THE WATER WHEEL

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Groundwater Special Edition

Celebrating SA's hidden treasure

WATER RESEARCH COMMISSION

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Cover: *The Water Wheel Special Edition on Groundwater celebrates the best of research around the country's hydrogeology. (Cover photograph by Koos van der Lende – Africa Media Online).*

THE WATER WHEEL is a two-monthly magazine on water and water research published by the South African Water Research Commission (WRC), a statutory organisation established in 1971 by Act of Parliament. Subscription is free. Material in this publication does not necessarily reflect the considered opinions of the members of the WRC, and may be copied with acknowledgement of source.

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WRC – Leading the charge on groundwater research

The Water Research Commission's continued commitment to expanding knowledge on the use and management of South Africa's groundwater resources underscores its leadership role in this domain. Article by Lani van Vuuren.

It was the prospect of storing treated sewage water in the sand beds of the Cape Flats that first led to the Water Research Commission (WRC) funding groundwater research nearly 40 years ago. Now several decades on the Commission is still the prime funder of groundwater research in South Africa.

Since the first WRC groundwater-related research project was initiated in 1974, funding for groundwater projects has varied between 6% and 16% of the Commission's annual research spending. A study investigating this research impact a few years ago found this investment to be the most significant contribution to the building of capacity for the sustainable utilisation and management of groundwater resources in South Africa.

Among others, the WRC has been instrumental in developing the strong research and teaching centres in groundwater hydrology in South Africa, most notably the Institute for Groundwater Studies at the University of the Free State (which has the longest standing relationship with the Commission out of any groundwater research entity) and the groundwater programme within the Earth Science Department at the University of the Western Cape. The WRC has also supported groundwater research at the universities of Fort Hare, Venda, Pretoria, Witwatersrand, North West and KwaZulu-Natal, in addition to an increasing number of research projects undertaken by research consultants and science councils, such as the CSIR and the Council for Geoscience.

Initial research focused on resource characterisation and groundwater technology. "Groundwater is often poorly understood because of its hidden nature," explains WRC Research Manager, Dr Shafick Adams. "As a result, assessments often rely on indirect measurements and long-term investigations, as well as investments to determine fully the behaviour of complex aquifer systems. The investments from the WRC in these areas over the years have undoubtedly led to a greater understanding of South Africa's complex aquifer systems, and finding ways to effectively manage them."

Since 2000 a greater resource management focus within an integrated water resource management framework was added to the WRC research portfolio. This progression of research focus reflects the progression of groundwater attention nationally, before and after the promulgation of the National Water Act (NWA) in 1998.

Groundwater has historically been considered the 'Cinderella' of water resources in South Africa. Since the promulgation of the NWA groundwater is no longer legally classified as a 'private' water source, allowing it to stand side-by-side with most often used surface water resources. Today, groundwater supplies more than 60% of rural communities with water. The water drawn from aquifers and springs is also the sole source for many towns in the drier parts of the country, as well as an important supporting source for large cities, such as Pretoria and Polokwane.

"While its recognition as a resource with significant potential has been slow, awareness is steadily growing around groundwater's potential to meet future water demand," says Dr Adams. "There is increasing recognition of the role groundwater can play in meeting our growing water needs."

As cities and towns grow and more industries arise, water supply has to be augmented to meet the growing demand. The Department of Water Affairs' reconciliation studies – which looked at available water resources in critical areas in South Africa and how this future demand can be met, has recommended groundwater sources in many cases. It is interesting to note that only about 20% to 30% of the country's estimated available groundwater resources are currently being used.

Unfortunately, there is still a stigma attached to groundwater in some areas, with many decision-makers seeing it as an unreliable source of water. Dr Adams explains the likely source of this myth: "At the local level, very few institutions have groundwater expertise in their employ, even in areas where groundwater is the sole source of water

Graeme Williams-Media Club South Africa

supply. This inevitably leads to the resource getting the blame for operation and maintenance failures."

The WRC invested more than R5-m in groundwater projects last year, with another R2.8-million planned spending this financial year. The current areas of focus include groundwater-surface interactions and improving understanding of South Africa's vast fractured rock aquifers in terms of hydraulic behaviour and chemical characteristics. Another focus is around building, understanding and developing the necessary tools for groundwater management at the local (i.e. municipal) level.

Recently, concerns over the potential environmental impact of hydraulic fracturing have also prompted the WRC to fund projects in this regard. Most of the Commission's projects take a multidisciplinary approach. "The discipline-specific approach to solving specific research questions is important, but on its own it cannot address current environmental, social and economic issues as well as the challenges faced with implementation," Dr Adams points out.

There are several WRC-funded groundwater-related research projects currently underway, which are sure to significantly enhance further the knowledge around this resource. These include the use of isotope hydrology to characterise and assess water resources in southern Africa. "The use of isotopes in water-related investigations was slowly being eroded in terms of capacity and infrastructure. With this study we are showing the usefulness of the application of isotope hydrology to improve our understanding of our water resources and how it interacts with linked systems," explains Dr Adams.

Another project is focusing on the optimal utilisation of geothermal resources. This project not only deals with the resource, but also how the resource can be used to develop the economy, create jobs, and so on.

A third project is investigating favourable zone identification for groundwater development, focusing on options analysis for local municipalities. This project builds on the recently completed projects around groundwater management functions, identifying and quantifying groundwater development options, and groundwater governance. "The scale of investment required in new water infrastructure over the next decade has been estimated at R668-billion," says Dr Adams. "This investment estimate relies mainly on surface water developments. Greater use of groundwater might mitigate these costs, and reduce the financial, environmental and social costs to the country."

The final suite of projects that needs highlighting is related to unconventional gas and groundwater resources. While the groundwater community has a good understanding of the top 300 m of the crust in the Karoo, it knows very little about the deeper systems where shale gas is found as well as the area in-between. These projects aim to enhance this understanding.

With commitment to such knowledge and capacity building, the South African groundwater sector is ensured of a successful future. ❑

A sample of the latest groundwater research reports available from the WRC

REPORT NO: 1763/1/12

A groundwater planning toolkit for the Main Karoo Basin (R Murray; K Baker; P Ravenscroft; C Musekiwa; & R Dennis)

The project aimed to identify favourable groundwater potential areas for bulk municipal water supplies, to provide a method to quantify them, and to provide the information in a manner so that it is accessable for planning purposes. In identifying favourable groundwater areas, the focus turned to developing a detailed transmissivity map of the Main Karoo Basin. Two methods were developed, namely the Aquifer Assured Yield Model and the Aquifer Firm Yield Model.

REPORT NO: 1974/1/12

Determining the socio-economic value of groundwater: Franschhoek case study (D Pearce; Y Xu; E Makaudze)

There is very little knowledge amongst policy and decision makers regarding the true value of groundwater. This study seeks to address this issue through the development and application of a holistic valuation model that incorporates all the significant use and non-use values of groundwater. The case study area is Franschhoek, in the Western Cape.

REPORT NO. 1760/1/12

Measurement of the bulk flow and transport characteristics of selected fractured rock aquifer systems in South Africa (G Steyl; J Bothwell; GJ van Tonder; B Zhao & J Odiyo)

In this research report the need for an effective method for regional bulk flow properties is discussed. An estimation method for transmissivity values in South Africa is given in respect to fractured rock aquifers with dual porosity properties. The influence of bulk regional transmissivity values for dual porosity medium is discussed in regards to the differences between the largest transmissivity value and the smallest.

REPORT NO: 1909/1/12

Reducing uncertainties of evapotranspiration and preferential flow in the estimation of groundwater recharge (N Jovanovic; RDH Bugan; S Israel; S Dzikiti; E Kapangaziwiri; D Le Maitre; A Rozanov; M Stander; D Mikes; F May; C Jarmain; C Everson)

It is widely acknowledged that groundwater recharge estimates can be improved through improved estimation of evapotranspiration (ET) and preferential flow. Uncertainties exist in the estimation of ET that would account for below-potential water use by vegetation as well as preferential flow paths of water and contaminants. The general objective of this project was to develop improved process-based estimates of groundwater recharge.

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Call for debate on unconventional gas mining to be broadened –

Research project sheds new light on debate on unconventional gas harvesting

Stephani Cawood

Various applications for unconventional gas mining have been lodged with the Petroleum Agency of South Africa (PASA). Yet, gaps still exist in the available knowledge on whether economically recoverable quantities of gas exist, and how to manage the possible impacts, should full scale gas mining proceed. Scientists, legislators and regulators are making use of the time available before gas mining applicants start exploration, or possibly mining, in order to develop the necessary strategic plans. Article by Petro Kotzé.

The University of the Free State Centre for Environmental Management (CEM) has been commissioned by the Water Research Commission (WRC) to undertake a project that will assist with addressing some of these knowledge gaps. The aims are to produce a background review report, develop an interactive vulnerability map and propose provisional screening level monitoring protocols for selected aspects. Together, these will make recommendations as to which areas are vulnerable to unconventional gas mining in South Africa and how hydraulic fracturing activities should be monitored. It will describe important entities that should be monitored for each phase of gas mining and how this monitoring should occur.

The project focuses on a wide array of biophysical and socio-economic aspects for the whole mining process from exploration through to the post mining phase.

A number of participants are involved. "The complexity of the problem being studied is such that it requires a wide array of scientists from varying disciplines," says CEM researcher, Surina Esterhuyse. The main researchers include scientists from the University of the Free State (the CEM and the Department of Sociology, as well as the departments of Physics and Statistics) in association with the University of Pretoria Natural Hazard Centre. Co-workers include independent consultants, as well as scientists from, among others, the Iziko African Museum, the Endangered Wildlife Trust, University of South Africa, the University of Fort Hare and the Technical University of Dresden.

The project spans over two years, but once it started in July 2012, researchers soon realised that their understanding of the issues that are really at stake were limited. Initially, the researchers' biggest concern was with the impacts of hydraulic fracking during shale gas mining, says Esterhuyse. "As our knowledge base increased, we realised that shale gas is just one resource in the suite of unconventional resources that may be mined using hydraulic fracturing. We also realised that although (mostly water-related) impacts could be associated with hydraulic fracturing itself, a larger suite of impacts on the biophysical and socio-economic spheres are associated with the unconventional gas mining process. These impacts could be far reaching and would require strategic and regional-scale planning if unconventional gas mining is to be effectively managed."

UNPACKING UNCONVENTIONAL GAS MINING AND FRACKING

Both conventional and unconventional gas resources are natural gas resources. They are differentiated by their degree of permeability and how they are extracted. While conventional gas (CG) is located in permeable rocks and can escape freely after drilling, unconventional gas (UG) is trapped in insufficiently permeable rock formations, such as shale, tight sands and tight coal beds. Resources from these reservoirs may include not only natural gas, but also oil as well as oil and gas condensates. In order to release these resources, a technology called high volume hydraulic fracturing (also known as slickwater fracturing) is applied. Other treatments can include acidising to dissolve carbonate materials in the host rock, as well as gel fracturing or gas fracturing.

High volume hydraulic fracturing involves drilling wells to the depth of the target rock (for instance a shale layer) where temperatures may range from 35 to 140°C. Different sections of the well in the production zone of the target rock are isolated and a mixture of 0.5% to 2% chemical additives and large volumes of proppant (that keep the fracture zones open), as well as large volumes of fluid (usually water) are pumped

The project focuses on a wide array of biophysical and socio-economic aspects for the whole mining process from exploration through to the post mining phase.

down the well. The hydraulic pressure used to deliver the fluid into the target formation may range from 10 000 to 15 000 pounds per square inch. This produces fissures in the reservoir and can open cracks in the shale up to 1000 m or more in all directions from the wellbore, which liberates trapped gas and allows the flow of gas into the wellbore and up to the surface.

HOW DOES THE MINING PROCESS WORK?

The process of unconventional oil and gas mining takes place in phases. First, it starts with the exploration phase, during which the presence of oil and gas, as well as the economic viability of extracting the resource is assessed.

Economic viability assessment usually requires in-situ well

Surina Esterhuyse

The Southern African Large Telescope outside Sutherland falls in a potential unconventional gas mining area.

A site abroad where refracking is taking place.

Barb de Luca

stimulation by means of hydraulic fracturing. After economic viability has been proven, the mining phase will follow during which oil and gas will be extracted by means of hydraulic fracturing and any other stimulation method that may be required.

In order to mine unconventional gas economically, economies of scale are used. Well densities may be as dense as required to make the venture economically successful. During the mining phase chemicals used for hydraulic fracturing, wastewater and brines from wastewater treatment should be properly managed. A well can be stimulated various times during its lifetime and when wells do not generate gas economically anymore, they are decommissioned during the post mining phase.

During this phase it is important to ensure proper well decommissioning, to perform continuous monitoring of water resources in previous gas mining areas and to ensure the long-term integrity of the decommissioned gas wells. The continuous integrity of decommissioned wells may pose a groundwater contamination risk over the long term.

Hydraulic fracturing itself, says Esterhuyse, as well as the activities associated with the different phases of unconventional oil and gas mining may result in various potential environmental and socio-economic impacts. These are uncertain and can range from positive to negative. Activities can include vegetation clearance during seismic surveys, trucking and storage of chemicals and fluids, wastewater and brine

The geographic area where unconventional gas mining may be practiced is not limited to only a few concession areas in the Main Karoo basin. Areas may also include Prince Albert and Carnarvon.

Surina Esterhuyse

management, installation of pipelines, gas compression and processing facilities.

Understanding that hydraulic fracturing is just one part of the unconventional gas mining process, and that impacts are associated with the whole mining process is just one of the commonly held misconceptions that the researchers encountered.

MORE COMMONLY HELD MISCONCEPTIONS

According to Esterhuyse, some of the most common misguided concepts are that the process only involves impacts related to the extraction of shale gas, when there are actually also differences between these and mining for coalbed methane. "Shale gas may require large volumes of water for fracturing operations while coalbed methane mining may produce large quantities of high salinity water, but may require less fracturing to stimulate gas," she says.

A second misconception is that environmental concerns are only related to water, when other aspects such as vegetation or socio-economics may also be affected during the process. "For example, if gas mining is not managed properly, it may lead to large scale fragmentation of landscapes and biodiversity and increasing social ills." Yet, it must also be understood that hydraulic fracturing can be done with gas and gels as well, which may limit the water requirements during fracturing operations.

Esterhuyse further cautions that the geographic area where unconventional gas mining may be practised is not limited to only a few concession areas in the Main Karoo basin. Rather, this mining method may be used anywhere within this basin and sub-basins where unconventional resources may occur.

People also need to understand that impacts from unconventional gas mining may occur on a regional scale and that these may be cumulative in nature, she says.

Lastly, it needs to be understood that unconventional oil and gas mining is fundamentally different from other mining types that have up to this stage been performed in South Africa. "Unconventional oil and gas resources tend to extend across much larger geographic areas and may consequently not be easily managed or regulated on a spatial or temporal scale."

PROJECT PROGRESSION

These insights stemmed from the production of the background review report, one of the first steps of the project. This information, together with the vulnerability map, will serve as a tool to be used by planners and regulators to aid in decision-making before allowing fracturing in certain areas. Esterhuyse cautions that it can, however, not replace local-scale studies that should be executed during exploration and mining licence applications.

Currently, they are in the process of identifying indicators or data sources that can indicate vulnerability for selected aspects. Baseline data on towns or regions that rely heavily on groundwater, regions in South Africa with high water-use demands, goundwater vulnerability and maps

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An example in Ohio, in the US, where a gas well has been constructed in close proximity to a residence.

There are more effects of unconventional gas mining than people realise, such as the clearance of large tracts of land.

Barb de Luca

showing sensitive river reaches will be included. Data sets on areas with special vegetation and demographic, health and socio-economic data (to identify, for example, health impacts) will also be added.

According to Esterhuyse, experts will be used to assist in the development of the vulnerability map throughout the mapping process. "Although this approach requires time and resources and is limited in its application and transferability to other regions outside South Africa, the integration of expert knowledge may significantly increase the usefulness and acceptability of the results," she says.

The eventual development of this map may take some time and it should be iteratively expanded as new data become available.

The main aim of the screening level monitoring protocol, again, is to identify the most important (screening level) entities or parameters that must be monitored during the different phases of gas extraction (pre-mining, during exploration, during mining and after mining). These will be relevant for groundwater, surface water, seismicity, vegetation and socio-economic aspects. "In this way it is hoped that the most important entities that should be monitored as allowed by the available time, money and resources of regulatory authorities, could be identified."

HOW DO WE PROCEED FROM HERE?

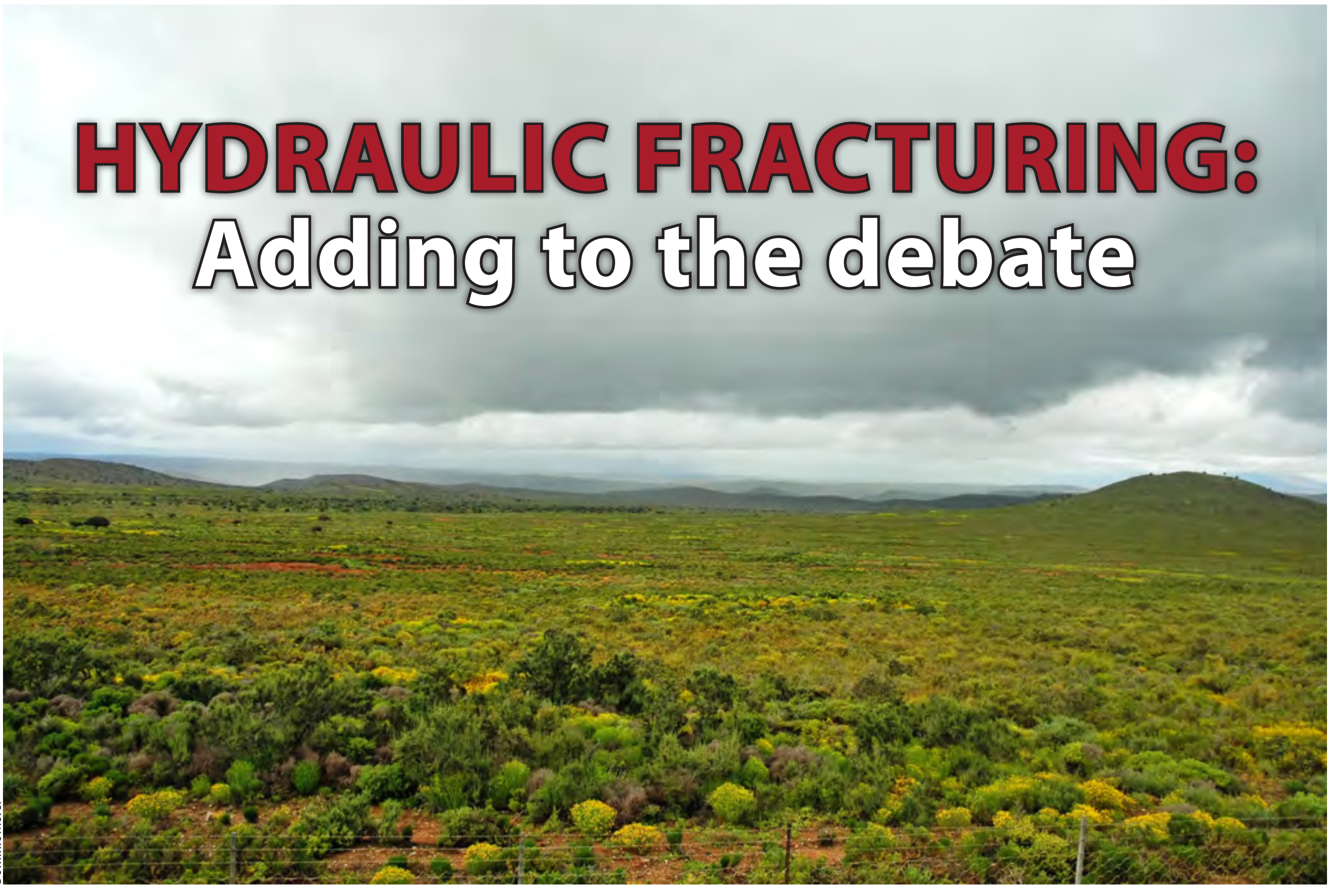
There is uncertainty at this stage on whether unconventional gas resources exist and if it would prove economically viable. Now may be the time to link economic benefits with environmental risks and industrial legacy. "We must assess whether proceeding with unconventional gas mining is acceptable on a long term strategic level, by identifying energy generation and job creation alternatives and performing a cost-benefit analyses on all these options."

Should unconventional gas prove to be economically viable and be a sound strategic energy generation option, proper management of unconventional gas would require a suite of management strategies, Esterhuyse continues.

Firstly, proper management of this activity could only be achieved by strategic planning on a regional scale, in order to avoid unintended long-term negative consequences on a spatial scale (between different geographic regions) and on a temporal scale (like groundwater contamination that is only identified years after the event). Understanding the capacity of a region, and subsequently determining the capacity for development in this region without crossing landscape limits, would be required. A vulnerability map could be a first step to help identify such landscape limits, says Esterhuyse.

Regional strategic environmental assessments as well as integrated catchment management may also prove useful. A transparent and consistent regulatory framework, that regulates unconventional gas mining activities in a coordinated fashion between local and national scale, should also be developed. ❑

HYDRAULIC FRACTURING: Adding to the debate



Dominic Morel

A solicited study funded by the Water Research Commission (WRC) looks at what we know about hydraulic fracturing, and what we should know if this is allowed to go ahead in South Africa. Article by Petro Kotzé.

Since the announcement that gas exploration might take place in the Karoo, the topic has caused both elation and concern – often placing polarised opinions directly opposite to each other. On the one hand, there is the prospect of job creation and a reduced dependency on coal-generated electricity. On the other, concern has been raised that the process could pollute already scare water supplies and the pristine way of life in the Karoo.

Lack of scientific proof to back-up claims on any side of the fence has fuelled the confusion. A recent WRC report aims to fill at least some of these gaps by looking at what we currently know about the process of hydraulic fracturing, and what could happen should the process take place. Led by Prof Gideon Steyl, research fellow at the Institute for Groundwater Studies (IGS) and a Professor in Chemistry, the key issues that the report focuses on are the shale gas reservoir potential in the main Karoo basin as well as other potential areas of interest; the location relative to and relationship between the shale gas reservoirs and the Karoo aquifer systems; and the potential impacts associated with hydraulic fracturing and accompanying processes. The research group also consisted of Prof Gerrit van Tonder, Professor in Geohydrology at the University of the Free State and Dr Luc Chevallier of the Council for Geoscience.

Prof Steyl is careful to point out that the observations and findings made are neither totally comprehensive nor exhaustive, since little data is available in the public domain on hydraulic fracturing in South Africa. "We are being honest about what we know and don't, know" he says. To shed some light on the matter Prof Steyl was one of a group of researchers that visited the Marcellus shale area in the USA, where hydraulic fracturing is currently taking place. Sites visited included the Pennsylvania drill rig in Whitneyville, the fracking rig in Grover, the wellfield north of Whitneyville, the Williamsport Municipal Water Authority and the Unites States Geological Survey (USGS) office in Harrisburg.

WHAT IS IT?

Shale gas is defined as gas generated from organic-rich shale. The target gas is methane, which is an energy source and can be used for the production of fuels or as a power

Courtesy Gideon Steyl

Above: *A drilling rig near Whitneyville, which was one of the sites in the USA that researchers visited for the recent WRC research project.*

Below: *A clearing in the State of Pennsylvania (USA) where the pipeline for the hydraulic fracturing is running.*

source for electricity generation. Methane is a dry gas and represents the final stage of hydrocarbon thermal maturation.

Organic-rich shales were originally muds deposited in marine or lacustrine basins, the organic material being derived mostly from algae, spores and pollen. These muds became buried and lithified over millions of years and generated various hydrocarbons with increasing depth of burial. Between two and four kilometres burial depth, oil is produced, between four and five, wet gas is produced and between five and six, dry gas, including methane, is produced. Deeper burial, such as what happened in the Bokkeveld Group (for example) results in low-grade metamorphism, the termination of hydrocarbon generation and the formation of graphite from the organic material. Deep core samples in the main Karoo Basin indicate that the Ecca Group shales have potential to generate dry gas south of approximately latitude 29°S.

Here, the Whitehill Formation contains the highest total organic carbon contents and presumably has the highest potential for generating dry gas. The most promising area to source gas from the Whitehill Formation is south of the southern limit of dolerite intrusion, but north of the Cape Fold Belt. In the region south-east of a line from Ficksburg to north of Laingsburg, where the top of the Lower Ecca Group is deeper than the minimum proposed depth of 1 500 m for hydraulic fracturing, shale with the best potential for dry gas lies in an east-trending zone between 30 km north of the southernmost exposures and 50 km north of the southern limit of dolerite intrusion.

These dolerite intrusions, says Prof Steyl, is what makes the South African geology unique, especially in comparison to areas where shale gas occurs in America. The intrusive dolerites are present over about 390 000 km^2 of the main Karoo Basin underlain by the Ecca Group (which increases the thermal maturity leading to the generation of dry gas). This causes gasification of the carbon in the shale that can only lead to gas being vented or being trapped in the sub-surface, potentially making it unavailable for hydraulic fracturing.

It is important to keep in mind that researchers only have a relative idea of the area's geology, "not an absolute" says Prof Steyl. The only way to get a clearer idea is by exploration and, he adds, even though some exploration has taken place in the area, it has not been comprehensive enough to create a clear picture of what exactly is to be found under the surface of the Karoo Basin.

Courtesy Gideon Steyl

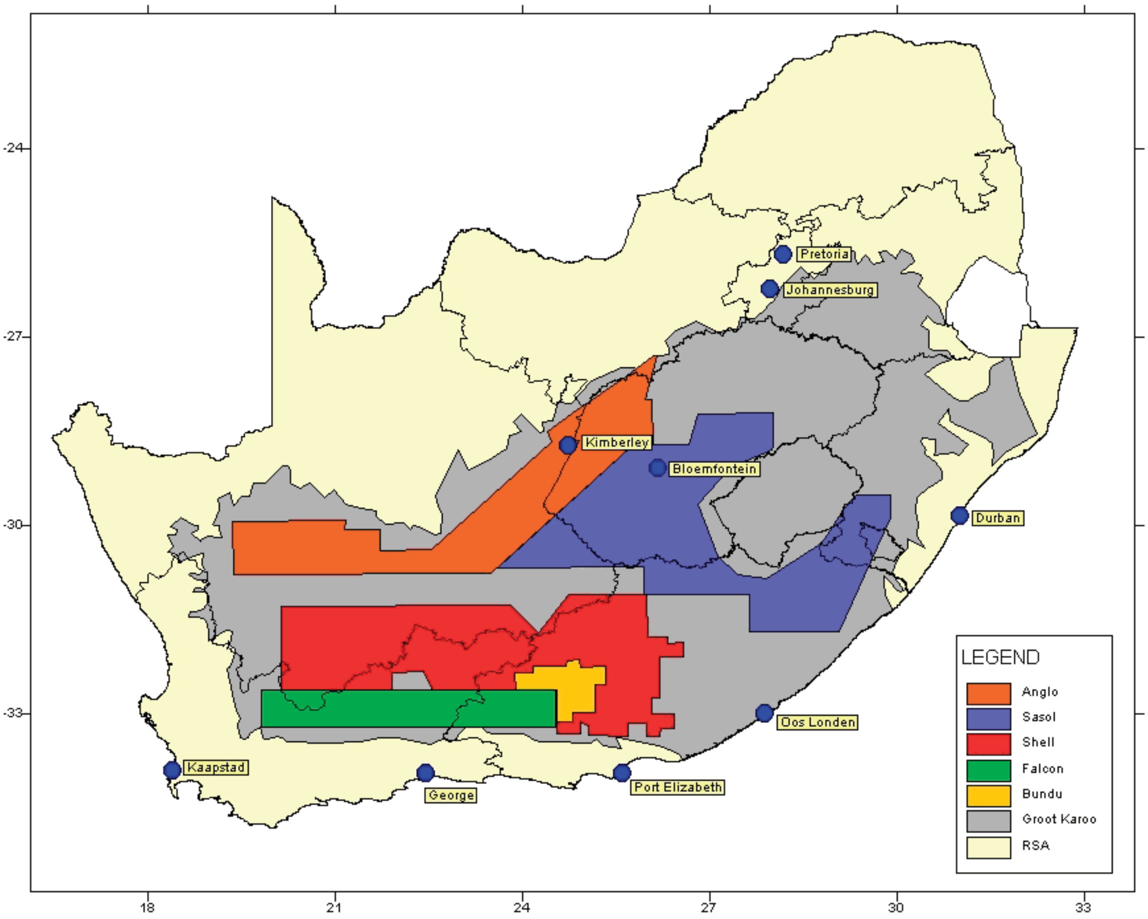
HOW IS IT DONE?

During the hydraulic fracturing process, drilling starts vertically, with casing installed until a depth where all viable aquifer systems (potable water) cannot be affected. Drilling is continued for a few meters and cement pumped into the casing, until the space between the wellbore and the outer casing is entirely filled with cement.

As the vertical drilling is continued intermediate casing is inserted to stabilise the deep borehole. This also serves to isolate and separate brines and hydrocarbons which might be trapped in the sub-surface, preventing borehole interference, natural gas contamination and protection of surface aquifer systems.

At the kick-off point drilling techniques are applied to force the drilling to occur in a horizontal direction through the production zone, which can stretch for as much as three kilometres. Once the horizontal borehole has reached its target extend, production casing is installed and cemented into place to prevent leaking. Subsequently the production casing is punctured at selected

There are currently a number of companies that have exploration rights to investigate natural gas resources in Karoo type formations. The area available for natural gas development is substantially larger than just the Karoo, with exploration areas covering six of the nine provinces in South Africa. A five-spot pumping test in the Waterberg has been operated since 2004 by Anglo Operations and 20 boreholes have been drilled in the main Karoo since the beginning of 2008 to test for coal-bed methane production potential. Most of the exploration rights for natural gas resources have been allocated for shale gas development.

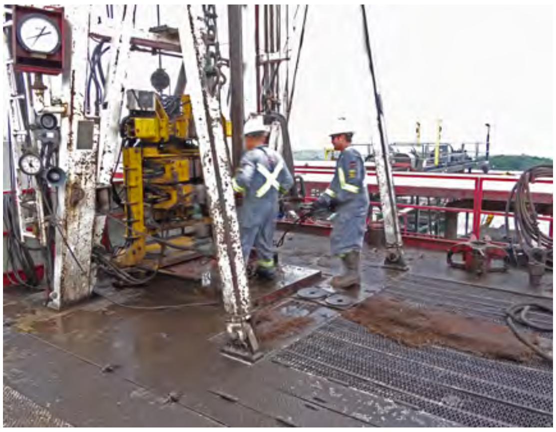


points where fracturing fluid will be pumped through at increased pressures to release the shale gas. This method (hydraulic fracturing) is commonly used to enhance the production of low permeability formations such as tight sands, coal beds, and deep shales.

The chemical composition of the fracturing fluid, as well as the rate and pressure at which it is pumped into the shale, are tailored to the specific properties of each shale formation and, to some extent, each borehole due to differences in

'Fracking' can be a confusing term since the term actually implies two very different processes. Hydro fracturing refers to the process of fracturing with water only, while hydraulic fracturing refers to fracturing using water with a chemical mixture.

The main concerns regarding the possible impacts of hydraulic fracturing on the environment (main concerns indicated in red).



Courtesy Gideon Steyl

Courtesy Gideon Steyl

Below: *A hydraulic fracturing operation with a Christmas tree blow-out preventer system in the middle of the picture, while the chemical components delivery system is on the right-hand side and one perforation transport truck is stationed on the left-hand side.*

Top: *Hydraulic fracturing drilling operations taking place at Whitneyville.*

Above: *The water containment facility on a hydraulic fracturing site consisting of 56 large containment vessels.*

Courtesy Gideon Steyl

volume. When the pressure increases to a sufficient level, it causes a hydraulic fracture to open in the rock, propagating along a plane more or less perpendicular to the path of the borehole direction.

There are a number of concerns regarding hydraulic fracturing, of which eleven were identified in the report. Should the process be approved, regulation to prevent environmental damage is the most important success factor, says Prof Steyl. A major concern in natural gas development is the prevention of migration of gas or other fluids out of the reservoir and into overlying strata, particularly fresh water aquifers. In cases where this has occurred, according to the report, it has been the result of well construction problems and not of hydraulic fracturing itself.

Water use, especially in a water-scarce area like the Karoo, is another major distress factor. A fracture treatment of a typical Antrim gas well, as located in Antrim, Michigan requires about 50 000 gallons (189 m^3) of water. This amount can increase to as much as 5 000 000 gallons (18 927 m^3) or more, the same amount typically used by eight to ten acres of corn during a growing season.

Proper management of produced water is particularly essential in protecting public health and the environment, says Prof Steyl. In Michigan, for example, produced water must be managed and disposed of according to strict rules.

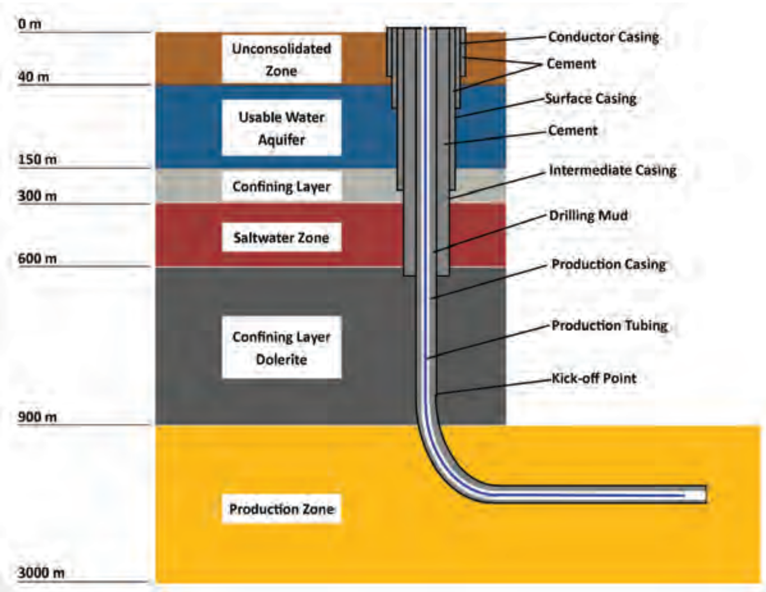
Accept for these three concerns, identified as the most probable points of impact, other main issues include the migration of gas, the management of produced water and the identification of chemical additives. Spills of chemical additives or flowback water can have adverse environmental or public health impacts.

The application of good management practices would significantly reduce these events from occurring. Additionally, monitoring by the regulatory body would ensure a continuation of good practices and, notes Prof Steyl, the monitoring team must be independent from the State, even though fines would be paid to the State. Ideally, such a team must consist of water, terrain and drilling specialists.

RECOMMENDATIONS

The most important conclusion from this report is regulation," stipulates Prof Steyl. "What is pumped in and out, the remediation and handling of the terrain and even water purification should be closely monitored."

For example, Michigan's laws and rules effectively protect water and other natural resources as well as public health and safety from potential adverse effects of hydraulic fracturing. Their Department of Environmental Quality has more than 50 staff employed in enforcing these state requirements and is taking a proactive approach in addressing large-scale hydraulic fracturing as well as other issues associated with



Courtesy Gideon Steyl

Left: *A conceptual model of borehole drilling arrangement for gas exploration.*

Bottom left: *The production facilities during the remediation of the site. Additional water containment facilities are shown in the background which will be removed before full production commences.*

Below: *A pond facility on site with geotextile liner and moundings. The research report recommends that these facilities should not be used in the South African environment.*

deep shale gas development.

Should the hydraulic fracturing process be used and allowed by the government of South Africa, the most critical recommendations to be followed are:

- No chemicals should be injected into the boreholes without full disclosure of the type of compound used.
- Waste pits should be avoided as far as possible.
- Drilling should be conducted at least 10 km from any residential areas.
- Drilling logs should be filed at the Department of Water Affairs (DWA) and Department of Environmental Affairs (DEA), and should be publically available within six months of drilling completion.
- Only best-practice guidelines should be implemented.
- A pilot study should be done a year in advance in which a monitoring network of boreholes (both shallow and deep) is installed to monitor the impact of hydraulic fracturing on the area.
- A baseline should be constructed before any drilling is done in an area, and should include atmospheric, soil, surface water and groundwater (isotopes, macro, micro and metal species) environments. It should be filed at the DWA and the DEA, the results verified by an independent body and the data be made available to the public (this is one of the greatest drawbacks in the international arena).
- All associated drilling footprints, including return water containment structures should be fully remediated to natural levels before the contractor is allowed to leave the site.
- Wastewater containers should be used to store and transport wastewater from the site to a suitable water treatment plant that can correctly purify the water.
- Strict legal licensing restrictions should be applied by the government in which the licence for drilling is leased to the drilling company.

Nevertheless, many questions remain. It is still unknown what the potential for shale gas extraction is or what the effect of our unique geology will be on such a project. A pilot study which involves exploration and drilling by an independent body of researchers could be an answer, concludes Prof Steyl.

To order the report, *State of the art: Fracking for shale gas exploration in South-Africa and the impact on water resources* (**WRC Report No. KV294/11**) contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565, Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy. ❑

Courtesy Gideon Steyl


Guy Stubbs/Africa Media Online

Breaking our (bad) management habits – Global project advocates for change

As the 2014 United Nations (UN) Millennium Development Goal deadline looms, relieving the plight of those millions of poor people without access to safe water is becoming ever more urgent. Groundwater can play an important role in local water supply. The secret, according to a present international multi-organisational project, lies in the way we manage our underground water resources. Article compiled by Lani van Vuuren.

Over the past 50 years, rapid population growth, increased urbanisation and unsustainable water use practices have placed enormous pressure on global water resources. Groundwater is playing an increasing role worldwide in human development and well-being, in particular in developing countries.

The ability of these underground resources to continue supplying our water needs is linked closely to the state of groundwater governance – the local, national and even international arrangements that directly impact groundwater use and aquifer pollution. International reports are that we are not taking very good care of this important resource, however. It is perhaps its inherent 'hidden' nature that still causes groundwater to not be included fully in decision-makers' plans and policies for water management, use and protection.

The Groundwater Governance Project is a three-year initiative (2011-2014) designed to address emerging global concerns on groundwater resources management. The overall project objective is to increase awareness of the importance of sound management of groundwater resources in preventing and reversing the global water crisis. The intention is to identify and promote best practices in groundwater governance as a way to achieve the sustainable management of groundwater resources.

Specifically, the project will develop a Framework of Action that is expected to catalyse policy reform and institutional strengthening at the global and national level in relation to groundwater resources. Funded by the Global Environment Facility, the project is being executed jointly by the UN Food and Agriculture Organisation, the UN Educational, Scientific and Cultural Organisation (UNESCO), the World Bank and the International Hydrogeological Association (IAH).

An integral part of the project has been a set of regional consultations used to acquire first-hand knowledge of regional issues from local groundwater experts. Among other South African organisations and institutions, the Water Research Commission has been involved in the sub-Saharan African regional consultation process.

Speaking at the African regional consultant event held in Kenya last year, Dr Rafik Hirji, of the World Bank stated the following on the importance of effective groundwater management for Africa: "Groundwater is emerging to be a strategic development issue for Africa. Hydrogeologists, groundwater managers and researchers have been aware of the emerging threat to groundwater resources, but until recently the wider community has focused neither on the creeping 'silent revolution' – a term coined to highlight the rapid development of groundwater that is largely unplanned, unmanaged and unregulated – nor its broader poverty alleviation potential."

"Given its important role in urban development, water supply, food security and climate change adaptation, and its broad poverty implications, groundwater is simply too big a development issue to be allowed to fail," he added.

GLOBAL GROUNDWATER FACTS

- Some 2,5 billion people depend solely on groundwater to satisfy their daily needs for water.
- Groundwater supplies around 43% of all water consumed in irrigation.
- Aquifers offer an important buffer by making water available even during long periods without rainfall.
- Groundwater systems constitute as much as 98% of all freshwater in liquid form.
- The top five groundwater extracting countries are India, China, USA, Pakistan and Iran.

Source: Groundwater Governance Project

IMPORTANCE OF GROUNDWATER IN AFRICA

Investigations on the availability and use of groundwater in Africa have revealed just how important this resource is to sustaining the livelihoods of people on the continent, and what potential it has to augment existing supplies. Recent studies led by the British Geological Survey and funded by the UK Department for International Development (DFID) have provided new information on the extent and potential of groundwater as a way to support development and even help buffer the potential impact of climate change.

The study produced the first set of quantitative continent-wide maps of groundwater available for Africa.

Investigations indicate that the continent has a total underground water storage capacity of around 0,66 million km^3. While not all of this groundwater storage is available for abstraction, the estimated volume is still more than 100 times the estimates of annual renewable freshwater resources in Africa. The largest aquifers are situated in northern Africa.

According to DFID, there are four main hydrogeological environments in sub-Saharan Africa. They are:

- Crystalline basement rocks, which occupy 40% of the land area of Africa;
- Volcanic rocks, which occupy 6% of the land area;
- Consolidated sedimentary rocks, which occupy 32% of the land area; and
- Unconsolidated sediments, which occupy 22% of the land area.

> **"Given its important role in urban development, water supply, food security and climate change adaptation, groundwater is simply too big a development issue to be allowed to fail."**

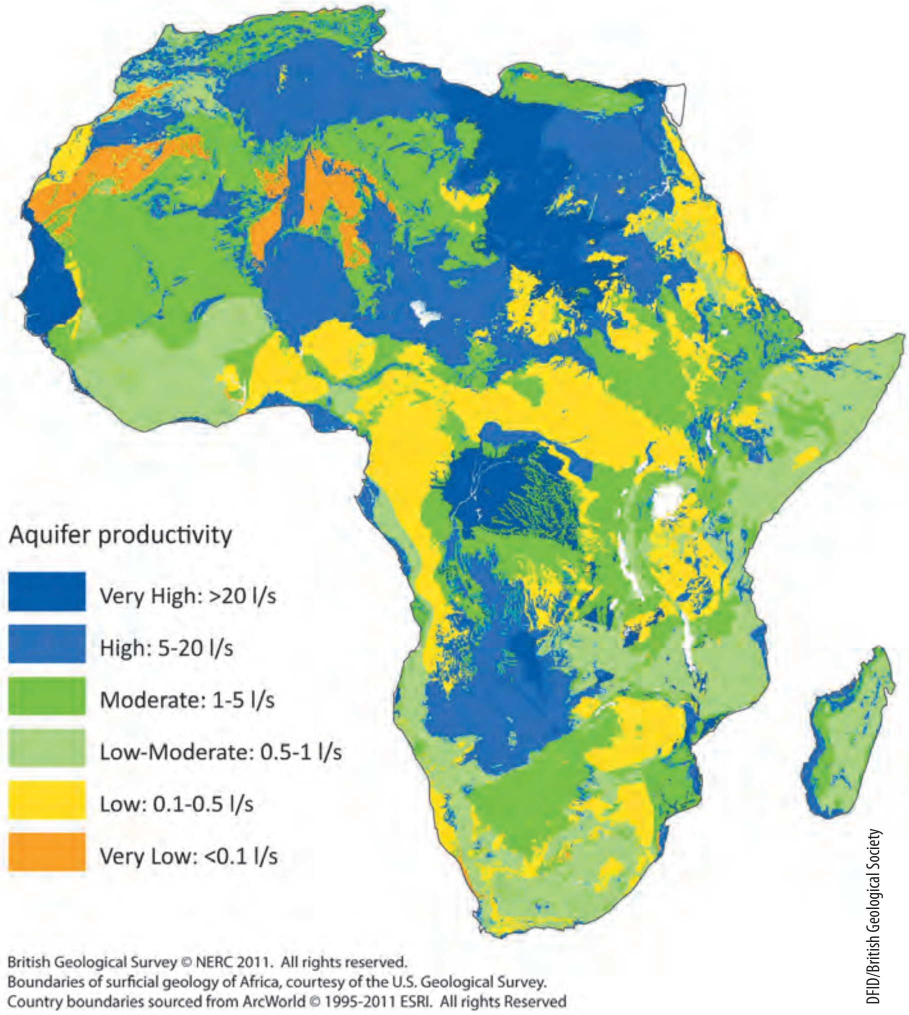
Over much of Africa, groundwater is the only realistic water-supply option for meeting especially dispersed rural demand. Most African countries rely to a large extent on groundwater for their drinking water supply, ranging from shallow hand-dug wells to deeper public supply boreholes. Overall, it is estimated that 75% of the African population is using groundwater as a main source of supply.

It is also reported that groundwater supplies are adequate for village subsistence level cropping – critical to the improvement of food security at local scale – stock watering and other local productive needs, such as brick-making. Most importantly, the different types of aquifers that occur through Africa can provide the much needed balancing of storage during times of recurring droughts and to migitate the expected impacts of climate change.

Studies indicate that groundwater in Africa is particularly resilient to climate change. Shallow groundwater in the continent has a residence time of several decades (measured by the age of the water in the aquifers) and so is a useful buffer against short-term climate variability and particularly drought.

A serious concern throughout the region, however, is the unsustainable implementation of rural water supplies. Many of the problems indicated have to do with lack of involvement of the local population. This includes poorly designed boreholes, poorly sited boreholes, inadequate maintenance, single use design versus actual

Aquifer productivity in Africa



DFID/British Geological Society

multiple use and lack of water.

The urban explosion is creating particular challenges, among the most pressing the need to provide safe water and sanitation. It is in these large unserved areas that groundwater is already playing a major, but mostly unrecorded role. Groundwater experts are calling for groundwater's role to be formalised, be it as a bridging supply, conjunctive or sole source.

Groundwater pollution is highlighted as a particular concern as a result of unplanned urban development and lack of management, with pollution of groundwater sources beneath African cities as well as in many rural communities reaching critical levels.

GROUNDWATER GOVERNANCE ISSUES

The Groundwater Governance Project has identified several principles that together can improve the way in which groundwater is being governed. The first is the issue of sustainability. A more informed appreciation of how governance arrangements can be used to manage or relax aquifers under pressure is called for. This will involve quite subjective criteria as to what social, economic and environmental consequences are acceptable for a particular system of groundwater supply and use.

The second principle is that of transparency. It is believed that access to clearly presented information is a fundamental pre-requisite for effective groundwater monitoring and reporting. Thirdly, decision-makers need to actively engage with groundwater stakeholders at aquifer scale. It is also important that groundwater users and polluters are visible.

Fourth is the principle of accountability. It is just as important to stress the social and economic benefits of groundwater use as it is to account the costs or consequences of use.

Groundwater management needs to be clearly integrated with water policy and management processes. The precautionary principle is also advocated for sustainable groundwater management.

Lastly, the principle of knowledge management is highlighted. A common plea made to hydrogeologists from non-hydrogeologists is that more could be done to popularise groundwater information and groundwater dynamics. While it is accepted that basic aquifer system behaviour in relation to supply and demand still has to be modelled to fully appreciate storage depletion in particular, these sophisticated interpretations need to get across to groundwater users to the point where groundwater use is moderated and aquifer protection can be advanced.

It is hoped that the Framework of Action to emanate from the project will do much to raise awareness of the importance of groundwater and catalyse policy reform to improve the way we view and use our precious groundwater resources.

To learn more about the Groundwater Governance Project Visit: www.groundwatergovernance.org

Photothèque Société des Eaux de Marseille

It is estimated that up to 75% of the African population is using groundwater as a main source of supply.

Groundwater is a crucial water sources, especially in rural areas.

Drinie van Rensburg

Groundwater and surface water interaction: FROM THEORY TO PRACTICE

All photographs courtesy of IGS

Historically, groundwater (GW) and surface water (SW) have been viewed, and managed, as two separate entities. Most water resource management plans focus on the latter, but the constant development of land and water resources has made it clear these systems affect each other both in resource quantity and quality. Article by Petro Kotzé.

Recent research has shown that development is not the only reason why it is important to understand how surface water and groundwater interact. Climate change is likely to affect the availability and distribution of both, so increasingly this interaction is playing a bigger role for water resource management.

In the simplest terms, if we don't know if, and how much water infiltrates from a river into an aquifer, we don't know how much water to allocate from the river to a particular user. In a water-scarce country like South Africa, explains Prof Gideon Steyl, research fellow at the Institute for Groundwater Studies (IGS) at the University of the Free State, we might increasingly have to look towards groundwater as a sustainable source of water. If this is the case, knowledge of the interplay between these systems is imperative.

In order to understand the mechanisms of this interaction, observational data is integral but, lacking in South Africa. Even more so, the available data is mostly segmented into purely atmospheric, surface hydrology or geohydrological data for specific areas. Mostly, no significant overlap exists between the surface and sub-surface hydrological data in order to ascertain a relationship between these two systems. Up until now, there has also not been a local test-site to rectify the situation.

Fortunately, this state of affairs is changing. Researchers from the IGS are tackling a multi-disciplinary project, investigating the multiple processes involved in surface water and groundwater interactions. These include surface hydrology, evapotranspiration, geohydrology and vadose zone hydrology (also known as the unsaturated zone, it is the portion of Earth between the land surface and the zone of saturation). The three-year study, which started earlier this year, is focusing on gathering all available data necessary to enable the group to identify important processes and field measurement methods. This knowledge can later be applied to more test sites.

"In the long term, it is hoped that the data will be developed into a set of 'checkpoints' that can be used by water resource managers to determine the amount of water that is available for use in a system."

A UNIQUE APPROACH

The study area is situated close to the Krugersdrif Dam in the Southern Free State, between the R64, S264 and the S328 roadways. Underlain by Beaufort Group formations with dolerite dykes intruding in certain areas, it is intersected by the Modder River from an easterly to a westerly direction. Flow in the river is controlled from the Krugersdrif Dam sluice gates, either at regular intervals or if water levels drop significantly downstream.

This is the ideal site for a number of reasons, explains Prof Steyl, who is leading the study. Among others, water seeps freely from the surrounding formations into the river at some places, which indicates that there is movement of groundwater into the river system. The area has escaped relatively unscathed from pollution and overdevelopment and also features a shallow water table.

The study covers the river, the riparian and background zones, and brings together specialists in the areas of surface hydrology, evapotranspiration, geohydrology and vadose zone hydrology. Prof Steyl adds that he also aims to involve a geophysicist (who, through the use of magnetic measurements of the area, can establish a well defined concept of the interaction of the dykes on the subsurface movement of water in the study area). Funded by the WRC, with support from the IGS, Department of Water Affairs (DWA) and local farmers and property owners, it is the first study of its kind to merge this variety of disciplines. In essence, the data will sketch a complete picture of all the elements involved in the interaction between water in the atmosphere, groundwater and surface water.

In order to obtain this data, the project involves a number of tests and observation locations. Firstly, boreholes are drilled in triangles, enabling participants to determine the local gradient in the riparian zone and the general area on both sides of the river. To date, researchers have constructed 40 holes, in two areas of about 4 km x 2 km and 1 km x 2 km. The holes are also of different depths so that both the surface and deep aquifer system can be characterised to determine if the river system is connected directly with the riparian zone or general area.

Prof Steyl explains that the next step is chemical analysis of water from the boreholes and river. Tests include macro- and micro-chemical analysis and, in a novel approach, isotopes, "something that's a bit unusual for us," he admits. The adage of this method enables them to pick up if a substantial volume of water from certain boreholes ends up in the river.

Researchers will furthermore apply geophysics (down-hole investigations and profiling) to establish local geological features and borehole characteristics, as well as pump tests to determine both local and regional hydraulic properties. An added advantage is that knowledge of the Free State's rock formations and isotopic composition will be gained, as not many of these types of studies have been done in that specific area. Further research includes the monitoring of the water levels in both the river and boreholes over a

The study area is situated close to the Krugersdrift Dam in the southern Free State.

Above: *(From left) Prof Gideon Steyl of the Institute for Groundwater Studies at the University of the Free State on site with PhD student Modreck Gomo and MSc students Khakliso Leketa and Shakhani Teboho.*

Right: *Dr Eddy van Wyk of the Department of Water Affairs inspecting a dolerite dyke showing the fractured zones in the rock face at the western site.*

few years (to determine fluctuations due to seasonal changes and river flow volumes).

Then, the unsaturated zone will be studied. This entails a soil profile analysis and determining the infiltration rates at the specified sites. Prof Steyl adds that there are many ways in which water can move through this zone. The techniques to be applied include physical measurements of how water moves through this zone, and through to the aquifer when it rains. Porous cups will be used not only to evaluate the flow of water in the subsurface, but also the chemical composition as it drains to lower levels. A second method will include geophysical methods. These rely on, among others, capacitance and resistivity of the subsurface environment. The project team has already had some success during the heavy rainfall that the area experienced during the study. "If we can get this aspect of the project right," notes Prof Steyl, "we will definitely have world-class data available."

Once the geophysical data are added, the team would theoretically have a 'picture' of all the elements at play in the aquifer. This is then combined with evaporation and climatic (analysis of the rainfall and temperature fluctuations at the river and background area) data.

In addition, the site is used as a training ground for post-graduate students at the IGS. Two students have already completed their MSc theses on the project, while it is expected that at least 60 geohydrologists (training and active in the field) will visit the site over the duration of the project. It is also expected that personnel from the DWA will visit in order to assist with the development of regional management plans during the course of the investigation.

RISING TO THE CHALLENGE

A study of this nature is not without its challenges. Indeed, one of its biggest strengths counts among them. "Analysing and interpreting the results in way that all the different parties agree on is easier said than done," admits Prof Steyl. In addition, correctly determining the recharge potential in the unsaturated zone, and obtaining sensible hydrological data (Prof Steyl's background is in chemistry and geology) is not easy.

He also admits that the research area is small, and that the data are very site specific. The evapotranspiration data, for example, are dependent on the types and distribution of flora on the site. It is thus hoped that the study might be continued for a further three years, in order to apply the mechanisms defined in the current study areas to other areas. Eventually, Prof Steyls and his team want to apply the results to areas representative of every groundwater and surface system. In the long term, it is hoped that the data will be developed into a set of 'checkpoints' that can be used by water resource managers to determine the amount of water that is available for use in a system.

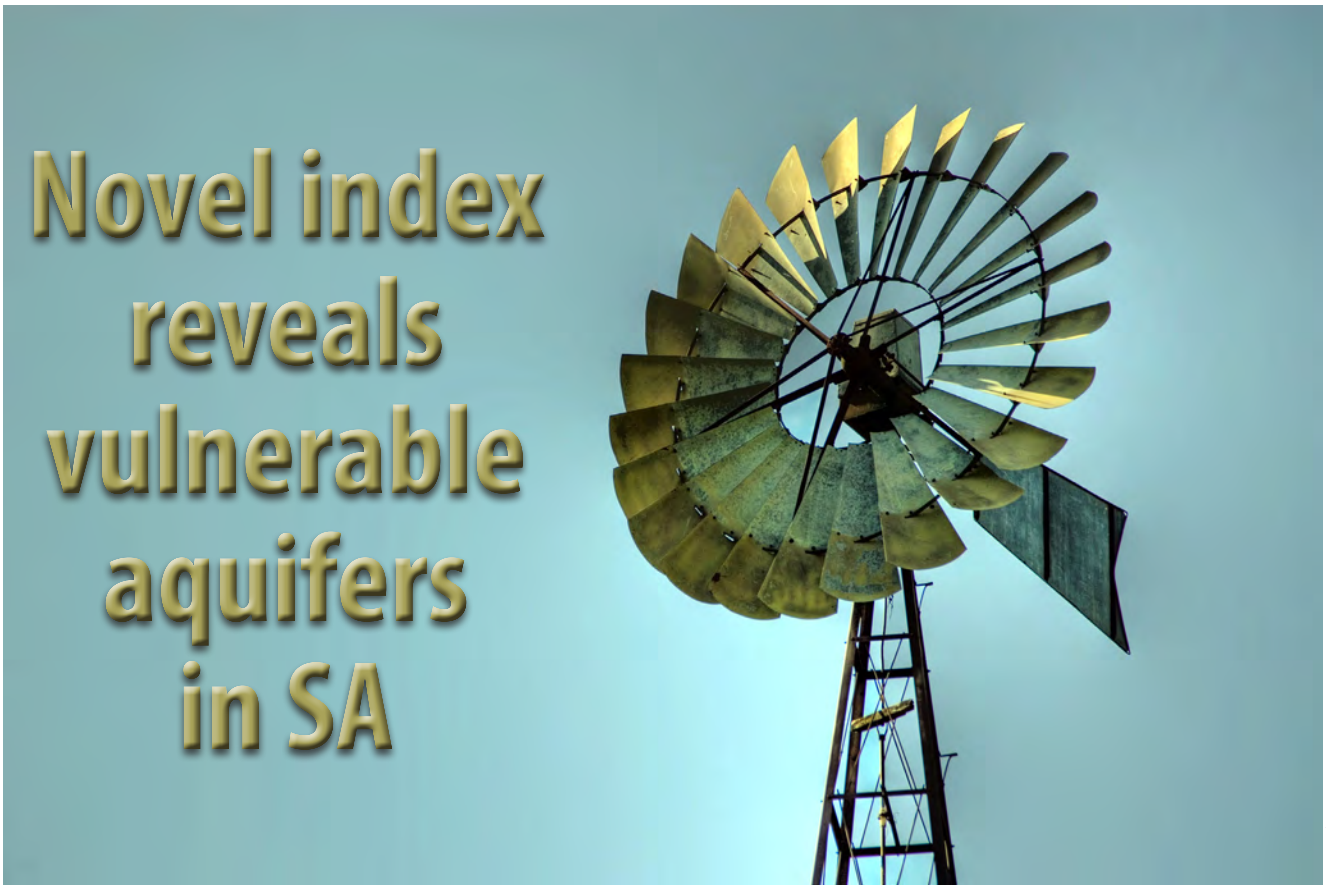
The project has already yielded interesting results in the geohydrology arena, which might have remarkable consequences for water resource management. Among these, notes Prof Steyl, are that the two sides of the Modder River are completely different worlds, not only geologically and chemically, but also isotopically. For example, while the one side of the river consists of basic sand formations, the other is made up mostly of chalk. Furthermore, it looks as if the river comes down much slower on the one side than the other.

Without a doubt, a study of this unique nature will continue to generate exciting results, not only for the researchers involved, but for those involved in water resource management who will eventually apply the results. Possibly more important is that it is the first step in the right direction, and that the generated data will go a long way towards filling a worrying gap that currently exists in the area of groundwater and surface water interaction. ❑

Top left: *The study site is intersected by the Modder River from an easterly to a westerly direction. Flow in the river is controlled from the Krugersdrift Dam sluice gates.*

Middle left: *Water seeps from the surrounding mudstone formations into the river, which indicates that there is a movement of groundwater into the river system.*

Bottom left: *MSc student Khakliko Leketa collects borehole samples for further lab analysis at the University of the Free State Soil Analysis Laboratory.*



www.sxc.hu

Novel index reveals vulnerable aquifers in SA

The potential impact of climate change still leaves more questions than answers. One area of research that is only now being explored is the potential effect of a changing climate on South Africa's groundwater resources. Article by Lani van Vuuren.

The United Nations Conference on Climate Change or COP17, held in Durban during December 2011, again emphasised the challenges South Africa faces in adapting and mitigating against the potential effects of climate change. South Africa already is a water scarce country and, while the exact nature of our future climate remains uncertain, further changes in respect of water availability as a result of changing rainfall patterns, extreme weather events and increased evaporation are predicted.

The potential impacts of climate change on water resources and hydrology in southern Africa have received considerable attention from hydrologists during the past decades. In areas such as the western parts of the country, where rivers are expected to become potentially drier in future, alternative sources such as groundwater have been put forward to keep up with future water demand. Yet, while groundwater forms an inextricable part of the hydrological cycle and is bound to be potentially impacted by shifting climate patterns in the same way as surface water resources, hardly any research has been done on the subject to date.

"The question of the likely impact of climate change on renewable groundwater resources is highly relevant," explains Dr Rainier Dennis of the Centre for Water Sciences and Management at North West University. "Climate change can potentially affect groundwater levels, recharge and groundwater contribution to the baseflow of rivers."

One possible reason for the dearth of knowledge regarding the potential impact of climate change on groundwater is that such studies normally require extensive time series records. "Traditionally, hydrological records are more easily available due to the fact that the resource is visible as opposed to groundwater," explains Dr Dennis. "The longest South African time series record with respect to groundwater levels does not exhibit any behaviour that can conclusively be attributed to any form of climate change."

REGIONAL INDICATOR

Dr Dennis and his research team have now successfully developed a regional screening tool with funding from the Water Research

Commission (WRC). This is seen as a first step in assessing the impact of climate change on South Africa's aquifers on a regional scale. "Aquifer recharge and groundwater levels interact, and depend on climate and groundwater use," explains Dr Dennis. "Each aquifer has different properties and requires detailed characterisation and eventually quantification."

The so-called DART methodology uses different parameters (**D**epth to water level; **A**quifer type (storativity), **R**echarge and **T**ransmissivity) to come up with an index that serves as a regional indicator of areas that are potentially vulnerable to the effects of climate change with respect to groundwater. Datasets of each parameter are generated over the whole of South Africa for the generation of this index for every month of the year for a certain climate change scenario.

The team considered two scenarios – one current and one future. The current scenario is representative of present precipitation patterns while the future scenario is representative of the predicted scenario based on a selected global circulation model (GCM). The future scenario selected assumes a moderate to high growth in greenhouse gas concentrations. GCMs are the primary tools for the projection of climate change from which data is downscaled for specific regions. The downscaled datasets for this project were made available by the Climate System Analysis Group at the University of Cape Town.

At first, it does not seem as if the country's aquifers will be that vulnerable to the potential effects of climate change. However, a closer look at the index reveals a different tale. "If the annual average change in the DART index is calculated then we do not see such a big variation in figures," notes Dr Dennis. "However, the index does show a substantial change for certain areas if one examines the results per month for the scenario tested. This implies that groundwater in affected areas will be more vulnerable in certain months than in others. Detailed studies on local scale will have to be performed, however, to verify that vulnerability can be managed."

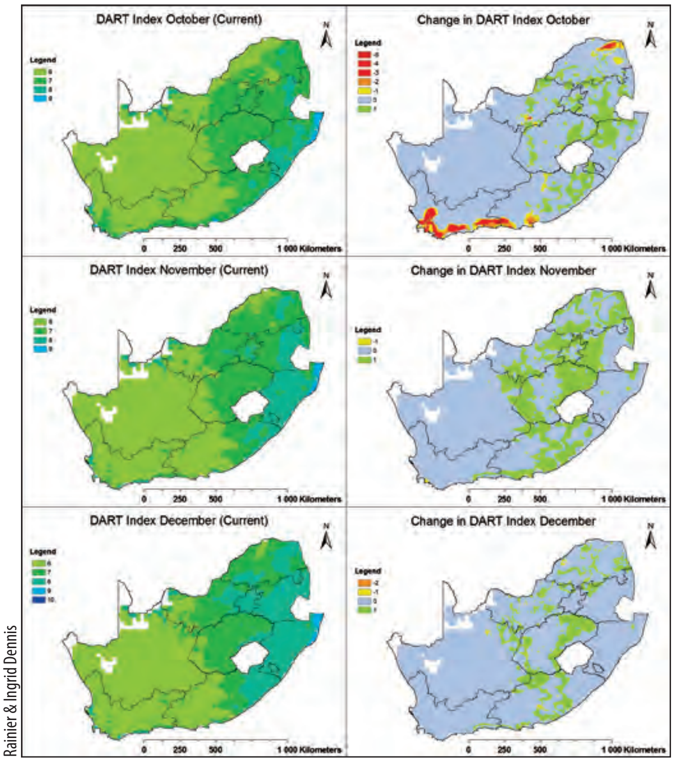
By far the greatest challenge of the project was the lack of available groundwater data. The availability of regional data to support the DART index was a major consideration in the selection of parameters. "Initially the index calculation required more parameters than the current four that are being used, but in the end we had to simplify the calculation based on the dearth of available data," Dr Dennis tells *the Water Wheel.*

SUSTAINABLE MANAGEMENT

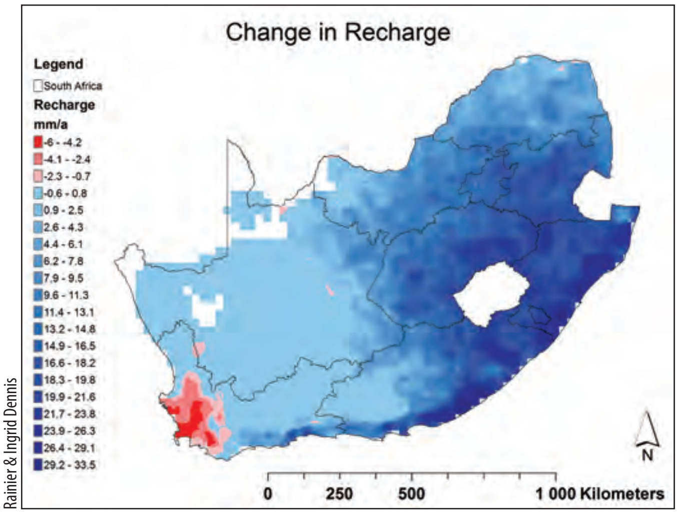
Regardless of the future climate scenario, for groundwater to remain a reliable resource it has to be sustainably used and managed. "Sustainable management, in turn, is based on sound monitoring of the resource," says Dr Dennis. "It is quite simple to verify if a borehole is being used in a sustainable manner if long-term water level measurements are available. Therefore we encourage all groundwater users to undertake regular water level monitoring as a general rule of thumb."

More research is required to say for sure if and how South Africa's groundwater resources will be affected by climate change. Due to the current lack of groundwater monitoring records, present research is dependent on the output of climate change models to produce possible future scenarios. There are quite a number of climate models available, each with its own suite of potential climate change scenarios. To complicate things further the output of these models are downscaled to the area of interest. This introduces a whole lot of uncertainty with respect to which model and which scenario to use. "Methodologies developed around climate change can be tested with various scenarios but we need more certainty as to which scenario we can expect for us to appropriately react to the expected changes," notes Dr Dennis.

It is expected that the knowledge generated by this study will contribute greatly to South Africa's adaptation to climate change, particularly the management of the country's water resources. The methodology has already been used in another WRC-funded study looking at adaptation to climate change. It is hoped that in the end, South Africa will be prepared whatever the scenario. ❑



Rainier & Ingrid Dennis



Rainier & Ingrid Dennis

***Top:** The DART index showing the expected change between current and future climate scenarios for the period October to December.*

***Above:** The projected change in annual recharge between current and future climate change scenario.*

Traditional water sources – Lifeline in a time of need

Althea Grundling

Traditional water resources are proving the only lifeline to poor rural communities in the scenic coastal region of north-eastern KwaZulu-Natal amidst failed local service delivery and drought conditions. Althea Grundling investigates the importance of traditional sources of water to a community in the grip of a nine-year drought.

Maputaland in north-eastern KwaZulu-Natal is well known for its beautiful beaches on the warm Indian Ocean and picturesque lakes such as Kosi Bay. The Maputaland Coastal Plain stretches from Mtunzini in the south, northwards into Mozambique, with the Indian Ocean to the east and the Lebombo Mountains to the west. It falls within the Maputaland-Pondoland-Albany biodiversity hotspot, which is an important centre of plant endemism and is home to the iSimangaliso Wetland Park, South Africa's first World Heritage Site that was rewarded this status in December 1999.

The area is characterised by sandy soils with rapid infiltration rates and a low soil water-holding capacity that forms the Maputaland Coastal Aquifer. Very little rainwater has recharged the aquifer over the last decade, and this has negatively influenced the wetlands in the area. The once expansive grasslands, forests and unique wetlands and peatlands (see *The Water Wheel* of July/August 2010) are facing increased threats from uncontrolled activities such as grazing lands and the encroachment by local farmers into peat swamp forests by slash-and-burn activities and draining these unique and threatened ecosystems. The expansion of plantations and groundwater abstraction pose serious threats to the wetlands of the Maputaland Coastal Plain.

Living in this remarkable landscape is the friendly and always helpful Tsonga people of the Tembe Tribe. This is one of South Africa's poorest communities, which almost entirely depend on the land and wetlands for their survival. Since 2002 the region has experienced a drought with below-average rainfall. The current rainfall (average of 580 mm/year from 2002-2010) is far below the long-term average annual rainfall of 760 mm/year (measured over the past 22 years). Many families are therefore suffering from a shortage of water for domestic, irrigation and livestock use. While tourists experience the region as a tropical paradise, dry wells and low groundwater levels are quite common at present, stressing the day-to-day struggle for clean drinking water.

Service delivery by the local municipality continues to fail in its efforts to supply reliable sources of domestic water. As a result of a massive borehole pump and pipeline initiative, the KwaNgwanase area has some hope of reliable water supply in the future if the groundwater levels can be maintained, but there remains many communities in the area that have no expectation to receive water from this source. Instead, these communities continue to struggle and depend primarily on traditional and natural water sources such as wells, streams, lakes, fountains and wetlands.

A LOCAL LIFELINE

Withdrawing water from shallow wells in the sandy aquifer is common practice among the Tembe people. Traditionally it is the women and children that draw water and carry it some distance for use at their homes. Water is also drawn from wells and boreholes to irrigate vegetables in the cultivated fields nearby or to water cattle and other livestock. Wetlands are important natural resources that are crucial to the survival of the inhabitants of this area not only in terms of fishing, harvesting of wetland vegetation and subsistence cultivation but also for precious drinking water. The need to access water and the lack of practical health and safety measures has been identified during research studies in the area.

Declining groundwater levels have forced the Tembe people to dig their wells deeper each year. Areas surrounding deepened wells can be very dangerous due to collapsing walls and edges of the wells. Unlined wells are also collapsing, not only blocking access to the water but rendering these wells potentially life threatening. Well sites are not always clearly marked or fenced-off and misbehaviour leads to wells and boreholes being polluted by litter. In some cases homemade ropes from Lala Palm (*Hyphaene coriacea*) leaves are used to draw water and hand pumps are not in use due to poor maintenance.

Maintenance on wells, boreholes and pumps is a high priority. There is a continual need for nylon rope, buckets and water containers as well as spare parts and tools to maintain hand pumps. The following practical measures could greatly enhance access to and sustainable use of these natural water sources:

- Erect notice boards indicating well sites.
- Stabilise walls and edges of the wells and line deep wells.
- Fence off wells with a gate that can be closed.
- Address the problem of littering in wells and boreholes.

Althea Grundling

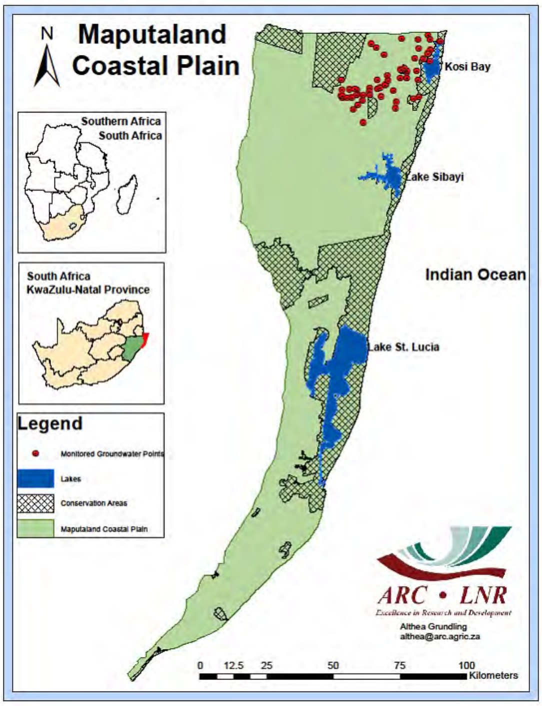
Above: *Children collecting water from a well fitted with a hand pump. A broken rubber washer (although relatively easy and cheap to replace) has rendered many of these wells in the area useless.*

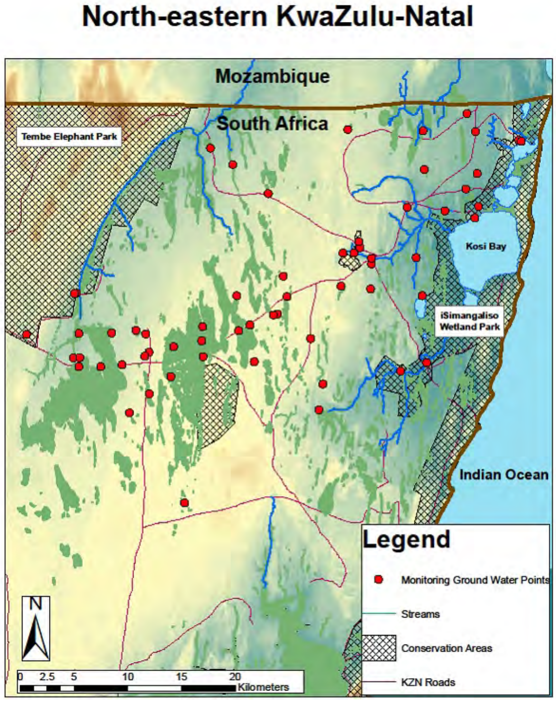
Below: *A local woman using Lala Palm (*Hyphaene coriacea*) leaves to make a rope.*

Althea Grundling

Below: Local communities are very dependent on the environment, such as harvesting wetland vegetation for weaving and thatching.

Bottom: Kosi Bay. While one of the most scenic areas in South Africa, the persistent drought in north-eastern KwaZulu-Natal has brought much hardship to the local rural people.





Althea Grundling

- Train local community members so that they can maintain their own hand pumps.

Research studies conducted in this area formed part of an Agricultural Research Council – Institute for Soil, Climate and Water (ARC-ISCW) project funded by the Water Research Commission to investigate the regional environmental factors and wetland processes on the Maputaland Coastal Aquifer. Groundwater levels were *inter alia* monitored and measuring points include natural features such as lakes, pans, rivers, wetlands and springs as well as anthropogenic features such as wells, boreholes and drains.

The research has shown that groundwater levels have a direct relationship with surface water bodies such as wetlands, streams and lakes and reiterated the fact that there is a lack of groundwater monitoring information and a strong and crucial need for a groundwater monitoring network in the area. From the observations made over the past decade there is a steady decline in the groundwater levels and it will take an extreme rainfall event or at least five years of above-average rainfall to replenish the

Maputaland Coastal Aquifer.

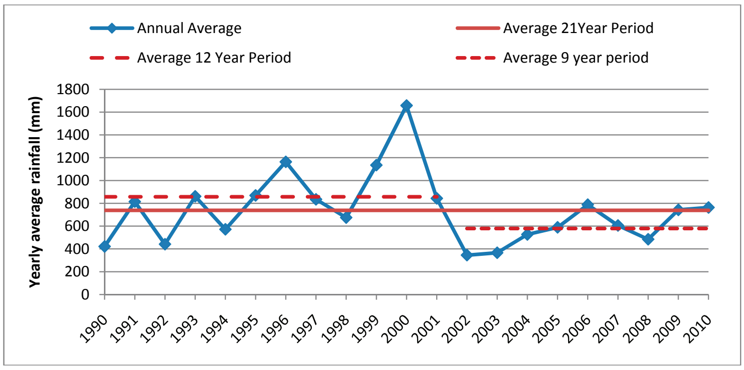
It is important to raise local awareness on water as a scarce resource on the Maputaland Coastal Plain and the fact that the pressure to utilise the groundwater resource is increasing. The local communities are vulnerable and due to limited alternative options, they often fall back on the natural resources, such as groundwater through wells. Certain commercial activities such as plantations are detrimental to the water source and other more beneficial and appropriate economic activities such as sustainable farming systems (outside sensitive wetland areas) and tourism initiatives need to be promoted. Working for Wells is one of the promising initiatives that have been identified by the author at the ARC-ISCW and any interested persons who would like to contribute towards this awareness raising and training initiative are welcome to contact her through *the Water Wheel* Editor. ❑

Piet-Louis Grundling

Above: *Althea Grundling (right) and research assistant Siphiwe Mfeka measuring groundwater levels in wells.*

Althea Grundling

Right: *The project team came across various precarious traditional water sources. As the water table drops the community is forced to dig deeper after water.*



New book celebrates life-giving Pretoria Fountains

A new publication, celebrating the role of groundwater in supplying South Africa's capital city, has now been published. The colourfully illustrated book, *Pretoria's Fountains – Arteries of Life*, is the first in a planned series by the Water Research Commission (WRC) aimed at illustrating the role groundwater plays in meeting not only rural but also urban water demands. The book is also available in electronic format, which includes a short film. With groundwater usually being a hidden resource, Pretoria's springs offer a rare visual glimpse of this important water resource, which has served the South African capital dutifully for over 150 years. The book was launched amid great fanfare at the University of Pretoria (UP) on 16 July. "Our aim with the project was to create awareness around the importance of groundwater and appreciation for our groundwater sources," said UP project leader and author, Matthys Dippenaar. "Compared to surface water resources, groundwater is better protected against contamination, evaporation losses and droughts, as the Pretoria fountains illustrate." The fountains, which were the city's only water source for 80 years still supply water of exceptional quality which requires no treatment bar the addition of chlorine. To order the book and/or DVD (free of charge), contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565; Email: orders@wrc.org.za or Visit: www.wrc.org.za to download an electronic copy.

All photographs courtesy UP

Project team Vevanya Naidoo and Matthys Dippenaar (both from UP) and Elanda Botes of the Groundwater Division of the Geological Society of South Africa.

WRC CEO, Dhesigen Naidoo, addressing the audience.

UP Vice Chancellor and Principal, Prof Cheryl de la Rey, WRC Research Manager, Dr Shafick Adams, UP project leader, Matthys Dippenaar and WRC CEO, Dhesigen Naidoo.

Book author, Matthys Dippenaar, signing copies of Pretoria's Fountains for guests at the launch.