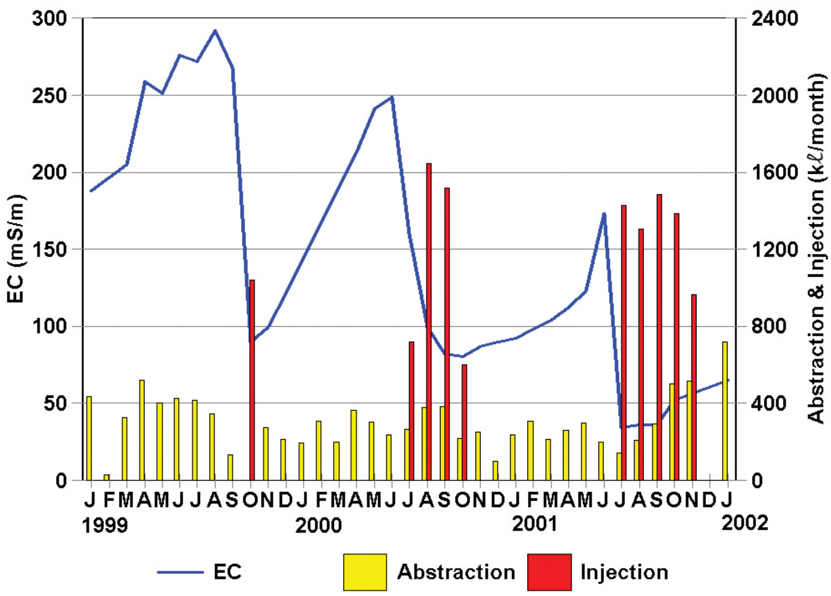


*The pumphouse of the abstraction borehole is surrounded by granite outcrops.*

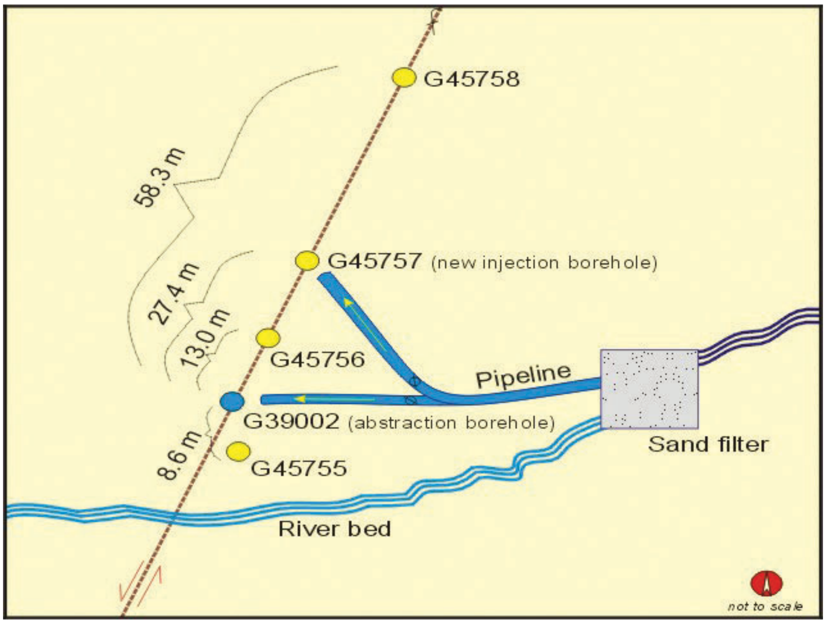
## MANAGEMENT

Once all the planning work has been done to implement an artificial recharge scheme, careful management is needed on an ongoing basis. One of the key management functions is to avoid clogging, the potential for which is especially high in borehole injection schemes. Artificial recharge schemes in primary aquifers - those made up of unconsolidated sand - are not as susceptible to this problem because they normally rely on infiltration. Full-scale artificial recharge schemes for augmenting primary aquifers are in operation at Atlantis in the Western Cape, where municipal wastewater is infiltrated into the dune sands aquifer, and in Namibia's Omaruru Delta, where runoff is used to recharge the river delta aquifer in the Namib Desert.

In terms of the National Water Act of 1998, all artificial recharge schemes must be registered and licensed with DWAF, but the Department endorses the concept in principle and was very supportive of the project. This is no doubt because it sees the potential of artificial recharge in fulfilling its mandate.




*Water quality at the Karkams abstraction borehole improved after each injection run, as reflected in the lowered electrical conductivity.*




*Layout of the Karkams artificial recharge scheme.*

Indeed, Dr Peter Dillon – Chairman of the International Association of Hydrogeologists' Commission on Managing Aquifer Recharge – highlighted this potential in his review of the project, concluding: "This is a low-cost technology and will be of great value in achieving South Africa's plan for enhancing water supplies to rural and remote communities."

Dr Dillon judged the Karkams scheme an "unqualified success", and declared that the Windhoek scheme would "stand out as an internationally acclaimed demonstration of artificial recharge".

International interest in the project is likely to be high, because, as Dr Murray explains:
"Artificial recharge is increasing quite significantly throughout the world. It's catching on because in virtually every case it's so much cheaper than either pumping water from some far away place or building a dam. Where the groundwater conditions and water source are suitable, it's usually the most cost-effective option. It must also be one of the more environmentally friendly options of conserving water, compared to diverting large quantities of water from a river or building a dam."

This leads him to a subject that he is obviously passionate about.

"Before we build more dams, we should be considering the existing natural storage space," he says, gesturing at the spectacular mountains outside his office window.
"In the Cape Town area we have this huge rock mass right on our doorstep, and a dependable winter rainfall – one of the highest in the country, at over 1 000 mm per year – and this lovely, fresh water falls straight onto the Table Mountain Group Aquifer."

"My long-term vision – a dream perhaps – is for the TMG Aquifer to be a massive artificial recharge scheme."

**Murray EC & Tredoux G (2002) *Pilot artificial recharge schemes: testing sustainable water resource development in fractured aquifers.* WRC Report No. 967/1/02**