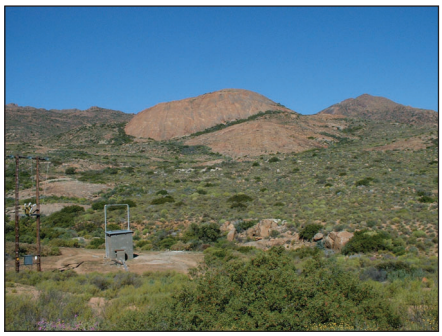

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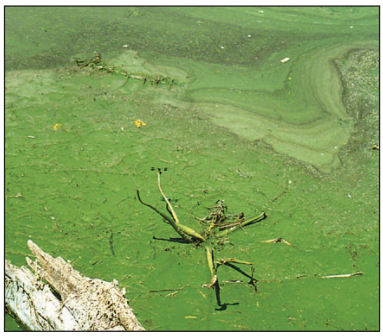

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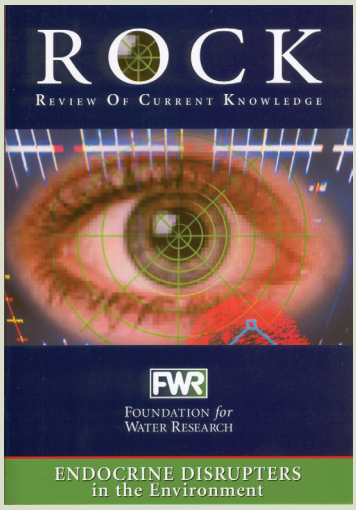

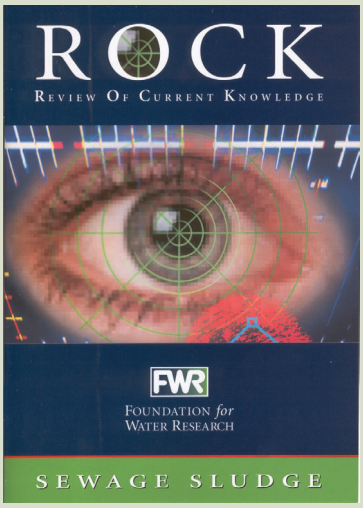

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Artificial Recharge Schemes - A Novel Method to "Bank" Water

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.

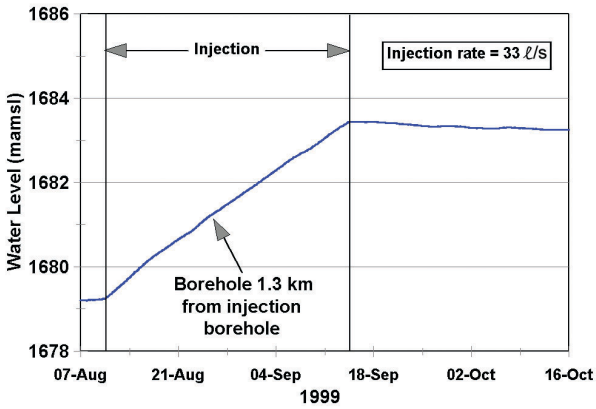
Since the 1950s, more than 100 Mm^3 has been pumped from the aquifer. This abstraction rate has evidently been over and above the sustainable yield – exceeding the natural recharge rate – as groundwater levels have declined drastically, resulting in a cone of depression in the southern wellfields. The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

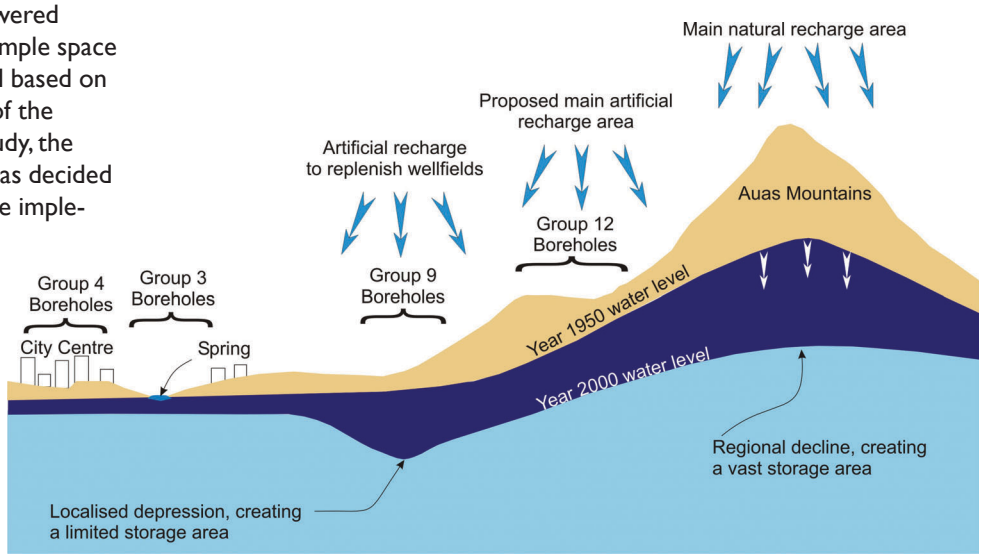
At the same time, the lowered water level has created ample space for artificial recharge, and based on the encouraging results of the CSIR-supervised pilot study, the Windhoek Municipality has decided to go ahead with full-scale implementation.

"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.

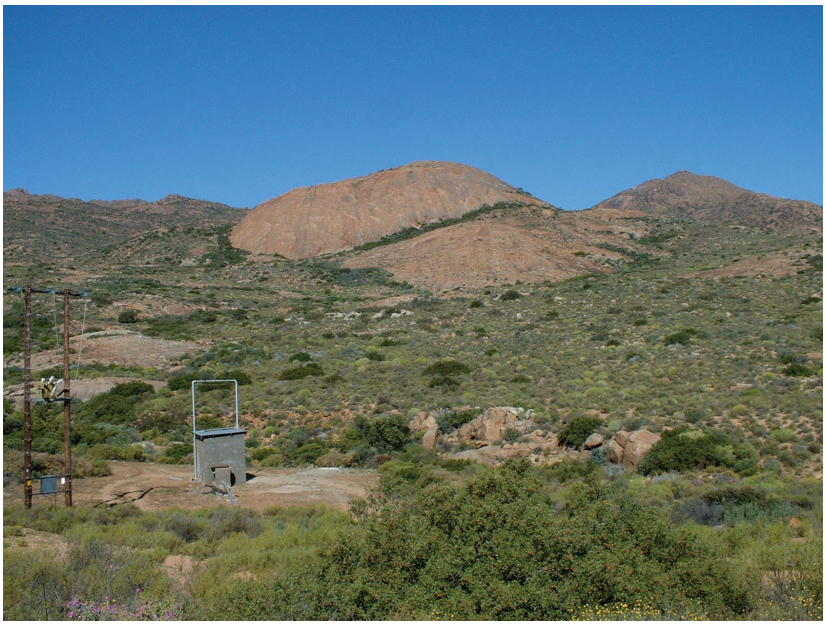
"Groundwater in Namaqualand is generally quite saline, and the injection of freshwater dilutes it," explains Dr Murray. "We got feedback from the residents of Karkams that this is the best water they've ever had!"

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."

MANAGEMENT

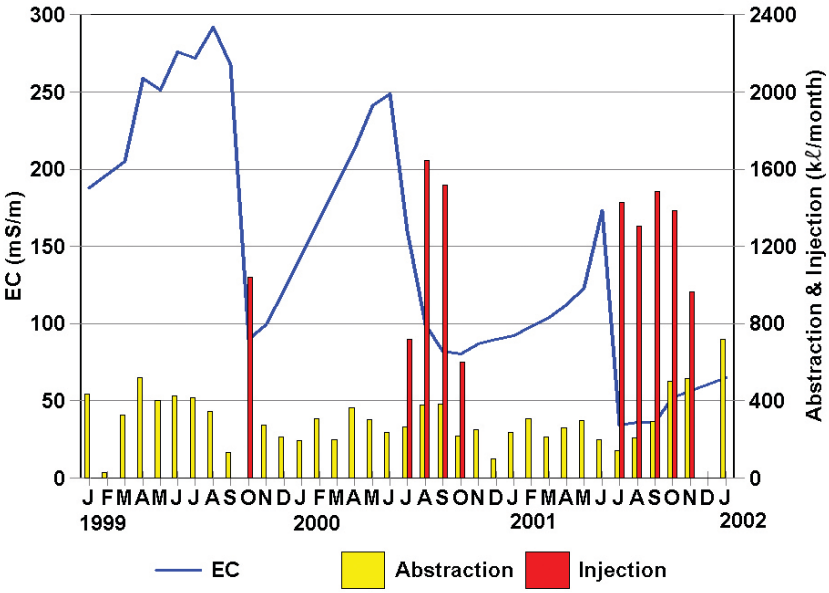
Once all the planning work has been done to implement an artificial recharge scheme, careful management is needed on an ongoing basis. One of the key management functions is to avoid clogging, the potential for which is especially high in borehole injection schemes. Artificial recharge schemes in primary 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.

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.

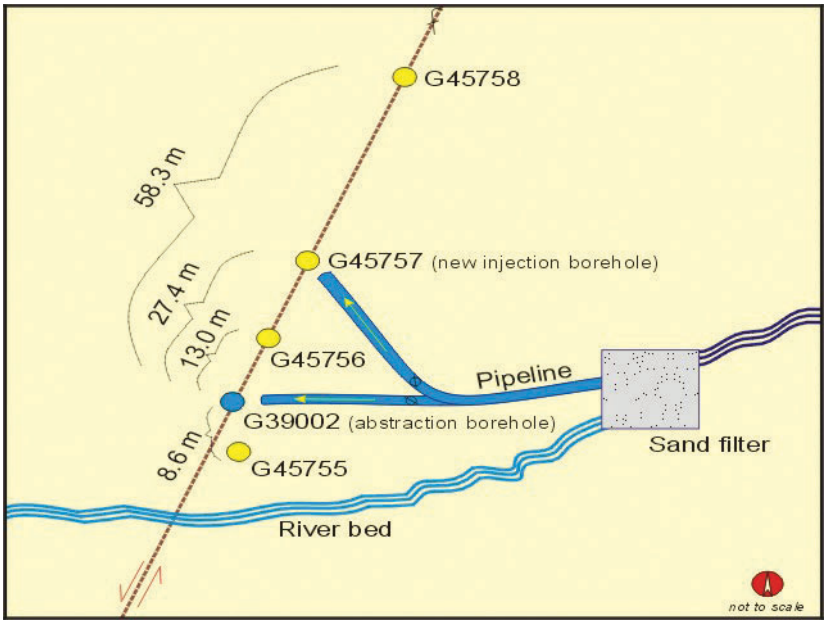


The pumphouse of the abstraction borehole is surrounded by granite outcrops.

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

Photo: Ross Canter

The Ecological Reserve: For People or for Insects and Fish?

What is the motivation for enforcing an Ecological Reserve? Who benefits? And whose interests was this new legislation designed to serve?

It seems that recent policy implementation processes may have been sending mixed messages. A variety of role-players - stakeholders, specialists, engineering and social consultants - have been heard to offer some of the following interpretations:

"The Reserve is water for 'goggas'."

"We can only use the water that is left over after we have allocated some for the ecology."

"(A higher Management Class means) more water for the Reserve means less water in your stomach."

"How can you tell people they can't have water because the fish need it?"

"Ecologists keep telling us about how the river ecosystem is the resource, and not just the water it provides. But what is a river except water?"

"The Reserve is just there to give consultants jobs."

"All we really need is sustainability. Why don't we just make all rivers Class D then we can get maximal use out of them while still ensuring a sustainable resource?"

"If 10% of the money already spent on Reserve determinations had been spent on supplying water to rural areas, we'd have done more good."

"How did ecologists in South Africa manage to negotiate so much power for protecting Nature in the new water policy?"

All of these quotes would suggest that South Africa is employing an approach to resource protection that values insects and fish more than people - and that the 'luxury' cause of biodiversity is diverting funds from much needed rural

Fishing for food and fun - KZN (photo: Umgeni Water)

development. But these are not the messages to be found in either the spirit or letter of the Water Act. Our new water policy is unashamedly anthropocentric. "The objective of managing the quantity, quality and reliability of the nation's water resources is to achieve optimum, long term, environmentally sustainable social and economic benefit for society from their use (White Paper, Principle 7) (DWAF 1997, p.35). "'Reserve' means the quantity and quality of water required… to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource" (National Water Act, Ch 1, para. 1.(xviii)). Principle 9 of the White Paper gives the purpose of the Reserve as "to maintain the ecological functions on which humans depend" (DWAF, 1997 p. 35). Our national government and all of its departments subscribe to a policy of "Batho pele" – people first.

How then does the Ecological Reserve serve 'people'? A principle often quoted by ecologists, which has been embraced in the new water policy (in direct opposition to previous legislation) is that the environment is not a competing water user. This does not mean that the environment has been declared a privileged consumer because the needs of plants and animals take priority over humans! It simply means that one can't actually think of the environment as a water user, when really the environment (in this case the aquatic ecosystem) IS the water resource. If the necessary ecological functions are not maintained then the quality of the resource – the water, the fish, the trees and grazing on the banks, the attractiveness to tourists etc. – will deteriorate. It is like trying to sustain output from a factory while denying one's workers sustenance or one's machinery maintenance! You very rapidly cease to function and produce your product and the service you are providing to society.

PURPOSE

The purpose of the Ecological Reserve is to make the necessary requirements for maintaining a particular status of the resource (ecosystem) both explicit, and legally defensible, so that it can deliver to society the services they desire. Obviously then there is no absolute or ultimate value of the 'Reserve' that could be objectively determined by engineers or scientists. The Reserve is linked to the achievement of a particular state of an ecosystem, and will depend on what state of the resource will benefit stakeholders most. This is a value-based decision that must reflect the full spectrum of societal needs and values. The Act has expressed this decision as a choice between different Management Classes, and Ecological Management Categories. Yes, all of these are defined as 'sustainable' – but we have the option as to what we would like to 'sustain'. What type and level of goods and services do we want our water resources to deliver?

This is not simply a decision about how much water we would like to abstract and use, versus how much we can afford to leave in the river to keep the conservationists happy. Water is just one good in the basket of goods and services that river ecosystems provide. When we think of the resource as simply a provider of water for industry, irrigation or domestic use, management decisions will always favour those who benefit from using the resource in this way. Abstracting water and returning wastes however reduces the ecosystem's ability to provide other goods and services, to other users. These include goods such as fish, and the numerous food, craft and medicinal plants provided by riparian vegetation, and services such as waste assimilation, recreation, aesthetics, tourism and various religious and cultural activities.

Deciding what particular state of the resource a Reserve must be set to maintain requires explicit recognition of the goods and services

that stakeholders wish to have delivered. This must aim to achieve equity in the distribution of the costs and benefits of different types of resource use, between the various sectors and regions in a catchment. Often it is the rural poor who rely most directly on a wide variety of ecosystem goods and services to meet their most basic needs. Taking care of ecosystems so that they can continue to provide this variety of benefits is thus a livelihood issue for these people.

Who then is responsible for creating negative impressions of the Reserve? Or is it simply that we are failing to communicate a sufficient understanding of its purpose and importance, and people (both stakeholders and specialists) are then free to draw their own, often erroneous, conclusions?

We need to be aware that in South Africa perceptions of conservation as a source of dispossession and inequality already exist, and with good reason. It is very easy to inadvertently reinforce these, particularly where applicants for new allocations are being asked to wait an unspecified but usually substantial period of time 'for the Reserve'. We also need to make sure that it is not these same people, who were disadvantaged or dispossessed by previous legislation, who are made to bear the cost of protecting a resource they are presently still not allowed to benefit from. Issues of allocations for emerging farmers and ensuring domestic supply must be seen to be addressed with the same urgency and commitment as the cause of resource protection is currently being afforded.

Correcting these impressions is crucial to achieving greater equity and sustainability of water resource use. Changing people's behaviour requires 'buy-in' to the intentions of this change. The Reserve, though protected by law, will be extremely difficult to police and enforce, and will need to rely to a large extent on voluntary compliance.

Laundry day at the river - Hazyview, Mpumalanga (photo: E. van Wyk)

As long as these negative sentiments and incorrect perceptions persist, the Reserve will only be considered in terms of a wasteful amount of water instead of the state of the resource needed to serve the people. There will be little commitment to implementation and equity will remain a pipe dream.

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Reeds for craft and building - KZN (photo: Umgeni Water)

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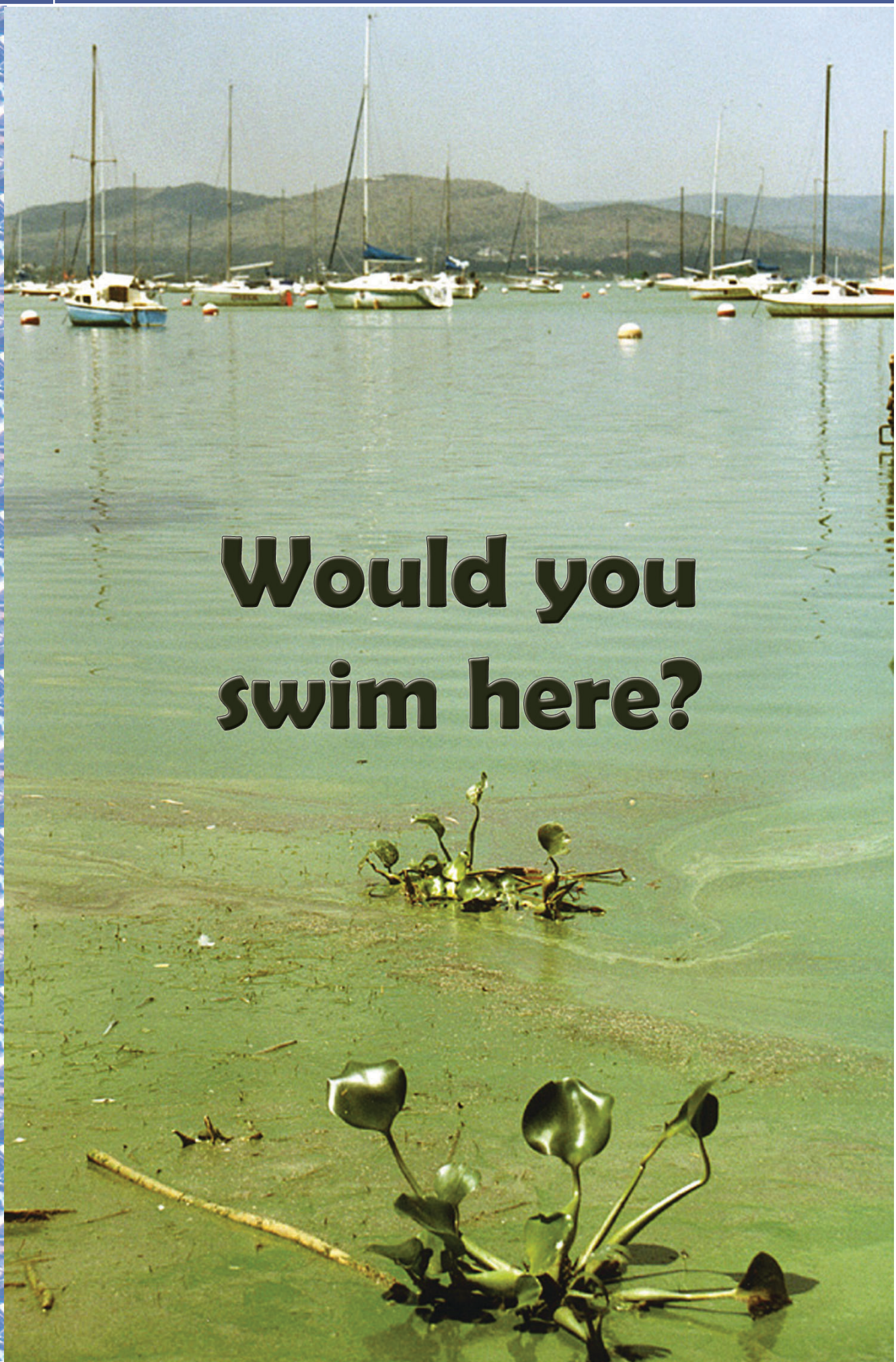

Would you
swim here?

In March this year, Hartbeespoort Dam experienced one of the worst algae blooms in its history. Some three hectares of water close to the dam wall were covered with a 30cm-thick sludge of rotting toxic algae, releasing smelly gases and necessitating an emergency clean-up operation. It was just another episode in the ongoing controversy surrounding what has become one of South Africa's most popular recreational dams and elite country settlements.

By Sophia Dower

Without a doubt, Hartbeespoort Dam has a reputation for being one of the filthiest dams in the world. But does it really deserve all the bad press its getting? Yes and no, says Carin van Ginkel, specialist scientist at the Department of Water Affairs and Forestry (DWAF) in Pretoria.

"More than any other dam in the world, Hartbeespoort suffers from massive seasonal growth of cyanobacteria (previously known as blue-green algae), which accumulates on the dam surface and rots in the sunlight. It releases offensive odours and often looks and smells like raw sewage - but it's not. The sludge is caused by the natural biodegradation of the cyanobacteria, and not human excreta."

Cyanobacterial blooms such as the one in April not only affect the taste and smell of the water supplied to local residents, the foul smell around the dam wall also puts off prospective buyers looking to purchase upmarket homes in the area.

Understandably, it has residents up in arms. Unfortunately, there's no easy solution.

THE ROOT CAUSE

The source of the huge outcry is tiny – a minute cyanobacteria called *Microcystis*, which, through a process known as eutrophication, develops to massive concentrations. Eutrophication is a natural process through which normal nutrient levels in the water are raised, but it is enhanced by human activity in the dam's catchment area. Coupled with other environmental factors such as low rainfall and warm, windless weather, this influx of nutrients leads to rapid and excessive growth of cyanobacteria and aquatic weeds.

Ironically, the cause of the stink is Mother Nature's way of absorbing and removing excess nutrients from the water. However, in attempting to rectify the problem, nature has created another – one that is proving extremely difficult to resolve.

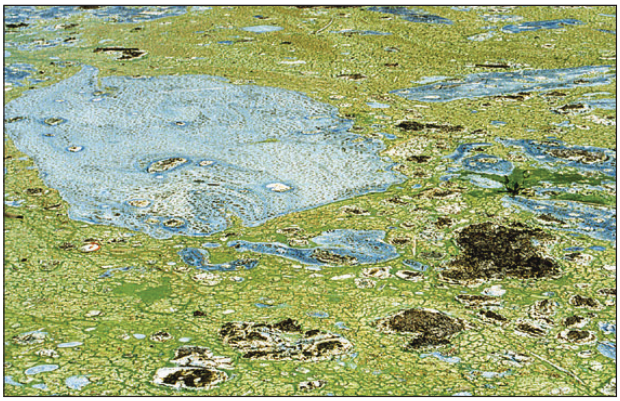
"Hartbeespoort dam is effectively a massive nutrient trap," says van Ginkel. "Approximately 16 sewage works and many industries discharge wastewater effluents from the high density Johannesburg and Pretoria area into the Crocodile River, the main river flowing into the dam. The aridity of South Africa and the historical Water Act enforced companies to discharge all effluent wastewater back into the rivers. All these companies are required to comply with strict water regulations and, since the promulgation of the National Water Act in 1998, are monitored by DWAF to ensure that they do so. Nevertheless, more than half of the water flowing into the dam is phosphorus and nitrogen-rich."

The release of wastewater into catchment areas is widely practised across the world, and is controlled locally by South Africa's new Water Act. So why is it a problem at the Hartbeespoort Dam?

"Much of the nutrients are trapped in the sediments at the bottom of the dam and remain inactive for extended periods," explains van Ginkel. "In summer, however, different thermal layers form in the water column. The deeper layer becomes anaerobic (oxygen depleted). Under these conditions phosphorus is released from the sediments. This process is known as internal loading. When mixed into the upper layers of the water, these nutrients boost algal growth. The cyanobacteria are able to regulate their position in the water column for optimal growth. During a cyanobacterial bloom of *Microcystis* the cyanobacteria form dense accumulations, which then floats to the surface. Once exposed to sunlight, it starts to decompose, and toxins that are normally bound inside the algae, are released."

Van Ginkel adds that the problem is not unique to Hartbeespoort, and occurs in about 20% of South Africa's monitored reservoirs. But for unknown reasons, nowhere else do these "hyperscums" produce so

With water-front properties starting at well over a million Rand apiece, DWAF is under increasing pressure to find a long-term solution to Hartbeespoort's algae problem.



As the cyanobacteria dies, it changes to blue-green and then to black-brown, forming a crust on the surface which looks - and smells - like raw sewage.

A typical cyanobacterial bloom initally looks like pea-green soup. Once it reaches the surface it is blown by wind into smaller inlets, where it accumulates and dies off.

rapidly or in such vast quantities.

"According to a recent DWAF eutrophication survey and prioritisation of monitored dams, Hartbeespoort is not the worst case in terms of its nutrient and algal biomass levels. However, it has relatively clear water that allows more light and heat penetration, which also contribute to algal growth."

SO WHAT'S THE FUSS?

The appearance and smell of the rotting cyanobacteria has led to a number of reports from concerned residents to DWAF that raw sewage is spilling into the dam. This is denied by both DWAF, private consultants and the industries operating in the area.

Petrus Venter, Deputy Regional Director: Water Resource Management of the North West Province, explains that a typical cyanobacterial bloom initially has the appearance of green pea soup. "Cyanobacteria on the surface is blown by wind into smaller inlets where it accumulates and dies off," he says.

"As the cyanobacteria dies it changes from white, to blue-green, and then to black-brown. It then forms a dry crust on the surface which is often mistaken for raw sewage." What happens to the dying bacteria is the same process that applies to a sewage treatment works, namely biological breakdown of organic matter. In this case, however, the organic matter consists of cyanobacterial accumulations.

Another concern voiced by visitors and residents, is the incidence of cholera. But, as Venter explains, there is no relationship between the algal growth and cholera. "The Department tests the dam water every two weeks and so far, no cholera has been detected." Additionally, because the cyanobacteria and phosphorus doesn't penetrate through the sediments, its presence in the dam does not affect local groundwater supplies.

In that case, what's the fuss all about?

"Cyanobacteria can potentially be dangerous to both humans and animals due to their ability to produce toxins. The effect depends on the amount that they ingest or come into contact with," says Venter. "Mostly animals are affected, as they drink the cyanobacteria clumped around the shoreline. The greatest effect on humans is that of the powerful, unpleasant smell. Exposure to the cyanobacteria can also cause gastro-enteritis, skin irritation, nausea and skin lesions. Contact with it is best avoided."

Besides the more obvious inconveniences, the dominance of the cyanobacteria wreaks havoc with the ecosystem in the dam. The decomposition of the cyanobacteria hyperscums depletes oxygen levels, and

(Top) When excess nutrients are released into the water, they boost algae growth. This forms dense accumulations and floats to the surface.

(Left) While cyanobacteria is not unique to Hartbeespoort, nowhere else do these "hyperscums" produce so rapidly or in such vast quantities.

The rotting algae is potentially dangerous to both humans and animals. It also gives off noxious fumes - unfortunately for the Hartbeespoort restaurant outside which this signpost appeared.

– under high temperatures – causes the nitrogen to form ammonia and methane, which can be very toxic to fish and birds. A number of fish and bird kills have been reported at different parts of Hartbeespoort Dam over the years.

TREATMENT OPTIONS

Ironically, the cyanobacteria that's causing all the stink is Mother Nature's way of absorbing and removing excess nutrients from the water. However, in attempting to rectify the unnatural balance of nitrogen and phosphorus, nature is creating a new problem – one that, in this case, is proving extremely difficult to resolve.

Venter explains that a number of treatment and management strategies are used worldwide, although many are not feasible for implementation at Hartbeespoort Dam for cost or practical reasons.

- "Problem" dams can be drained and the sediment dredged. However, draining a major water source is not an option in a country as arid as South Africa.

HARTBEESPOORT – A 30-YEAR-OLD PROBLEM

Originally built for irrigation purposes, the construction of Hartbeespoort Dam served as a job creation scheme to help alleviate the tremendous poverty that prevailed after the First World War. Today Hartbeespoort is the main water supply for some 139 000 households in the Brits and surrounding areas.

When it was filled, the dam was classified as a pristine dam. It was only in the 1970s that cyanobacterial blooms became a problem. The dam's growing popularity as a recreational area, plus the rapid urban developments upstream, soon led to higher nutrient levels in the water – nutrients commonly found in fertilisers, industrial wastewater, sewage effluent and products such as soap and washing powders.

In 1970, the dam was raised by 2,44 m to increase the gross capacity to 205 million m^3. When full, the dam's shoreline is over 56 km long, and the surface area is 2 062 hectares. The dam has a catchment of 4 112 km^2, which is drained by the Crocodile River and its tributaries, the most important of which are the Jukskei, Hennops and Magalies rivers.

Nor does this tackle the root of the problem – nutrient-rich water inflows.

- Dam water can be aerated by feeding air through pipes along the dam floor. This mixes the water and increases oxygen levels, inhibiting cyanobacterial growth. This method has been tested elsewhere in South Africa, but with limited success.
- Chemical additives, such as iron or aluminium sulphate, or copper, prevent the phosphorous from being released or "seeping out" of the sediments. While these additives have no impact on crop irrigation, they could pose a problem for domestic uses.
- The creation of a wetland or pre-impoundment dam could filter nutrients out of the water before it reaches the dam. This is an option that is being considered for the Hartbeespoort Dam.
- Bio-manipulation involves analysing the impoundment's ecosystem and removing any natural elements that somehow contribute to the release of phosphorus from the sediment; or adding elements that absorb the phosphorus or control the cyanobacterial growth. One option is harvesting surplus fish, such as carp, which is a bottom-feeder that disturbs the sediment to such an extent that phosphorus is released from the sediments.
- Physical removal of the cyanobacterial scum is the most successful management option used to date. In April, two private companies were contracted by the department to clear the surface of the rotting biomass. This involved pumping the algae through pipes over the dam wall to a safe dry area on the northern side, where it was treated to mitigate the odours and accelerate the natural decomposition process. The clean-up was coordinated by ENVIROKONSULT, a local private company of environmental scientists, and HAZMAT (Enviroserv) which handled the mechanical removal of the dried cyanobacterial scum.

"In a nutshell, we need to find a long-term solution that suits all the different people who currently benefit from the dam," says Venter. "The users and their varying needs – from irrigation to recreation to domestic use - limit our options. Therefore, they should all play a part in finding the solution."

MAKING PROGRESS

The Hartbeespoort Water Action Group (HWAG) was formed in 2000, comprising members of the Department and the local community. HWAG has been quite active in obtaining funds, both from government and from some of the companies operating close to the dam. This funding has yet to be put to good use.

Venter explains that the Department is working with HWAG to appoint a private consultant to put in place a long-term business plan with sustainable water management and rehabilitation strategies.

"The group has formed a Section 21 company, and will be implementing levies on local industries and residents, which can then be used for problem management." At this stage, however, promises have been more forthcoming than hard cash, and Venter says progress is slow. "Some equipment has been bought with a view to handling fast, effective clean-ups such as the one in April," he says. "But much-needed finance is still outstanding – as is commitment from many of the larger property developers in the area."

To date, however, both the department and local action groups can boast a number of achievements:

- DWAF has instituted measures to limit the discharge of phosphorus into surface water. Specific standards (1 mg/ℓ ortho-phosphorus) were introduced in 1985 and have been managed ever since. Some treatment works already comply with a standard of 0,5 mg/ℓ ortho-phosphorus.
- Dam water and rivers up and downstream are regularly monitored for the presence of pollutants and cholera.
- DWAF has developed, and manages integrated resource and wastewater management plans, and conducts regular general inspections. It also facilitates clean-up actions and preventative measures.
- Residents and visitors to the region participate in projects to eliminate algal growth, such as the skimmer project which traps and removed algae from the water surface with nets.
- Cyanobacterial bulldozing takes place to move solid scum away from the shoreline, and a floating weir has been installed to separate certain parts of the water, to enable a process of phosphorus removal.
- An ultrasonic algae killer has been installed in an experimental project during the year 2000 cyanobacterial bloom in the Leeuspruit section of Hartbeespoort Dam.
- General public awareness and education campaigns have been launched, aimed at residents and visitors.

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WATER HARVESTING:

A KEY TO FOOD SECURITY FOR AFRICA?

A team of Free State researchers believe they have found an affordable and effective tool to significantly increase food production in Africa. With the water harvesting technique they have enhanced, the productive potential of millions of the continent's semi-arid hectares can be unlocked. Marleen Smith reports.

One may just as well describe it as a wage which is sweeping across the former homeland villages of Thaba Nchu, east of Bloemfontein.

A water harvesting technique being developed by a team of researchers from nearby Glen is making productive again village land which has been lying fallow for ages. Probably the most talked about part of this revolution is how it provides food and income where there was either none or too little before.

Best of all is that it costs very little apart from manual labour in an area where jobs and wage money are almost as scarce as food.

Researcher Cobus Botha says the evident success of the technique is selling it fast among villagers.

Botha is leader of the water harvesting research projects executed by the Agricultural Research Council's Institute for Soil, Climate and Water at Glen.

The research project, with a total investment of more than R10 million, is being funded by the Water Research Commission, and has been expanded to focus on other techniques and provinces within South Africa.

One of the backyard farmers, Daniël Mutaung from the village Feloané near Thaba Nchu, on his maize plot which was cultivated conventionally (without the use of the water harvesting technique).

Daniël Mutaung on his maize plot in which he used the water harvesting technique. Both pictures were taken on the same day.

Botha says the six villages who employed the technique as part of the research project during the previous production season, has increased to 32 this year. More than 230 backyards in these villages have been prepared by their owners to use water harvesting in the coming season to grow food crops.

TECHNIQUE

The technique is simple: A field is divided into 3 m wide contour strips. The 3 m strips are further divided into two areas – a 2 m run-off strip and a 1 m water-collection strip, consisting of a shallow furrow No tillage is practised on the run-off strips. One of the most important farming activities is to keep these strips clean of weeds. Crops are planted in rows on both sides of the basins.

During a rainstorm, run-off water from these 2 m strips is collected in the basins.

In the basins, the water percolates deep into the soil, from where it does not evaporate.

Botha says this is critical, especially during the fallow period between crop growing seasons. Rainwater stored in the soil during this period gives the crop a significant pre-planting water advantage. Further adaptations of the technique include the use of organic mulches and/or stones to prevent evaporation and facilitate infiltration in the basins.

Run-off, and therefore soil erosion, is completely stopped by the basins. Evaporation is reduced significantly by the mulch and stones, which lower the temperature of the soil surface.

Stones can also be used on the run-off strips between the crop rows to improve movement of the water to the basins, Botha says.

The technique is especially suitable for the Thaba Nchu and neighbouring Botshabelo area, where soils are predominantly marginal, with a high clay content and low infiltration rate. Surface crusts form easily on the soil, inducing runoff. Annual rainfall is low and erratic, with low humidity levels and high temperatures during the summer. Around 75% of the rainfall in the area occurs during high intensity thunderstorms, which increases runoff and crust-formation.

With the water harvesting technique these environmental attributes, which normally have a negative impact in conventional crop production systems, are turned into benefits for the farmer.

The technique capitalises on the negative soil characteristics such as low infiltration rate and crusting. It also optimises the use of soil's high water storage capacity and fertility.

Furthermore, the technique frees farmers from unaffordable mechanical dependence to produce crops.

OXEN

As Esau Motlalile, one of the villagers, explains "livelihoods in the area had depended for years on croplands and livestock farming. Oxen were mainly used to prepare the croplands. Modernisation then changed this into the use of tractors, with oxen being considered outdated. This was also due to the deteriorated quality of their livestock.

However, very few had the money to continue farming due to the high mechanical costs.

Masses of our people neglected the use of their cropland due to a lack of finance and agricultural equipment."

HOMESTEAD TRIALS

Homestead trials are far more convincing to villagers than the ARC team's initial cropland trials in water harvesting, says team leader Cobus Botha.

"The backyards are the most effective point of departure, from where villagers can be convinced to employ the technique on their croplands as well," he says.

This is because the villagers are more involved in the homestead production than in crop production on fields far away from their houses.

"When they open their doors in the morning, they look onto their water harvesting plots. In the evenings it is the last thing they see before turning in."

"When it rains, they see exactly how the water collects in the basins on their plots outside. They discuss with guests and neighbours how their backyard crops are growing."

Given the fact that no demonstrations with vegetables were provided by the ARC research team, the villagers became 'researchers' in their own right. They themselves proved that vegetables could also be successfully grown with the new technique.

Many of the farmers also stopped producing crops due to continuous crop failures, attributing it to the low and erratic rainfall and marginal soil quality.

The water harvesting technique overcame these problems, making their land productive again, Motlalile says. So much so that the communal and backyard farmers experience yield increases described by some as miraculous. They have even moved from planting mainly traditional crops such as maize and sunflower to a range of vegetables.

In demonstration trials on village croplands the water harvesting technique out-yielded conventionally produced crops with as much as 50% for maize and 55% for sunflower.

In general, the average improvement was 40% on maize croplands, and 25% on sunflower croplands.

Consequent demonstrations in village backyards proved to be even more convincing. During one such trial, maize produced with the water harvesting technique yielded 1438% more than plots which were conventionally treated. For dry beans a mean advantage of 322% was obtained in the backyards.

INCOME

The new technique not only improves the area's food security as far as both quantity and quality are concerned; it also provides additional financial income.

Last season, Samuel, a backyard farmer, harvested 45 large watermelons from an area of 150 square meters. He sold them for an average R14 each, earning R630. Several other villagers earned extra money by selling what they could not eat themselves.

Dr Malcolm Hensley initiated the water harvesting research projects at Glen.

Veteran soil scientist, Dr Malcolm Hensley, initiated the water harvesting projects at Glen six years ago. Hensley, now retired from his ARC post, believes this technique can make not only large tracts of sub-Saharan Africa, but of the whole continent self-sufficient in food production.

He quotes Nobel Prize winning agronomist Norman Borlaug, who has estimated that 600 million hectares of unploughed land in Africa is actually arable. A considerable part of this vast area is probably suitable for application of the water harvesting technique, Hensley believes.

Currently cultivated land in South Africa comprises around 12 million hectares, which is enough to make the country self-sufficient in its food production.

If Borlaug's estimate is correct, it seems that Africa can easily be self-sufficient with regard to food production - if only the correct cultivation methods are employed and the necessary fertilisers are available, Hensley says.

He started researching water harvesting in the late eighties, when realising there was not enough food and work for all in South Africa.

Dr Leon van Rensburg, head of the ARC group of researchers at Glen, in an on-station trial plot used for the water harvesting projects.

The water harvesting research team of the ARC's Institute for Soil, Climate and Water at Glen. From the left are, in front: Naphtaly Mokgohloa, Tshepo Moshonyane, Daniël Thuthane and Elias Sebolai, all technical assistants; behind: Dr Leon van Rensburg, head of the ARC researchers at Glen, Cobus Botha, leader of the water harvesting projects, Trix de Bruin, administrative assistant, Kobus Anderson, Malerata Macheli and Petrus van Staden, researchers, and Thomas Mandries and David Thamae, technical assistants.

He realised that this age old principle, which has been used for centuries in regions like the Middle East, could just as successfully be introduced to African conditions.

For the future, Hensley also wants to see more work being done on techniques to harvest water from outside a field, like from rooftops, streets or adjacent kopjes. Water harvested in this way is already being used successfully in other countries. For Botha, a further avenue is integration of the water harvesting crop production with villagers' existing stock farming.

He also wants to work towards commercialisation of the technique so that it could also be employed in larger scale farming enterprises. Taking into account the large tracts of marginal land not being cultivated currently by commercial farmers, water harvesting on a commercial scale might well be just as big a success as in rural villages.

SA'S POVERTY PROBLEM

Water harvesting technology is very important in South Africa, where the majority of the poor rely on rainfed agriculture, says Water Research Commission research manager Dr Sizwe Mkhize.

"If they can effectively use rainwater, we'll directly or indirectly address the country's poverty problem."

Mkhize says most homesteads have corrugated iron roofs and water tanks which were used in the past to harvest rainwater for domestic use. This is not necessary any more as the majority of settlements now have potable water schemes.

"That investment in corrugated iron roofs and water tanks has to be redirected now, and if it could be to produce food, all the better," Mkhize says.

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Floods and Droughts: Making Sense of Disaster

Trying to make sense of disaster – one man at the University of the Free State (UFS) dedicated his life's work to answering questions about disasters; what causes it, the extent of damage and disruption, the probability of similar disasters happening in future and measures that could be taken to prevent or minimise the disruption and damages should such a disaster recur.

His name is Prof. Giel Viljoen and the crowning glory on his research spanning 25 years, was delivering the F.R. Tomlinson Commemorative Lecture on 24 May 2002 at Ilanga Estate, Bloemfontein.

"Too much or too little water: research dedication and lessons for new generation agricultural economists" was the title of his paper which focused mainly on the determination and management of the economic impacts of too much water, or floods on the one hand, and too little water, or droughts on the other. The paper gave an overview of the research that he and his research teams conducted over the years.

"My interest in flood and drought impact research started in 1975, after abnormally high rainfall during 1974 over large parts of South Africa. This rainfall pattern continued until the early eighties, but was quickly followed by a dry spell caused by abnormally low rainfall in various parts of the country and the imposition of water restrictions from 1983 to 1987," explains Prof. Viljoen.

But, following the principles of sensible research, let us start at the beginning. The first genuinely scientific research into flood impact assessment in South Africa started in 1975 after extensive flooding in 1974 in the central interior. The Department of Water Affairs requested the Water Research Commission to approach the Institute for Social and Economic Research (ISER) at the University of the Orange Free State and the Bureau for Economic Investigation at the University of Stellenbosch to conduct a joint scientific investigation into the nature and extent of the damage caused by the floods. Prof. Viljoen, then a senior lecturer with a Masters in Agricultural Economics under supervision of Prof. Dirk Smith, headed the UOFS research team. This opportunity also gave him the perfect start to his doctoral thesis, which he completed in 1979. This initial exploratory phase, completed in the early eighties proved invaluable for follow-up research in the 1990's.

Says Prof. Viljoen: "The data obtained during the ex-post phase were not sufficient to construct a complete set of loss functions needed for flood control planning, so it was decided to start the next phase of ex-ante research which would render it possible to construct loss functions without floods actually occurring. Unfortunately, we had to postpone this research, because the interior of the country was entering a dry phase with abnormally low rainfall."

"The widespread drought necessitated water restrictions. Once again, the Water Research Commission approached three different institutions to research the nature and extent of the socio-economic and financial effects of water restrictions. Again the ISER became involved, along with the Bureau for Market Research at the University of South Africa and the Centre for Applied Social Research at the University of Natal. By that time, I was promoted to professor and headed this operation from the UOFS'side. The three bodies worked together on one research area, stretching from the Ngagane River state water scheme, the Umgeni catchment area, the Riet River state water scheme, the Vaalharts state water scheme and the Vaal River system, each concentrating on a different sector."

The research on water restrictions was another first for South Africa; consequently a research methodology had to be developed. Fortunately, the methodology developed in the flood damage research could be reformulated and adjusted to be applicable to the restricted water situation. After the conclusion of the research by the three bodies, the ISER was asked to compile a summative report on the findings of the three bodies for the period 1983 to 1985. They also wrote a report on the total financial consequence of the water restrictions during the period that the restrictions were in place.

"Many important and interesting findings came out of this research, such as calculating the average worth of water in different sectors – useful when estimating different intensities of water restrictions in various sectors. The loss function concept, developed during the flood damage research, was also expanded and adjusted to be applicable to the Vaalharts irrigation area," says Prof. Viljoen.

The rain returned and South Africa experienced more extensive flooding in 1988. The Water Research Commission provided funds to the Department of Agricultural Economics at the University of the Free State to start the ex-ante phase of research, which had to be postponed in the eighties.

One of the most important outcomes of this research was the development of a computer simulation program, named FLODSIM for the irrigation regions in Upington, the Orange River and Vereeniging on the Vaal River, which was exceptionally hard hit by the floods. Another model, ANUFLOOD, developed by the Centre for Resource and Environmental Studies at the Australian National University in Canberra was adapted in cooperation with Australian researchers for urban areas in South Africa. Research was expanded to include the Mfolozi sugar cane production area in KwaZulu-Natal, the Uitenhage and Despatch formal urban areas along the Swartkops River and the Soweto on Sea informal urban area along the Chatty River in the Eastern Cape. Another computer programme, named TEWA, a GIS programme using the same information as ANUFLOOD, took form.

In the late 90's, the process to develop a new Disaster Management Act for South Africa commenced. This Act, which would make provision for a pro-active, national flood management policy will be accepted by Parliament later this year. The new Act requires that structures be put in place to manage natural and human made disasters. With this in mind, a focused attempt at transferring technology was launched to raise awareness among role players and authorities of the technological aides available to assist them in their planning. The computer models, FLODSIM, TEWA and FLODCAL – a computer-based questionnaire – all originated from the research that Prof. Viljoen conducted over the years.

His latest undertaking is managing a postgraduate disaster management training programme, with a solid focus in supplying disaster managers with the skills they need to comply with the requirements of the new Act and the ability to deal with disasters in whatever form.

His accomplishments are numerous, but he remains humble about his success. In his view, his greatest accomplishment is not the many useful computer models and important findings that emerged from his research, but the fact that he was privileged to successfully lead many multi-disciplinary research projects and that he was able to develop something that is of practical use in the real world.

Prof. Viljoen is a well-traveled man, and his expertise in his field becomes evident when one sneaks a look at his passport. Many foreign research visits were undertaken since 1976 with a visit to the United Kingdom and the United States in connection with flood damage research. Since then he has also visited Israel, many countries in Europe, Australia, New Zealand, Ethiopia and Thailand; all in the name of research. His busy academic and research schedules, has left little time for his hobbies, which include tennis, karate, and leather- and woodcraft. He is also an avid rugby, tennis and golf spectator.

This grandfather of four still has many research ambitions that he wants to achieve before retirement. Although he has extensive experience as a manager, including positions such as head researcher and later acting director of the ISER, chairman of the ISER management, chairman of the Unit for Agricultural Management Training and Research and head of the Department of Agricultural Economics at the University of the Free State, his first love remains research. He still dreams of creating an even more sophisticated flood and drought management model; of leaving a legacy that will make the growing threat of droughts and floods a little less daunting.

"Research is never complete. Once you have found certain answers to questions, it leads to even more questions that can only be answered through more research. The earth's climate is changing, which will result in more droughts and more floods. I currently serve on the Drought Task Group of the International Commission of Irrigation and Drainage (ICID). They requested that more research is done on managing droughts as more and more countries suffer from water shortages. I am the coordinator of a group that is currently developing measures to manage irrigation droughts. Floods will always be a global reality, but droughts will cause more and more crises worldwide," he says as he dons his characteristic beret and gathers his briefcase, on his way to lead another gathering of researchers.

A Hundred Years of Research Towards the Conservation and Sustainable Management of South Africa's Land, Water and Climate Resources

ARC - Institute for Soil, Climate and Water: 1902-2002

The ARC-Institute for Soil, Climate and Water celebrated its Centenary during 2002. The oldest of the institutes of the Agricultural Research Council was established in 1902 as the Division of Chemistry in the Transvaal Department of Agriculture. In 1962 the Division was renamed the Soil Research Institute, and became the Soil and Irrigation Research Institute in 1971. The Institute adopted its present name upon the establishment of the ARC in 1992. This article proudly highlights some of the research achievements by the ARC-ISCW staff towards the conservation and sustainable management of our natural agricultural resources.

SOIL SURVEYS AND LAND EVALUATION FOR IRRIGATION

During the last 100 years the Institute has dealt with numerous investigations into salt-affected soils. At the first South African Irrigation Congress in 1909, concern was expressed at the extent of salt-affected soils, the sediment content of water supplies, the lack of suitable land for irrigation development and serious deficiencies in farm management. Even in those early days it was pointed out that for successful irrigation scheme development a careful soil survey must first be carried out; the volume of water which can be brought into the scheme must be known; and the irrigation scheme must proceed strictly along business lines. The same philosophy is still very relevant today.

The Institute was involved with the soil investigations and irrigation planning of all the major irrigation schemes in South Africa. More than 80 years ago, a Soil Survey Division was established whose main function was to examine proposed irrigation schemes. A review of such soil surveys reveals that soils free of limitations for irrigation are limited in their extent. However, it appears that waterlogging and salinisation affects only 13-18% of the area under regular irrigation, which, although still considerable, is lower than that experienced in many countries. Possible explanations for this relatively favourable state of affairs are the strict emphasis placed on the potential for waterlogging and its prevention in the Institute's selection criteria for irrigated soils, and the generally good water quality that has historically been available for irrigation. But with the salinity of South Africa's water resources on the increase due to mining, urban, industrial and agricultural developments, and the availability of water on the decrease, soil salinity due to deteriorating water quality is now on the rise.

The ARC-ISCW is presently involved in several studies on the use of poorer quality water for irrigation and to determine the effect of contamination of soils and water by industry and mining. Notably, the Blesbokspruit Wetland and adjacent farmland in Gauteng has been monitored on a monthly basis since 1996 to track the effect on soils and crops of irrigating with poor quality underground mine water. The uniqueness of this project lies not only in the amount of data generated but also in the fact that commercial farms use the water successfully. Through measuring soil salinity and other soil chemical properties at regular intervals, fluctuating trends in soil salinity and sodicity have been observed. Electrical conductivity values at the bottom of the root zone increased from 70 mS m^{-1} in 1996 (when mine water was first released) to 177 mS m^{-1} in 1999 (a dry year), but dropped to 95 mS m^{-1} in 2001 (a wet year). Long-term trends were masked by seasonal events such as high or low rainfall and irrigation

demand, and the extent of winter irrigation.

Although the role of the Institute has now changed from primarily irrigation planning and development on the best soils to one of using poorer soils and waters in a sustainable manner, the fact that more than 3000 irrigation, salinity, drainage or waterlogging reports have been produced during the last century indicates the significant contribution the Institute has made to the knowledge base on the irrigability of South African soils.

The Water Research Commission has funded research into water management techniques in rainfed agriculture, conducted by the Institute at its experimental station at Glen, near Bloemfontein. See article on p 17.

CROP WATER-USE EFFICIENCY UNDER IRRIGATION

The WRC supported research on the water use of irrigated crops conducted by the ARC-ISCW over a period of more than 20 years. Much of this work was carried out at a field experimental station set up at Roodeplaat, near Pretoria. Considerable infrastructure was established including four weighing lysimeters and two rain shelters. The facilities were used from 1977-1989 in studies aimed at gaining a better understanding of the process of water movement through the soil-plant-atmosphere continuum and in particular on the effects of water stress on crop growth and water use. The field research trials used spring wheat as the test crop during the winter seasons and soybeans in the summer, and several international scientists participated in the detailed measurements of various plant physiological properties. This work culminated in a multi-disciplinary project conducted from 1990-94 that focussed on characterising the interactive effects of water and nitrogen on the growth, water use and yield of irrigated spring wheat. Guidelines were developed for farmers regarding the amount of irrigation water to apply and the optimal nitrogen application recommended for a specific target wheat yield in the warm irrigation regions of South Africa. For example, for spring wheat cultivars grown in a deep soil with a high clay content, in order to obtain a grain yield of 6 000-7 000 kg ha^{-1} a nitrogen fertiliser application rate of 135 kg N ha^{-1} was recommended. The field study indicated that a seasonal water use of approximately 550 mm would be required for this target yield if irrigation was applied weekly, but only 440 mm if it were applied once every two weeks. The efficiency of irrigation water could thus be improved if these guidelines are followed, and a higher yield produced per unit of irrigation water applied.

In the same project a significant contribution was made to the detailed monitoring of plant-water relations when the heat pulse system, which had previously been used only on plants with robust stems such as soybeans, was adapted for use with thin-stemmed wheat tillers. The technique was then calibrated and used successfully to make continuous measurements of single stem transpiration under field conditions. But perhaps the main legacy of the project was the large and comprehensive dataset that was generated. This was used to validate selected crop growth models and made available to other research institutions for the same purpose. Some of the data was subsequently included in the SWB irrigation scheduling model (developed at the University of Pretoria), which the Institute then also helped to validate.

In the late 1990s, in order to assist the many small-scale emerging farmers, the ARC-ISCW's research focus changed to determine the water requirements of vegetable crops grown in small flood-irrigated plots.

WATER HARVESTING UNDER RAINFED AGRICULTURE

The WRC has also funded research into water management techniques in rainfed agriculture, conducted by

The Water Research Commission supported research on the water use of irrigated crops conducted by the ARC-ISCW over a period of more than 20 years.

the Institute at its experimental station at Glen, near Bloemfontein. In-field rain water harvesting (IRWH), incorporating appropriate tillage and mulching practices, has proved to be a very effective method for enhancing rainfed crop production in marginal areas. IRWH techniques on clay soils, combining basin tillage, a bare no-till runoff strip and mulching, have resulted in both improved crop yields and precipitation-use efficiency (PUE: kg ha^{-1} grain yield divided by mm seasonal rainfall). Over a 4-year trial period the IRWH technique produced on average an additional 1.5 kg ha^{-1} grain per mm of rain in comparison to the PUE of 3.9 kg ha^{-1} mm^{-1} for conventional tillage. Even more impressive was the fact that the yields from the water harvesting techniques remained superior to those of conventional tillage irrespective of climatic conditions. Production conditions varied from very unfavourable during the 1998/99 season (401 mm rain) to very favourable in 1997/98 (633 mm). Grain yields varied from 0-3 133 kg ha^{-1} using a conventional tillage production system to 132-4 678 kg ha^{-1} when the water harvesting technique was used, with the average yield for IRWH being 810 kg ha^{-1} higher. The IRWH technique is more effective in converting water into food because it combines the advantages of water harvesting, no-till, basin tillage and mulching. The hydrological cycle is modified in such a way that more water is made available to the crop. Losses through runoff are prevented entirely and mulching further conserves water by enhancing the infiltration rate, allowing it to percolate deeper beyond the evaporation-sensitive zone.

CLIMATE MONITORING NETWORK AND DATABANK

The ARC-ISCW's climate monitoring network has expanded since its inception in 1940 to 250 mechanical and 270 automatic weather stations. An automatic weather station (AWS) is equipped with state-of-the-art communication technology which enables the provision of near real-time information for stress-sensitive crops, pests, diseases and crop production indices. Sixty percent of the stations are privately owned and incorporated into the monitoring network through maintenance and calibration service contracts. These contracts entail quality processing of data to facilitate *inter alia* early warning with respect to diseases. The climate monitoring network recently expanded to previously disadvantaged areas in the Eastern Cape where more than thirty AWSs have been established.

The climate databank includes information from the national networks of the ARC, the South African Weather Service and smaller monitoring institutions. It has recently been upgraded to provide numerous user-friendly agrometeorological applications. Currently under development is the accessibility of this databank via the Internet to provide clients with report and query application products.

During the 1980s much agrometeorological research was directed to producing climate zones to extrapolate point climate data, but recent advances in technology and computing facilities now make the generation of climate surfaces a preferable option. The development of 10-daily, monthly and annual long-term mean rainfall and temperature surfaces, which use a grid resolution of 1 km^2, was a significant one. These surfaces have numerous applications in the agricultural industry, including the successful delineation of crop production areas.

SOIL RESOURCE INFORMATION

During the last 30 years the Institute mapped the soil, terrain and climate resources of South Africa in a countrywide Land Type Survey. Over 7 000 land types were identi-

In a current WRC-funded project, models are being tested to assess their ability to predict the impact from various management practices typically used in South Africa's agricultural production systems.

fied and their properties inventorised on a total of 69 maps. Each land type differs significantly from those surrounding it in terms of its soils, terrain and macroclimate properties. As these properties are important in determining agricultural suitability, the land type maps and inventories have proved invaluable in assessing agricultural potential in South Africa, and have found numerous applications in the agricultural industry and the field of environmental quality.

LAND QUALITY INDICATORS

A healthy and productive soil resource base is essential to meet the needs and aspirations of present and future generations. Indicators of land and soil quality are being developed to monitor human impacts on land. The current condition of land in Mpumalanga was assessed for rainfed and irrigated crops, rehabilitated open-cast mined land and for rangeland in the grassland and savanna biomes. The recommended indicators to address future land quality were changes in land use, soil condition (chemical properties) and water quality, at monitoring intervals of 5, 2.5 and 0.5 years respectively.

Soil phosphorus (P) level was used as an indicator of land degradation in Gauteng. There was a unique relationship between soil P concentration and the intensity of degradation in terms of vegetative cover, whether it was for grassland or alien vegetation sites within the study area. The P concentration mostly increased with increasing degradation intensity and was generally higher for severely degraded sites compared to non-degraded sites. The implication here is that soil P could be used as an indicator of environmental degradation.

EROSION

The Instutute has been active in erosion studies for many years. Back in the 1930s these concentrated on the fundamental relationship between soil type, soil condition and rainfall erosivity, and on procedures to control erosion of natural grazing and cultivated land. Runoff plots and lysimeters were used to determine the magnitude of soil loss. Later, rainfall simulator and mini-flume investigations on a selection of soils evaluated the effect of a range of soil physical, chemical and mineralogical properties on the erosion process. In 1973, the Institute published a report on the vulnerability of South African soils to erosion. The effects of slope, water droplet energy, rainfall erosivity, soil stability, soil water infiltration, soil dispersion and crusting all received research prominence. Methods of reducing the soil dispersion and crust formation that lead to erosion, using soil amendments such as gypsum and polyacrylamide, were investigated in collaboration with Israeli scientists. The importance of soil mineralogy has improved our understanding of the erosion process; for example the mica content was identified as the single most dominant soil characteristic promoting interrill erodibility of Mollisols.

Later research provided opportunities for erosion assessment and prediction modelling at scales ranging from small catchments up to countrywide. Erosion models such as the Revised Universal Soil Loss Equation (RUSLE) produced estimates of soil loss under differing management systems. The significance of these studies is that estimated soil loss values could be displayed at either farm, district or provincial levels. The Lesotho Highlands Water Project served as a benchmark study to indicate land with potentially high or low erosion hazard. In a current WRC-funded project, models are being tested to assess their ability to predict the impact from various management practices typically used in our agricultural production systems.

The satellite-based Vegetation Index and Bare Soil Index have further

enhanced capabilities in erosion research. The ARC-ISCW also maintains the South African database for the World Overview of Conservation Approaches and Technologies (WOCAT), aimed at evaluating soil and water conservation technologies.

SOIL DEGRADATION DUE TO STRIP MINING

Some of the most productive rainfed agricultural land in South Africa is found on the Mpumalanga Highveld. Stable land surfaces with gently rolling topography, receiving 750-800 mm annual rainfall, are occupied by moderately deep, highly weathered soils with favourable water-holding characteristics and response to fertilisation. Strip (opencast) mining became widespread in this area during the mid-1970s. Of a total of 2.7 million ha underlain by coal reserves in Mpumalanga, approximately 7% may ultimately be mined by strip mining methods. Guidelines for strip-mine rehabilitation were published and a growing awareness of the serious loss of agricultural potential and changes in soil hydrological properties resulting from this mining process led to a number of investigations.

The most widespread limiting soil property in rehabilitated strip-mined soils was found to be the high bulk densities induced by soil leveling operations using heavy rehabilitation equipment. Maize field trials conducted at representative rehabilitated sites produced a mean yield of only 2 400 kg ha^{-1}, about half the norm for the area and below the economic break-even yield for maize. Maize production was thus proven to be uneconomic if soil limitations are not corrected. Water extraction by maize and grass roots was limited in the cover soil where high bulk densities were present, despite evidence of water in deeper soil and spoil layers.

POLLUTION

Due to growing public concern and awareness of food quality, issues relating to trace elements in agricultural soils and chemical residues in agricultural produce have become increasingly important. Our health depends to a large extent on the supply of mineral nutrients in our daily diet, and deficiencies and toxicities are therefore critical. Since our food is produced mainly on the land, soil is the primary source of these mineral elements in the food chain. Ground-breaking work has been done in determining baseline concentrations of trace elements in South African soils. Areas with deficiencies or toxicities have been identified, whilst in Mpumalanga the influence of agricultural practices on the trace element content of soils has also been studied.

A related research field is the disposal of sewage sludge on land. Strict guidelines for sludge disposal on agricultural soils apply in South Africa. Most wastewater treatment plants dispose of their sewage sludge on dedicated land disposal sites. This is a quick and cheap but controversial practice. The impact on the environment is believed to be negative, but very little research has been done to determine the extent of the damage to the soil and water resources. A WRC-funded study to develop suitable management and environmental quality guidelines for waste disposal is presently in progress at the ARC-ISCW.

CARBON SEQUESTRATION

Global warming, caused by elevated levels of greenhouse gases in the atmosphere from human activities such as the burning of fossil fuels, is another issue of increasing concern. In particular it can have serious ramifications for agricultural production and food security, greatly affecting marginalised populations in rural areas. Carbon sequestration (the building up of carbon levels in the soil) is one way of counteracting this concern. To establish the potential for carbon sequestration in South African agriculture, the Institute derived the baseline carbon levels from over 2 000 soil profile analyses and produced maps to show the estimated distribution of carbon in South African soils. Although only an approximation, this unique approach illustrates the potential for building up carbon levels based on long-term soil and climate properties. Research indicates that carbon levels in cultivated land are generally about half of those in undisturbed grassland.

CONCLUSION

Much of the natural resources information collected by the ARC-ISCW over the last 100 years has been published in scientific journals, in reports or on maps which are archived at the Institute. Electronic dissemination of information has recently gained momentum, notably via the Agricultural Georeferenced Information System website (www.agis.agric.za). Readers are encouraged to consult this website or contact the Institute directly should they have any information requirements.

For further information please contact: ARC-ISCW, Private Bag X79, Pretoria 0001. Tel: (012) 310 2500; Fax: (012) 323 1157; E-mail: info@iscw.agric.za; Website: www.arc-iscw.agric.za

SOUTHERN AFRICA & AFRICA 2003

ENVIRONMENTAL COURSES

A series of environmental courses on the new environmental law, implementing environmental management systems and audits, water quality management, environmental risk assessment, air quality management, the legal framework for managing water in South Africa, etc will be held throughout the year by CEM (the Centre for Environmental Management) at the University of Potchefstroom (PU for CHE).
Enquiries: Mrs Dydre Greeff/Mrs Madel Lottering.
Tel: (018) 299 2714 or (018) 299 2725. Fax: (018) 299-2726.
E-mail: aokdg@puknet.puk.ac.za or aokml@puknet.puk.ac.za
Web: www.puk.ac.za/education/shortcourses/environment.html

ISO 14001 WATER RESOURCES JULY 26 - AUGUST 1

A special session, sponsored by the Water Research Commission, with the theme "Rangeland and Water Resources" is being convened during the 7th International Rangeland Congress which will be held at the International Convention Centre in Durban.
Enquiries: E-mail: delegates@sbconferences.co.za
Tel: 031 3032480.
Fax: 031 3129441.
Web: www.ru.ac.za/institutes/rgi/irc2003/IRC2003.htm

HYDROLOGY SEPTEMBER 3 - 5

The 11th South African National Hydrology Symposium and workshop will be held at the PE Technikon in Port Elizabeth, Eastern Cape. The theme will be: "Water resources in Southern Africa – the future is not what it used to be!"
Enquiries: Juanita McLean.
Tel: (046) 6224014.
Fax: (046) 622 9427.
E-mail: juanita@iwr.ru.ac.za
Web: http://www.ru.ac.za/institutes/iwr/SANCIAHS2003

IWA SEPTEMBER 14 - 19

The International Water Association (IWA) will host a regional conference in Cape Town with the theme: *Water as the key to sustainable development in Africa*. Simultaneously with this event, the IWA specialist group on biofilms and the specialist group on health related water microbiology will also be having their international specialist conferences.
Enquiries: Prof TE Cloete, IWSA National Committee.
E-mail: tecloete@postino.up.ac.za
Tel: (012) 420 3265.
Fax: (012) 420 3266.
Web: www.iwaconferences.co.za/

WATER MICROBIOLOGY SEPTEMBER 14 - 19

An international symposium on health-related water microbiology will be held in Cape Town.
Enquiries: Ms Heidi Botha, Organising Committee, 2003 Cape Town Symposium (HRWM), Department of Virology, University of Pretoria.
Tel: (012) 319 2351.
Fax: (012) 325 5550.
E-mail: bothah@med.up.ac.za

ENVIRONMENTAL MANAGEMENT OCTOBER 7 - 9

A short course on environmental management will be held at the Post-Graduate Centre of the University of Pretoria.
Enquiries: Ms Marina Nell.
Tel: (012) 420 5010.
Fax: (012) 362 5285.
E-mail: marina.ce@up.ac.za

WATER-RELATED DISEASES NOVEMBER 1 - 8

The 1st annual international scientific conference on water-related diseases, sponsored by the Global Council on Water Diseases, will be held in Abuja, Nigeria.
Enquiries: Please visit the conference website:
http://www.gcowd.com

MINE WATER NOVEMBER 3 - 5

A conference with the theme "Implementing sustainable development in mining: From talk to action" will be held at the Indaba Hotel in Sandton.
Enquiries: The Conference Administrator – attention: Ms Ammie Wissing, Conference Planners, PO Box 36782, Menlo Park 0102.
E-mail: wissing@iafrica.com
Tel: 012-348 4493.
Fax: 012-348 1563.

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WATER SUPPLIERS FEBRUARY 19 - 24

The Union of African Water Suppliers (UAWS) will be holding its 12th bi-annual African congress in Accra, Ghana.
Enquiries: Mr Dennis D Mwanza, Water Utility Partnership (WUP), 05 BP 2642, Abidjan, Cote d'Ivoire.
Tel: +225 21 2408 28. Direct line: +225 21 2408 13. Cell: +225 07 0199 01. Fax: +225 21 75 8656/7.

OVERSEAS

GROUNDWATER MAY - DECEMBER 2003

The Centre for Groundwater Studies (CGS) in Australia will be organising short courses on groundwater related themes throughout the year. CGS courses can be counted towards a Master of Science in Groundwater Hydrology degree offered by Flinders University in Adelaide, Australia.
Enquiries: Trevor Pillar.
Tel: 61 8 8201 5632.
Fax: 61 8 8201 5635.
E-mail: cgs.training@groundwater.com.au
Web: www.groundwater.com.au

ACTIVATED SLUDGE JULY 28 - AUGUST 1

The 14th annual short course on the methodologies and laboratory techniques to generate process control parameters for operating an activated sludge process will be held in Estes Park, Colorado.
Enquiries: Thomas G Sanders, Course Director, Department of Civil Engineering, Colorado State University, Fort Collins, CO 80523.
Fax: (970) 491 7727.
Tel: (970) 491 5448.
E-mail: TGS@engr.Colostate.Edu
Web: http://www.engr.colostate.edu/depts/ce/

BASIN MANAGEMENT AUGUST 17 - 22

The 7th International Conference on Diffuse Pollution and Basin Management will be held in Dublin, Ireland.
Enquiries: IWA Conference Secretariat, Centre for Water Resources Research, Civil Engineering Department, University College Dublin, Earlsfort Terrace, Dublin 2, Ireland.
Tel:00 353 1 7167 499.
Fax: 00 353 1 7167399.
E-mail: dipcon@ucd.ie
Web: www.ucd.ie/~dipcon/dipcon.htm

BIOFILM SYSTEMS SEPTEMBER 2003

The 5th International Conference on Biofilm Systems will be held in Noordwijkerhout, the Netherlands.
Enquiries: Mark van Loosdrecht, TU-Delft, Julianalaan 67, 2628 BC Delft, the Netherlands.
Tel: +31 15278 1618.
Fax: +31 152 78 2355.
E-mail: m.c.m.vanloosdrecht@tnw.tudelft.nl

WASTEWATER PLANTS SEPTEMBER 1 - 4

The 9th Conference on the Design, Operation and Costs of Large Wastewater Treatment Plants will take place in Prague, Czech Republic.
Enquiries: Prof Dr Jiri Wanner, Dept of Water Technology and Environmental Engineering, Prague Institute of Chemical Technology, Technicka 5, CZ-

166 28 Praha 6, Czech Republic.
Tel: +420 2243 53149.
E-mail: jiri.wanner@vscht.cz

IRRIGATION
SEPTEMBER 1 - 5

The 4th International Symposium on Irrigation of Horticulture Crops will be held in Davis, California, USA.
Enquiries: Conference & Event Services, One Shields Avenue, Davis, CA 95616, USA. Fax: (530) 752 5791.Webpage: http://www.cevs.ucdavis.edu

OZONE
SEPTEMBER 1 - 5

The 16th Ozone World Congress will be held in Las Vegas, Nevada, USA.
Enquiries: GDT Corporation, Phoenix, AZ 85027.
Tel: (623) 587 8858.
Fax: (623) 587 1511.
Web: www.gdt-h2o.com

RIVER MANAGEMENT
SEPTEMBER 2 - 5

The 6th International River Management Symposium with the theme – Urban rivers: balancing the expectations – will be held in Brisbane, Queensland, Australia. The symposium brings together world authorities to share the world's best practise in river management issues, including river ecology, land use planning, community partnerships, institutional arrangements, economics, coastal systems, engineering and technology.
Enquiries: Mr Stephen Nelson.
Tel: +61(0)7 3846 7444.
Fax: +61(0)7 3846 7660.
E-mail: symposium@riverfestival.com.au

WATER USE
SEPTEMBER 3 - 5

The 6th inter-regional conference on land and water use planning and management will be held in Albacete, Spain.
Enquiries: Dr Antonio Brasa-Ramos.
Tel: +34 967 599 200.
Fax: +34 967 599 238.
E-mail: Antonio.Brasa@uclm.es
Web: http://crea.uclm.es/congreso.html

SINKHOLES
SEPTEMBER 6 - 10

The 9th multidisciplinary conference on sinkholes and the engineering and environmental impacts of Karst will be held in Huntsville, Alabama, USA.
Enquiries: ASCE.
Tel: 1-703 295 6300.
E-mail: conferences@asce.org
Web: http://www.asce.org/conferences/karst2003/index.cfm

WATER INFORMATION
SEPTEMBER 9 - 12

The 6th water information summit with the theme: "Breaking the barriers – Let water information flow" – will be held in Delft, the Netherlands.
Enquiries: Ms Ingeborg Krukkert (IRC), PO Box 2869, 2601 CW Delft, the Netherlands.
Tel: +31 15219 2985.
Fax: +31 15219 0955.
E-mail: wis6delft@irc.nl
Web: www.irc.nl/news/wis6.html

DRAINAGE
SEPTEMBER 10 -13

The 9th international drainage workshop - drainage for a secure environment and food supply - will be held in Utrecht, the Netherlands.
Enquiries: Alterra-ILRI, PO Box 47, 6700 AA Wageningen, the Netherlands.
Tel: +31 317 495 549.
Fax: +31 317 495 590.
E-mail: drainage2003@ilri.agro.nl or ilri@ilri.nl

ODOUR CONTROL
SEPTEMBER 14 - 17

The second IWA international conference on the development of odour measurement, regulation and control techniques will be held in Singapore.
Enquiries: Ms Tan Kim Suan, Corporate Communications Manager, Institute of Environmental Science & Engineering Innovation Centre (NTU), Block 2, Unit 237, 18 Nanyang Drive, Singapore 637723.
Tel: +65 6794 1533/1534.
Fax: +65 67921291.
E-mail: KSTAN@ntu.edu.sg or KSTAN@iese.ntu.edu.sg
Web: www.eti.org.sg or www.iese.ntu.edu.sg

WETLANDS
SEPTEMBER 14 - 17

The 8th symposium on the biogeochemistry of wetlands will be held at Ghent University in Belgium.
Enquiries: Saskia van der Looven, Ghent University, Het Pand, Ondergbergen 1, B-9000, Ghent, Belgium.
Tel: +32 9 264 6001.
Fax: +32 9 264 6230.
E-mail: Saskia.Vanderlooven@rug.ac.be
Web: http://allserv.rug.ac.be/~janverme/Wetlands/

ICID
SEPTEMBER 14 - 19

The 54th IEC meeting and 20th ICID regional conference on irrigation and drainage will be held in Montpellier, France.
Enquiries: Mr Francois Lacroix, AFEID, Parc de Tourvoie, 92160 Antony, France.
Tel: +33 01 40 966197.
Fax: +33 01 40 966196.
E-mail: francois.lacroix@cemagref.fr
Web: http://afeid.montpellier.cemagref.fr/cei2003.htm

WATER MANAGEMENT
SEPTEMBER 15 – 18

The Monitoring Tailor-Made IV conference will be held in St Michielsgestel, the Netherlands. The conference deals with strategies and practices for the collection and dissemination of information in support of integrated water resources management.
Enquiries: The Conference Secretariat, IWAC (International Water Assessment Centre), PO Box 17, 8200 AA Lelystad, the Netherlands. Tel: +31 320 298 894. Fax: +31 320 297 642. E-mail: mtm@riza.rws.minvenw.nl
Web: http://www.mtm-conferen.nl

FRACTURED ROCKS
SEPTEMBER 15 - 19

A conference on groundwater in fractured rocks will be held in Prague, Czech Republic. The conference is organised by the IAH Working Group on hard rock hydrogeology.
Enquiries: Jiri Krasny.
E-mail: krasny@natur.cuni.cz
Web: http://www.natur.cuni.cz/gwfr2003

HYDROLOGY
SEPTEMBER 16 - 19

An international conference on GIS and remote sensing in hydrology, water resources and the environment will be held at the Three Gorges Dam Site in China.
Enquiries: Prof Yangbo Chen, Department of Water Resources and Environment, Sun Yat-Sen University, 135 Xingangxi Road, Guangzhou, China 510275.
Fax: +86 203402 2397.
E-mail: eescyb@zsu.edu.cn
Web: www.hydroinfor.zsu.edu.cn/

GROUNDWATER
SEPTEMBER 17 - 19

The international groundwater modelling centre (IGMC) will present a short course - MODFLOW and More 2003: Understanding through Modelling - in Golden, Colorado, USA.
Enquiries: IGMC.
Tel: +1 303 273 3103.
Fax: +1 303 384 2037.
E-mail: igwmc@mines.edu

DESALINATION
SEPTEMBER 28 - OCTOBER 2

The International Desalination Association's conference and workshop on integrated membrane systems for brackish water, seawater and wastewater desalination will be held in Paradise Island, Bahamas.
Enquiries: AMTA/IDA.
Tel: 760 643 1750.
Fax: 760 643 1761.
E-mail: amtaorg@aol.com
Web: www.membranes-amta.org

BENCHMARKING
SEPTEMBER 29 - OCTOBER 2

A conference on the global developments in water industry performance benchmarking will take place in Perth, Australia.

Enquiries: Office of Water Regulation.
Tel: +61 (08) 9213 0100.
E-mail: benchmarkingwater@wrc.wa.gov.au
Web: www.wrc.wa.gov.au/owr/

SEDIMENTS
SEPTEMBER 30 - OCTOBER 3

The 2nd international conference on the remediation of contaminated sediments will take place at the Palazzo del Cinema, on the island of Lido, Venice, Italy.
Enquiries: The Conference Group, 1580 Fishinger Road, Columbus, OH 43221, USA.
Tel: 614 488 2030.
Fax: 614 488 5747.
E-mail: info@confgroupinc.com
Web: http://www.battelle.org/environment/er/conferences/sedimentscon/default.stm

WATER RESOURCES
OCTOBER 5 - 9

The 11th world congress on water resources - Water Resources Management in the 21st Century will be held in Madrid, Spain.
Enquiries:
E-mail: wwater2003@cedex.es
Web: www.cedex.es/iwracongress2003/

WASTE MANAGEMENT
OCTOBER 6 -10

The 9th international waste management and landfill symposium will be held in Cagliari, Sardinia, Italy.
Enquiries: Professor R Cossu, Image Department, University of Padua, Via Loredan 20, 35131 Padova, Italy.
Tel: +39 049 8726986.
Fax: +39 049 8726987.
E-mail: eurowaste@tin.it or info@sardiniasymposium.it

WEFTEC 2003
OCTOBER 11 - 15

The Water Environment Federation's 76th annual technical exhibition and conference will be presented in Los Angeles, California, USA.
Enquiries: WEF.
Tel: 1-703 684 2452.
Fax: 1-703 684 2401.
E-mail: confinfo@wef.org
Web: http://www.weftec.org/

CONTAMINATED SOILS
OCTOBER 20 - 23

The 19th annual international conference on contaminated soils, sediments and water will take place at the University of Massachusetts in Amherst, MA, USA.
Enquiries: Denise Leonard.
Tel: 413 545 1239.
E-mail: info@UMassSoils.com
Web: http://www.UMassSoils.com

WASTEWATER
NOVEMBER 12 - 14

The 4th international symposium on wastewater reclamation and reuse will be held in Mexico City, Mexico.
Enquiries: Blanca Jimenez, Instituto de Ingenieria, UNAM, Apartado Postal 70-472, Ciudad Universitaria, 04510, Mexico, DF.
Fax: +525 622-3433.
Email: iwa@pumas.iingen.unam.mx
Web: http://www.iwahq.org.uk/template.cfm?name=wwrr4

GROUNDWATER
DECEMBER 9 - 12

The National Groundwater Association's 2003 Ground Water Expo will be presented in Orlando, Florida, USA.
Enquiries: NGA, Dept 481, Columbus, OH 43265-0481.
Tel: 800 551 7379/614 8987791.
Fax: (614) 898 7786.
E-mail: ngwa@ngwa.org
Web: http://www.ngwa.org/convention/national.html#2003

WATER HISTORY
DECEMBER 11 - 14

The 3rd conference of the international water history association will be held in Cairo, Egypt.
Enquiries: Alv Terje Fotland.
Tel: +47 55 589315.
Fax: +47 55 589892.
E-mail: a.fotland@iwha.net
Web: http://www.iwha.net/

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WASTEWATER
JANUARY 26 - 29

A conference on wastewater treatment for nutrient (nitrogen and phosphorus) removal and reuse will be held in Bangkok, Thailand.
Enquiries: Dr Ajit Annachhatre, School of Environment, Resources and Development, Asian Institute of Technology, PO Box 4 Klong Luang, Pathumthani 12120.
Tel & Fax: 662 524 5644.
E-mail: ajit@ait.ac.th

DRAINAGE
MARCH 21 - 24

The 8th international drainage symposium together with the 10th national symposium on individual and small community sewage systems, will be held in Sacramento, California, USA.
Enquiries: American Society of Agricultural Engineers, 2950 Niles Road, St Joseph, MI 49085.
Tel: 269 429 0300.
Fax: 269 429 3852.
E-mail: AS31@umail.umd.edu
Web: http://www.asae.org/meetings/sew04/index.html

AUTOMONET
APRIL 19 - 20

An international conference on automation in water quality monitoring - networks for surveillance, early warning and process control strategies and techniques of real time water quality assessment - will be held in Vienna, Austria.
Enquiries: Bernadette Ebner, KUONI Incoming Service GmbH, Wahringer Str 2-4/40, A-1090, Vienna, Austria.
Tel: +43(0)1 319 7690-26.
Fax: +43(0)1 3191180.
E-mail: bernadette.ebner@kuoni.at

FILTRATION
APRIL 19 -23

The 9th world filtration congress, sponsored by the American Filtration and Separations Society, will be held in New Orleans, Louisiana, United States.
Enquiries: Ms Kathy Hemming.
Tel: 1 703 538 1000.
Fax: 1 703 538 6305.
E-mail: Kathleen.hemming@verizon.net
Web: www.afssociety.org

PIPES
APRIL 19 - 22

A conference called Plastic Pipes XII will be held in Milan, Italy.
Enquiries: Michael Ball, PPI.
Tel: (202)462 9607.
E-mail: mball@plasticpipe.org
Web: www.plasticpipe.org

WATERSHED 2004
JULY 11 - 14

The Water Environment Federation (WEF) will sponsor an international speciality conference in Dearborn, Michigan, USA, on integrated resource management and environmental protection using watershed approaches.
Enquiries: WEF, 601 Wythe Street, Alexandria, VA 22314-1994, USA.
Tel: 703 684 2400 x 7010.
E-mail: watershed04@wef.org

HYDROLOGY
JULY 12 - 16

This conference – Hydrology: Science and Practice for the 21st Century – will be held in London, United Kingdom, and is designed to bring together hydrologists involved in scientific research and operational practice to address key issues affecting hydrology in the new century.
Enquiries: For more information, please visit the website: www.hydrology.org.uk/bhs2004/welcome.htm

WORLD WATER
SEPTEMBER 20 - 24

The International Water Association (IWA) will hold its 4th world water congress in Marrakesh, Morocco.
Enquiries: AMEPA.
Tel: +212 3763 2093.
Fax: +212 3763 7682.
E-mail: sehi@elan.net.ma
Web: http://www.iwahq.org.uk/

FIRST ANNOUNCEMENT AND CALL FOR PAPERS

WISA
Water Institute of SA

BIENNIAL CONFERENCE AND EXHIBITION

CAPE TOWN INTERNATIONAL CONVENTION CENTRE SOUTH AFRICA

2 - 6 MAY 2004

CALL FOR PAPERS

Anyone who is interested in making a presentation at this conference, either orally or by means of a technical poster, who need not necessarily be members of WISA,are invited to submit a short (a maximum of one page) abstract of their proposed presentation by ***30 June 2003.***

TOPICS

The following topics are provided only to provide guidance on the wide range of topics that may be covered at the conference:

Anaerobic Processes, Analytical Equipment and Techniques, Aquatic Ecosystems, Collection and Reticulation Systems, Community based Projects, Community Water Supply and Sanitation, Consumer Education, Developing Communities, Dune Rehabilitation, Education and Training, Environmental Aspects, Fluoridation, Groundwater Management, Health Related Aspects, Impact of HIV and AIDS, Industrial Water and Effluent, Legislation, Management and Institutional Affairs, Marine Disposal, Membrane Technology and Applications, Mine Water Quality Management, Nutrient Removal, Potable Water Treatment, Plant Operation, Public Participation, River Basin Management, Role of Water Scientists, Sludge Management, Social Impacts, Urban Run-off, Wastewater Technology, Water Distribution, Water Quality Management.

ALL ENQUIRIES

Telephone: (011) 805 3537 • Fax: (011) 315 1258 • E-mail: conference@wisa.co.za

REPLY FORM:

All Abstracts must be submitted in electronic format using either Microsoft Word or Corel WordPerfect. The covering e-mail should detail the suggested session, and whether the submission is for a poster or oral presentation. E-mail: conference@wisa.co.za.
Only in exceptional circumstances will a faxed or paper copy be accepted. WISA, P O Box 6011, Halfway House 1685

I am interested in (please tick):

- ☐ Making an Oral Presentation
- ☐ Making a Poster Presentation
- ☐ Exhibiting

Surname:..... Initial:.....(Dr/Prof/Mr/Mrs):.....
Organisation:.....
Postal Address:.....
Postal Code:..... Country:..... Telephone:.....
Fax:..... E-mail:.....

Please attach a ONE page abstract of the proposed presentation.

Please tick the most appropriate session into which you think your presentation would fall.

- ☐ Community Water Supply & Sanitation
- ☐ Education and Training
- ☐ Environmental Aspects
- ☐ Health Related Aspects
- ☐ Industrial Water & Effluent
- ☐ Information Technology
- ☐ Legislation
- ☐ Management & Institutional Affairs
- ☐ Membrane Processes
- ☐ Plant Operation
- ☐ Potable Water
- ☐ Wastewater
- ☐ Other (Please Specify): .....
  .....
  .....