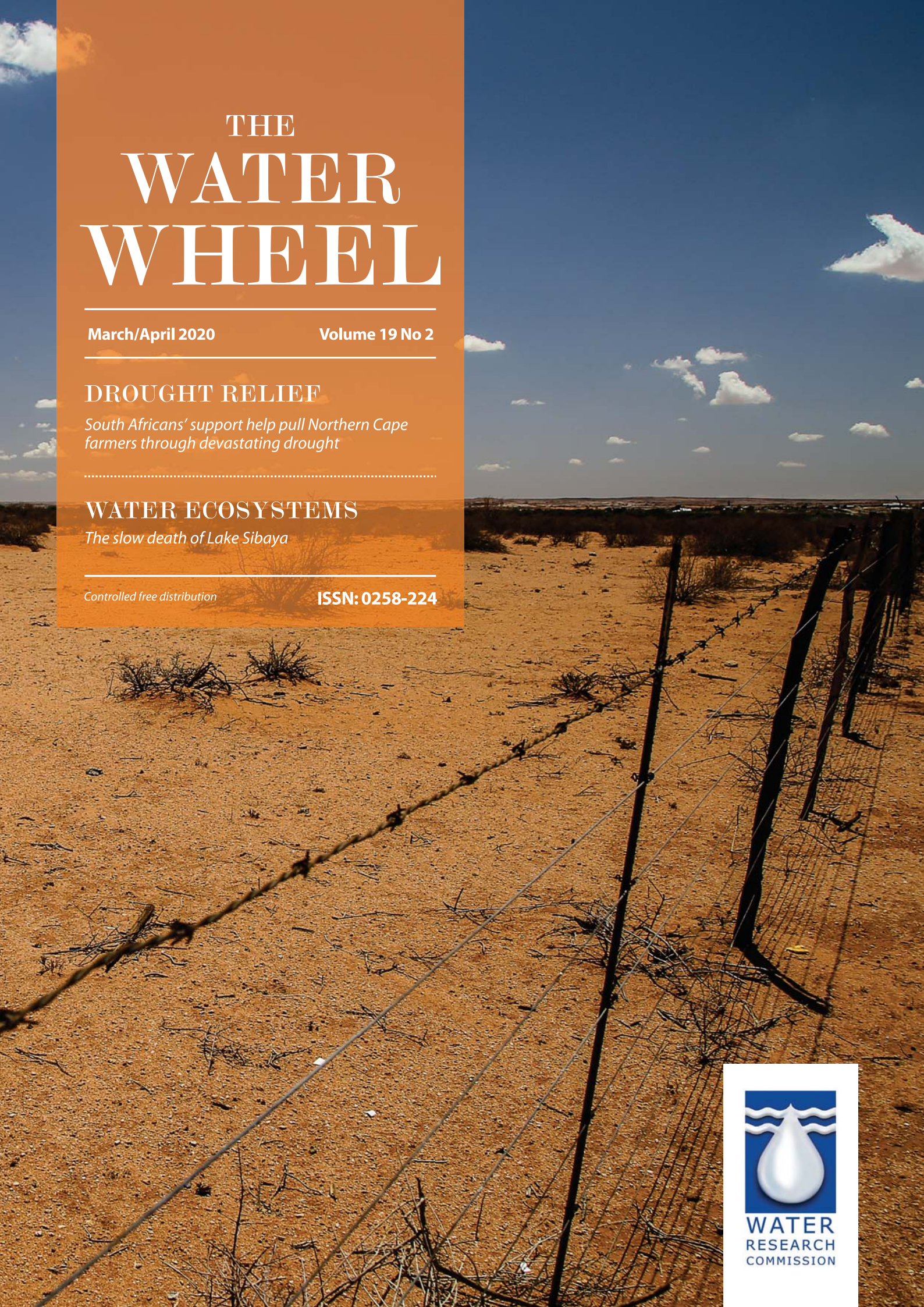

THE WATER WHEEL

March/April 2020 Volume 19 No 2

DROUGHT RELIEF

South Africans' support help pull Northern Cape farmers through devastating drought

WATER ECOSYSTEMS

The slow death of Lake Sibaya

Controlled free distribution ISSN: 0258-224

WATER RESEARCH COMMISSION

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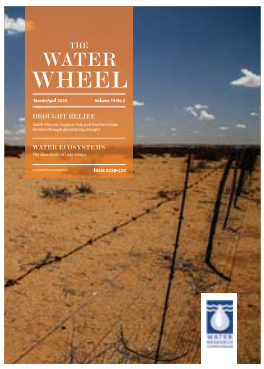

Members of the public are offering relief to farmers experencing drought in the Northern Cape. See story on page 10.

THE WATER WHEEL

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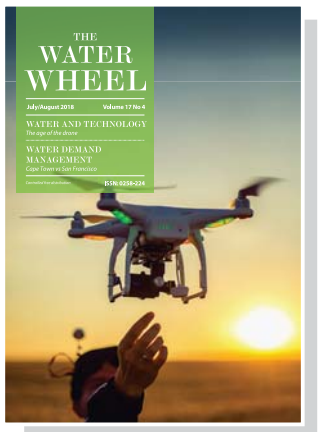

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FLUID THOUGHTS

WRC CEO, Dhesigen Naidoo

Sustainable social housing as a theatre for change

South Africa is struggling. This is true for much of the world, but this is where we live. We have a seemingly perfect storm of another economic dip tempered with deep social upheaval and an increasing ecological deficit as we continue, on the one hand, to depend on coal for our meagre energy supply and have to deal with new pollution threats like microplastics and pharmaceutical waste on the other. Its tight! And globally we have seen an exponential increase in natural disasters – bushfires in Australia, tornadoes in the US, continued drought conditions, tempered by destructive flooding events in South Africa.

At the same time, on the other side of this paradox, we have the highest levels of research derived scientific knowledge and the largest number of knowledge-based solutions and innovations in history. The problem that this community of practice has is the meagre spaces available to pilot, demonstrate and upscale these new solutions and practices that will radically and positively change our fortunes with respect to water, energy, food and health security. All of this at a lower carbon budget.

Using the water domain as an example, we know the benefit of a constellation of local and global partnerships in such promising domains like Water Sensitive Design, Recycling and Reuse platforms and New Sanitation. These include global heavyweights like the Gates Foundation, the Toilet Board Coalition with major multinational partnerships.

In the energy and wastewater domains rapid movements in the REEEP (Renewables IPP) and global movements in more accessible renewables are now reaching a rapid downward gradient in costs. Add to this the improvements in more traditional energy options being optimised for both higher efficiencies and low emissions.

Waste beneficiation has made great strides that has resulted both in waste minimisation and real entrepreneurial opportunities that have emanated for very viable business development and jobs creation.

While many innovations and smart solutions have been tested beyond the laboratory, out in the field, we have not seen the potential symphonious harmony and resource efficiency that would emanate from a composite demonstration site. That opportunity lies in the planned Social Housing projects in the Department of Human Settlements 2020 plan, especially those designed with mixed-development ambitions. This would lay out the blueprint for the Resilient Cities of the future.

What this requires is a design that organises significant water supply from the new 'taps' of rain and stormwater harvesting, infrastructure for scaled water reuse and recycling, quality enhancement through natural wetland preservation and where useful artificial wetland construction – we would greatly increase the water security levels in the settlement. Add to this better energy efficiency and alternative power generation through solar, wind, biomass and other options together with a now considerably lower energy demand from the water infrastructure – energy security becomes an enhanced possibility.

If we add to this mix smart and innovative urban gardening techniques, including vertical farming, we have an improvement in food and nutritional security. This water-energy-food nexus enhancement has the added boon of significantly reducing greenhouse gas emissions and lowering our carbon budget.

Smarter waste beneficiation and innovative waste management will reduce settlements' carbon footprint, and the whole environment will be both ecologically enhanced and aesthetically pleasing. It will become a great place to live and work.

If we have two or three or four of these new settlements developed in this way it will set the path for town-wide developments and lay the foundation for Africa to be the first continent to develop truly resilient and sustainable mega-cities. Then our mantra from WSSD 2002 – People, Planet Prosperity – will be truly realised.

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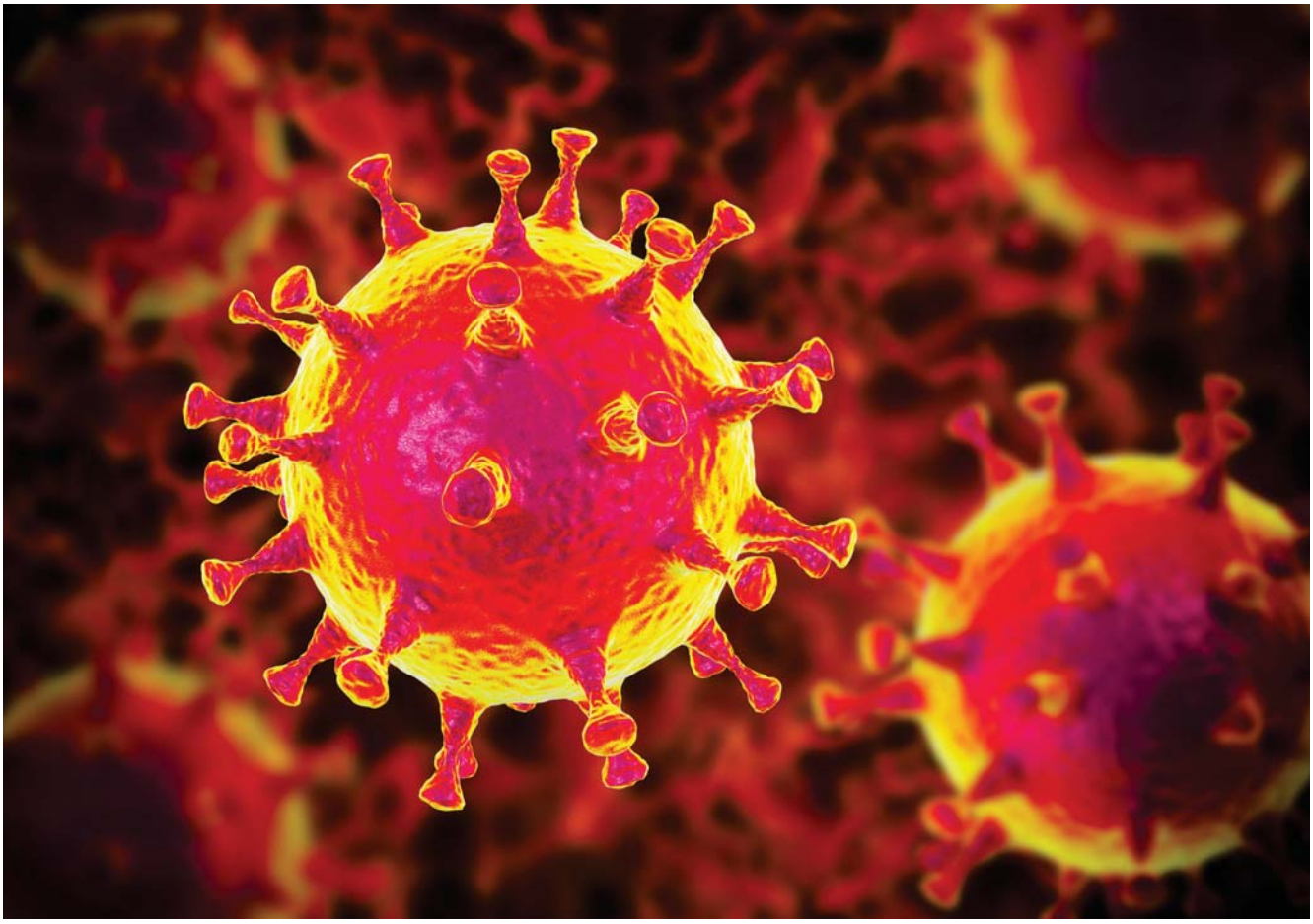
CORONAVIRUS DISEASE (COVID-19)

Water Quality, Sanitation and Hygiene Management in light of Coronavirus Disease (COVID-19)



What we know

Coronavirus disease (COVID-19) which has been declared a pandemic by the World Health Organisation (WHO) is caused by the SARS-CoV-2 that was isolated in Wuhan, China in January 2020. SARS-CoV-2 belongs to the family of zoonotic Coronavirus (meaning they are transmitted between animals and people). The virus has not been previously identified in humans and, as a result, humans do not have immunity to the virus.

Individuals and people at high risk

For individuals at high risk (people > 60 years and those with underlying medical conditions (heart ailments, HIV/AIDS, diabetes, respiratory conditions) infection can result in the development of severe pneumonia and can ultimately lead to death. At the time of writing there was no known vaccine or medication that can treat the disease.

To date, the disease has been confirmed in over 100 countries, including South Africa. Based on known infectious disease epidemiology models, it is expected that the number of cases will continue to rise, peak and then subsequently plateau off.

The South African National Institute of Communicable Diseases (NICD) continues to provide up to date status/changes of COVID-19 transmission in the country.

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How the virus is transmitted
The virus is thought to spread mainly from person to person: between people who are in close contact with one another through repiratory droplets produced when an infected person coughs or sneezes.

It may be possible that a person can get COVID-19 by touching a surface or object that has the virus on it and then touching their own mouth, nose or eyes. This is not thought to be the main way the virus is spread.

Know the signs and symptoms
COVID-19 presents as a respiratory illness with symptoms very similar to influenza disease such as:

- Fever
- Cough
- Shortness of breath

Seek medical advice if you develop symptoms or have been in close contact with someone known to have COVID–19.

Keeping drinking water safe
South Africans get their drinking water from a variety of sources, the two main sources being surface water and groundwater. Safe water sources include tap water and well managed boreholes and wells while unsafe water sources include rivers, and unmanaged wells and boreholes. Viruses, such as rotavirus, norovirus, polio virus and hepatitis A are known to persist and be transmitted through untreated water but, **to date, there has been no evidence that COVID-19 can be transmitted through treated drinking water or through groundwater. Thus, its persistence in water still remains to be verified.**

Being a virus that is susceptible to environmental conditions, COVID–19 should be very fragile and will easily die off when in unfavourable conditions (commonly used disinfectants, such as chlorine as well as to high heat, low or high pH and sunlight).

For South Africans who have access to tap water
It is therefore reasonable to assume, based on limited research available, that South Africans with access to tap water from a well-managed drinking water distribution system are highly unlikely to contract COVID-19 from their drinking water. A well-managed drinking water distribution system should ideally use filtration and disinfection, and should have a free residual chlorine (0.2 and 0.5 mg/L) throughout the distribution system to ensure effective inactivation of the virus.

For South Africans who do not have access to piped water
For South Africans who use alternative sources of water, such as springs, streams, boreholes, rainwater etc. and/or also store water in their homes for a period of time, the same rules with regard to household water treatment at point-of-use and safe storage apply.

As a general rule, safe disinfectants in the form of bleach, hyphochlorite or chlorine should be used to disinfect the water before use.

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COVID–19 should be inactivated through:

- Correct application of boiling (meaning, rolling boiling water for 2-3 minutes)
- Irradiation (solar and UV) disinfection
- Sedimentation and filtration techniques

It must be noted that, although drinking water in itself might not lead to the transmission and spread of COVID-19, collection of water from community stand pipes, shared boreholes, or from tankers, and other related activities bringing healthy individuals in close proximity to those infected might aid human-to-human transmission.

Wastewater and the Use of Sanitation Services

Unlike treated drinking water and groundwater, COVID–19 is likely to be present in wastewater where active infections are present. Furthermore, based on observations, COVID-19 may be transmitted through the faecal-oral route. It should be noted though that, at the time of writing, there were no reports of faecal–oral transmission of the COVID-19 virus or transmission via wastewater systems with or without wastewater treatment. Approximately, 2% to 10% of persons with COVID-19 disease present with diarrhoea at the early stages of infection rather than a fever. Molecular analysis in 2 studies has shown that the virus can survive in wastewater, faeces and urine for at least 14 days at 4°C and approximately 2 days at a higher temperature of 20°C.

The indirect and direct reclamation of wastewater effluent for reuse is increasingly being recognised as one of the sustainable measures to augment water supply in South Africa, in light of climate change and increasing drought conditions. Current wastewater reuse practices in South Africa include greywater harvesting and use, treated wastewater reuse for irrigation as well as treatment of wastewater effluent for drinking purposes in areas like Beaufort West where the water supply is a blend consisting of approximately 20% reused water. Given knowledge of the virus structure and the die off rates of other coronaviruses when exposed to different inactivation methods, it can be assumed that treated wastewater, even if from a COVID-19 infected area, will still be safe for reuse if treated to the required quality with currently used water reuse technologies and systems.

Safe practices at wastewater treatment plants

In the absence of new information and research findings with regards to COVID–19 and wastewater, current occupational health and safety best practices at wastewater treatment and water reuse plants should be implemented.

- Workers should always use personal protective equipment (PPE) and adhere to practices that will minimise or completely prevent their exposure to untreated water as they are the ones most at risk not only of getting COVID-19 but other waterborne diseases
- Personal protective equipment should ideally consist of a mask, goggles, a fluid-resistant apron and gloves
- Workers should perform hand hygiene practices, such as handwashing using soap and water or a hand rub using an

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alcohol-based formulation after removing PPE

Once again, the people most at risk will be those working with faecal sludge when emptying pits or fixing sewerage systems and it is critical that they continue to maintain best practice for safely managing faecal waste.

Safe practices in households

The safe confinement of human wastes (faeces and urine) is effective in preventing transmission of viruses and pathogens. Households that have flush toilets connected to a well-designed and maintained public wastewater system or septic tank do not face any additional risk of contracting COVID-19. The same applies for households with access to a well-constructed pit toilet with a ventilation pipe.

Toilets should be flushed with the lid down to prevent droplet splatter and aerosol clouds. An investigation in Hong Kong regarding COVID-19 cases in an apartment building revealed the possibility of virus spread through an improperly sealed pipe, which carried infected faecal matter through the building's ventilation system and into people's bathrooms. So far this is the only study that had reported transmission through a sewerage system.

Best hygiene practice to curb the spread of COVID-2019

Frequent and proper hand hygiene has been identified as one of the key measures in preventing the spread of COVID-19. Not only is proper hand hygiene important in curbing the spread of this particular outbreak, but this practice is also important in preventing the spread of other harmful microorganisms in general.

Hands must be washed, after using the toilet; after disposing of faeces; after changing babies' nappies and disposing of their faeces; before preparing food; before eating; before feeding children; immediately after handling raw food; after contact with contaminated surfaces, e.g. rubbish bins, cleaning cloths; after handling pets and domestic animals; after contact with blood or bodily fluids, e.g. faeces, vomit; before and after dressing wounds or giving care to a sick person; after wiping or blowing your nose. Hands must be washed using soap and clean water.

As South Africa heads into the winter season, a drop in ambient temperature and in humidity levels provides ideal conditions not only for COVID–19 to thrive, but also influenza viruses. The following preventative and good hygiene practices apply:

- avoid contact with others if they have cold- and flu-like symptoms
- clean and disinfect surfaces and floors regularly
- cough and sneeze into your elbow
- avoid touching your face, especially eyes, nose and mouth
- stay home if you are unwell

In the instances where water is not available, an alcohol-based sanitiser product, with an alcohol concentration of at least 60% v/v can be used. If hands are visibly dirty, an alcohol-based rub is likely to be ineffective due to the fact that alcohol does not penetrate soil very well. If this is not available then alternative such as the following can be used:

- Mild (0.05%) chlorine solutions e.g. unscented bleach
- Methylated spirits
- Antiseptic products

WRC Reports:

- **WRC Report No. TT 460/11:** Provides guidelines for managing water-related microbial diseases specifically looking at health and hygiene awareness
- **WRC Report No. 2134/1/18:** Understanding and addressing the exposure of workers, the public and the environment to pathogens during pit emptying

For more information:

- South Africa Coronavirus update, http://www.nicd.ac.za/
- Water Research Commission (WRC) Knowledge Hub (www.wrc.org.za)
- WHO (Water , Sanitation, hygiene and waste management for COVID-19 Technical Brief (3 March 2020) https://www.who.int/publications-detail/water-sanitation-hygiene-and-waste-management-for-covid-19
- Global Water Research Coalition(GWRC). COVID-19 Virus Water, Sanitation and Wastewater Management. Fact Sheet (10 March 2020)

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CLIMATE CHANGE

South Africans' support help pull Northern Cape farmers through devastating drought

While prolonged drought has brought many farmers in the Northern Cape to their knees, concerned citizens have rallied across to the country to help where they can. Petro Kotzé visited Kenhardt, one of the worst affected areas.

Petro Kotzé

A sheep carcass on a livestock farm in Kenhardt, South Africa.

After headline grabbing droughts over the past years, near-, to above-normal rainfall fell over most of South Africa again this year. Yet, prolonged drought is still continuing in certain parts of the country.

According to the latest map of the Standardized Precipitation Index (a widely used drought index that can be calculate over different time resolutions) most parts of the Northern Cape is still extremely dry (as well as a significant part of the Eastern Cape).

Here, the ongoing drought has wreaked havoc. Head of disaster management for Agri-SA, Willem Symington, himself a farmer from Kenhardt in the Northern Cape, says that they are well familiar with drought and they have learned to manage it well.

Yet, the unusual conditions of this drought have brought many farmers to their knees. Their plight has rallied South Africans across the country to help.

A drought like we've not seen in a long time

The Northern Cape is the largest province in South Africa. With a landmass of 361,830 km^2 it covers approximately 30% of South Africa. It's also home to the smallest share of the country's population. Only 2.1% or 1.23 million South Africans reside here.

The landscape is mostly desert and semi-arid, allowing only 2% to be used for crop farming mostly along a strip next to the Orange River, where farmers irrigate export grapes. Another 1%

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or so is conserved, but by far the bulk of the land (96%) is used for stock farming, including beef cattle, sheep and some goats. Game farming is also popular.

Most farmers here rely on late summer rainfall. As cold fronts pass to the south of South Africa a band of low pressure (troughs) develops over the Northern Cape, moving from west to east, explains Dr Andries Kruger of the South African Weather Service. In ideal conditions these troughs transport moist air from the northern parts of the subcontinent close to the tropics into the province. As this moist air lifts, storms develop and produces rainfall. In the south and far west of the province, the passage of cold fronts allows for winter rainfall.

Under these conditions the average rainfall across the province (for the period 1981 to 2010) is about 226 mm, says Dr Kruger.

Local farmers speak of a seven- or eight-year drought, but Dr Kruger says that since 2013, four years can technically be considered dry, being years during which 75% or less of the average normal rainfall fell. Actually, in 2019, the lowest rainfall in the province since at least 1922 was logged.

The harsh conditions of that year was given added punch by abnormally hot temperatures. Due to the large spatial variability in the climate of the province, it is not possible to determine average temperature, but surface temperatures follow a general pattern of long-term warming, notes Dr Kruger.

In fact, he says, a large part of the province has undergone stronger warming than the rest of South Africa. "We have found that the data from long-term temperature stations in the province indicate a disproportionate contribution to the above-normal temperature anomalies during the last number of years," says Dr Kruger. Because the Northern Cape covers such a large part of South Africa, the anomalies in temperature here contribute significantly to the overall situation in the country. "In this regard 2019 and 2015 can be considered to be the two hottest years in South Africa since at least 1951, being about 1.1 degrees Celsius above the 1981 to 2010 average," he adds.

Kruger adds that, from a statistical perspective the drought is not only unusual because 2019 is the driest year since 1922. Additionally, only the late fourties and early fifties, and the first half of the sixties show a similar scale of grouping of dry years since at least 1921.

On the other hand, "wet" years have been few and far in-between. "If a wet year is considered to be a year with rainfall at least 125% above the normal there has only been four years meeting that criteria for the Northern Cape over the last 20 years, being 2000, 2001, 2006 and 2011," he explains.

The impact on the ground has been devastating.

Farming through the drought

According to Agri SA's 2019/20 Agriculture Drought Report, more than 15 500 farms covering more than 20 000 000 hectares are severely affected by the prolonged drought in the Northern Cape. The total area affected by the potential disaster drought in the province is well over 27 million ha with a carrying capacity of over a million livestock units.

Petro Kotzé

Farmer, Wynand Bezuidenhout, on his farm just outside Kenhardt, four years into the ongoing extreme drought.

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Petro Kotzé

The SA Water Warriors arrive in Kenhardt.

Herman Smith has been farming in the Kenhardt area since the nineties. "This is a completely different drought," he says. "It just never rains". The ongoing dry spell could cause the end of his business, as he says he won't be able to continue farming like this for much longer. His sheep have dwindled in number from 300 to 116.

Third generation farmer, Memory Buis, has been farming here for 32 years. Their flock of sheep has been reduced from 360 to 42. "We will not stand up from this again," she says.

Local farmer, Johann Beukes, says that some people are against the ground. He explains that they usually get around R1 200 for an 18 kg lamb but now, the lamb needs R250 of supplementary feed to survive, slashing income substantially. "For cattle, the losses are even bigger," he says. The drought has significantly reduced his numbers of sheep, cattle and horses too.

Symington, also Agri Northern Cape's vice president, says the impact of the drought circles much further than the farmers. Though there is also mining activity in the province, most communities in towns rely on common allowances and livestock farming. "If you take the livestock farming away, the local economy collapses." He says that due to the loss of buying power, this is already happening. "All small businesses are under pressure, because people don't have money to buy stuff anymore." In a province where adult poverty rates were notched at 54.3% even before the drought, the impact is substantial.

According to the mentioned Agricultural Drought Report, employment in agriculture for the Northern Cape declined with 22.5% (9, 000) on a year-on-year basis. It further states that the direct impact of this current drought and potential escalation if the drought prevails will be "disastrous" to the economy of the Northern Cape Province.

Yet many farmers, at least, simply have to stay put. "We have no plan B," says Symington adding that at his age (55) alternative options are severely limited.

Though government support has been announced, for many, it might be too little, too late. Symington explains that by January 2019, an estimated R800 million in relief funding would have been necessary to feed remaining livestock. This January, the South African government announced that R300 million will be set aside for emergency drought relief in the province, on top of R30 million provided last year.

In the interim, South Africans from across the country have rallied in support of drought affected communities, especially farmers. Commercial, emerging, small-scale and subsistence farmers have received aid from various fundraising projects and donations, according to Agri SA. Many are driven by NGO's like Agri Northern Cape, Agri SA, Gift of the givers, "Save the sheep" and numerous other groups as well as business and individuals. Another is the South African Water Warriors, a group of volunteers that conduct outreaches to deliver donated goods to farming communities worst affected by the drought. Mostly, this takes them to the Northern Cape, says founder Deon Smit. This February, it took them to Kenhardt.

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Petro Kotzé

(This page and the previous page) The SA Water Warriors load donations in Cape Town, ready to be driven to Kenhardt.

South Africans from across the country have rallied to help

SA Water Warriors member, Tina Connoway, joined one year ago, and her work with the organisation has since taken her on outreaches to Kamieskroon, Oudshoorn, Springbok, Kliprand, Prins Albert and most recently, Kenhardt. For her, the impact of the drought has gotten worse over the past year, "looking at how many farmers have taken their own lives, or have just given up."

Established two years ago, the Water Warriors initially helped vulnerable people during the Cape Town water crisis. Soon after, farmers started contacting them for help, and the requests have not stopped since. "We receive many more than we can handle," says Smit. They try and select those communities where the suffering is greatest, and where help has not been received before. A local contact then compiles a list of the farmers and farm-worker families in need of help.

It takes about six to eight weeks before they have enough donations for an outreach, explains Connoway. "We'll take anything that people give," she says. For Kenhardt, this amounted to a delivery of 37 000 litres of drinking water, nine trucks of feed, a cooler truck of perishable goods and 26 ***bakkies*** and four trailers of groceries for distribution to 355 families of farmers and farm workers.

Smit stresses that they are not affiliated with any political party, government or membership-based organisation, nor do they ever accept any funds from farmers for the help and goods they deliver. Everything is paid for by donations, and every single sent of donated funds go to help farmers, he says.

The difference the donations, and volunteers' effort make, is tangible. On their arrival in Kenhardt, the streets were lined with local families waiting to receive them. "You cannot describe the impact this has," says farmer, Nolan Jordaan. Many receiving donations in Kenhardt on the day reported the same, saying that the money they save in groceries, will allow them to buy feed to keep their animals alive for longer. "If I can take care of my animals, I can take care of my people," says Beukes.

Still, Symington says it's not been easy. "We farm in hard country," he says. "But when it comes to donations, and people are good to you, that's when you cannot control your emotions anymore." After taking care of your family, workers, animals and community for decades, and then suddenly have to stand in line for handouts, is difficult, he says. "But we are very thankful."

What the future holds

According to the SA Weather Service seasonal climate watch from February to June 2020, the dry period is set to continue as the El Niño-Southern Oscillation (ENSO) is currently in a borderline weak El Niño state. The forecast indicates that it will most likely remain at the border between the weak El Niño and neutral states for the rest of the summer season and early autumn.

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The rainfall forecast for early-autumn (Feb-Mar-Apr) and mid-autumn (Mar-Apr-May) indicates enhanced probabilities of below normal rainfall over most of the country with the exception of the eastern parts during mid-autumn. With regards to temperatures, mostly higher than normal temperatures are expected for the rest of summer and early autumn over most of South Africa with the exception of the far south-western parts.

Over the longer-term, Dr Kruger says that projections of future climate change indicate an expectation of general drying of the Western Cape and the far north-eastern parts of South Africa. "Regarding the Northern Cape we do not see any evidence of significant long-term drying considering the period 1921 to present." Yet, how long the drought will still continue for, is anybody's guess. Kruger says "historical rainfall patterns cannot be used with confidence to predict future rainfall patterns through extrapolation."

For the moment, however unlikely it sounds, many farmers say they are also seeing benefits to the drought. "This has really brought our community together," says Buis, as she sorted donated soap, rusks, flower and soya mince into packages for families.

For Symington, the help that farmers in the Northern Cape has received from private organisations and individuals is unbelievable. "Our country is not in a good place, but it's like South Africans have taken ownership of our agriculture." He says that the donations must already amount to hundreds of millions of Rand. "What is happening here is a bigger story than the World Cup."

Sources:
Department Statistics South Africa (http://www.statssa.gov.za/)

Petro Kotzé

Tina Connoway, SA Water Warriors member.

Petro Kotzé

SA Water Warriors Founder, Deon Smit.

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WATER PERSONALITY

South Africa's 'professor of toilets' helps to drive global water-saving plans

The Durban-based Pollution Research Group has established itself as a world-leader in water conservation and pollution research – especially through its drive to re-invent toilets, save water and develop better sanitation solutions for poor communities and the environment. Prof Chris Buckley spoke to Tony Carnie about how it all started, and the journey still ahead.

Tony Carnie

The nascent Pollution Research Group (PRG) began to bubble back in the early 1970s, housed in the Chemical Engineering building at the former University of Natal in Durban.

Nearly 50 years later – but now in the subterranean basement – the university's world-acclaimed contract research group has grown considerably under the co-leadership of Prof Chris Buckley and Susan Mercer.

Now aged 70, but still sprightly and brimming with ideas, he has supervised more than 100 Masters and PhD students at the PRG, and for several years has been among the University of KwaZulu-Natal's top grant-holding fund raisers.

In the mid-1960s, Prof Buckley obtained a student loan from the old Durban Corporation to study chemical engineering, later entering the cavernous main laboratory to launch his fourth-year project: finding ways to reduce the volume of industrial dyes in textile effluent. Buckley recalls that as a youngster, he was placed in the "D class" at Westville Boys' High School, where he enjoyed geography and book-keeping (accounting).

"I was no good at learning subjects like history or Latin, and my spelling and writing were terrible (and still is) . . . But I could add up pounds, shillings and pence just by running my fingers down a column of numbers."

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Tony Carnie

Buckley with a framed photo of the 1970 crop of final-year chemical engineering students. He has been based in the same building ever since.

To pay back part of his student loan, he was required to spend his vacations as an underling in various divisions of the local municipality.

"You would be apprenticed to a welder or a diesel mechanic; in the roads, construction or water works departments and you were the lowest of the low. They gave me a Land Rover and I would spend my days driving around the city collecting water samples from the Umlaas River or municipal swimming pools and dropping them off for lab analysis. It was pretty routine stuff, but I got to see parts of the city most people never get to."

After completing a MScEng partially based at the Southern Wastewater Treatment Works on the filtration of sewage sludge Prof Buckley started work on his PhD thesis on the filtration of compressible sludges, but never completed it.

"There were just so many other far more interesting things to do," he says.

It was around this time that the newly-established Water Research Commission (WRC) began to fund a series of water pollution research projects at the then University of Natal. Prof Buckley was already attached to a similar research group established by AECI (African Explosives and Chemical Industries), but soon moved over to join the university's new Pollution Research Group, which was now funded for contract research by the WRC.

Prof Buckley took over leadership reigns in 1985, and was appointed as the full-time head in 1987. During these early years, his research focused on reducing water pollution and energy costs in the textiles industry, later moving towards waste minimisation and cleaner production in metal finishing, metal processing, mining, petrochemicals, sugar, beverages and power plants.

Clients included Eskom, Sasol, several textile groups, Tongaat Hulett and Iscor. "Each project increased our knowledge and experience and we started to get quite a lot of repeat business for our contract research work."

But it was the WRC, he says, which played a central role in sustaining the development of the PRG. "I can't recall a single year since the mid-1970s where we have not had some form of funding from the WRC. Without that continuity of funding, which kept us going, our people would have disappeared. It meant that we did not have to keep writing new funding proposals each year, because we had a retainer and this allowed us to develop a clear vision.

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Tony Carnie

Ncebakazi Ngubane collects dried faecal pellets from a LaDePa machine, a laboratory-scale version of a device which extrudes faecal sludge into pelletised form which is then heated at high temperature to inactivate pathogens.

"At the beginning, the PRG was tiny – just three or four people. We gradually expanded a bit, and for many years there were generally less than eight people (compared to almost 35 salaried staff today). At one point we had three people called Sue working for us (Sue Mercer, Sue Winship and Sue Wadley). There seemed to be so many Sues around that we renamed our office the 'Sue-wer'," he chuckles.

It was a nickname that captured the often mischievous sense of humour of the maverick professor, and the PRG's growing research focus on better ways of dealing with poop and reducing water waste. Two decades ago, the collection and management of human urine and faeces was not an issue that many academics really wanted to get involved in – but that was not the PRG's approach.

"I guess our work takes a special sort of enthusiasm and quite a bit of cajoling, but now we are the go-to people for data in this area, along with testing and development of new sanitation solutions.

"Bear in mind that about 35% of the water used in most households gets flushed down the loo – and one of the reasons for this is that some of the first flush toilets were developed in the 1800s, and their design was shaped by the need to have a 4-inch diameter outlet pipe."

This was because early pipe glazing techniques were determined by the width of a glazier's hand. This resulted in large diameter pipes and correspondingly large volumes of water being used to flush the u-bend effectively.

Such historical anachronisms, Prof Buckley observes, can be perpetuated in design for centuries – much like the narrow gauge of several modern railway lines, which some historians say can be traced back to the width needed to accommodate the backsides of two horses pulling a Roman war chariot.

Now, with clever modern technology and re-engineering, Prof Buckley says it is possible to re-design toilet pedestals to use as little as 1.5 litres to flush away faeces – compared to the 10 litres used in some of the older chain-pull toilet cisterns. "In a water scarce country like South Africa we need to keep squeezing down the volume of water wasted on toilet flushing."

The PRG's more recent focus on sanitation and toilet design dates back to the mid-1990s, when Prof Buckley's group and the Ethekwini Municipality began to work together with funding from the WRC on an anaerobic baffle reactor to digest human waste at the Umbilo Wastewater Treatment Works. Later, the PRG and Ethekwini also collaborated on the design and operation of ventilated pit latrines and urine diversion toilets.

During this collaboration, a question arose on whether the solids (sludge) from urine diversion toilets could be used to grow trees and vegetables or to manufacture agricultural fertilisers.

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PRG engineer, Lindelani Xaba, and University of South Florida postdoctoral scholar, Dr Cynthia Castro, discuss the operation of a prototype water-saving system at a community toilet block in the Durban North area. The system, designed by the University of South Florida, saves water by passing wastewater through an anaerobic digester and advanced membrane filters. The recycled water is used to flush toilets

Tony Carnie

Prof Chris Buckley prepares faecal samples for freeze-drying in the PRG laboratory.

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Prof Buckley suggested that the best way to find out was to do actually do it, and the Ethekwini Water and Sanitation Unit decided to provide the funding and equipment to establish a test site.

The PRG leader is a firm believer in the dictum that you need to practise what you preach, when testing new toilet designs. Thus, in 2008, he installed a prototype version of a modernised 'thunderbox' in the back garden of his home in Westridge, Durban. This toilet was designed to separate human urine and faeces at source as a means to reduce the volume of effluent entering municipal sewage treatment works and also to turn poo and pee into valuable commercial resources.

Prof Buckley and his students tested it for more than a year – a tradition that continues today at the PRG, where nearly 20 prototype toilet systems are being tested and developed as part of the Bill & Melinda Gates Foundation "Re-invent the Toilet Challenge".

During a recent visit to the PRG headquarters, Prof Buckley took me on a tour through the basement and showed me many things – including a much-improved urine diversion pedestal developed by the Vienna-based EOOS Design Studio. Near the entrance there is a Biosafety Level 2 warning sign – as well as an Uncle Sam sign (adapted from a 1917 US wartime poster) exhorting staff and visitors to the PRG to test-drive the latest prototype for the benefit of science.

Tony Carnie

PRG technician, Christy Govender, busy installing a 3D printing machine that will be used to manufacture a variety of prototype toilet pedestals.

Elsewhere in the basement, technician, Christy Govender, was busy installing a 3D printing machine that will be used to 'print' a variety of new toilet pedestals, while lab technician, Thabiso Zikalala, was collecting faeces samples from a refrigerated archive for further analysis.

Fellow lab technician, Ncebakazi Ngubane, helped to explain the workings of a large, red "LaDePa" machine (**La**trine **De**hydration and **Pa**steurisation), a laboratory-scale version of a device which extrudes faecal sludge into pellets which are then heated at high temperature to destroy or inactivate pathogens and intestinal parasites such as the Ascaris egg. The objective is to process the organic, nitrate and phosphorous components of faecal waste streams into farm fertilisers, or alternatively, as a new source of biofuel.

Neil Macleod, former head of the Ethekwini Water and Sanitation Unit, has commented previously that: "We recognise faeces and urine as potential sources of nutrients and energy, rather than as material to be 'avoided at all costs' and kept as far away from people as possible. This pelletiser is part of a series of interventions to recover nutrients from human waste and then recover energy from what is left."

Much of this research would not have be possible, however, without extensive financial support from the WRC and the Bill & Melinda Gates Foundation. Gates visited Durban in 2004, and Prof Buckley and municipal officials spent three days guiding him and other senior foundation officials around several dense informal settlements in Durban to showcase a variety of innovative sanitation projects.

Prof Buckley fretted that those three days might come to naught, but he was later invited to Seattle to develop a detailed funding proposal and in 2011, the PRG landed a US$400 000 grant to advance global toilet technology through the foundation's global "Re-Invent the Toilet Challenge". Yet, technologies developed in a laboratory still have to be proven to work in the real world.

So we hop into Prof Buckley's late-1980s model Toyota Corolla sedan for a guided tour of some of the PRG technology demonstration projects, including several informal settlements which lack formal electricity or sewerage networks. At one such project, we meet PRG engineer, Lindelani Xaba, and visiting postdoctoral scholar, Dr Cynthia Castro, who are busy evaluating the performance and operation of a prototype water-saving system at a community toilet block in the Durban North area.

The system, designed by the University of South Florida, saves water by passing wastewater through an anaerobic digester and advanced membrane filters. The treated water is then returned to the ablution block to flush the toilets. The system also captures biogas, which could be used as a heating fuel, and incorporates a solar-powered energy system so that it can be used in remote areas which are not connected to the electricity grid.

Our next stop is the Newlands Mashu Agro-Ecology Hub, where wastewater is collected from 86 nearby homes and treated with a combination of technologies to clean the water to fertilize

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Tony Carnie

Lab technician, Ncebakazi Ngubane prepares water samples for analysis.

and irrigate (fertigate) farm crops. The wastewater first passes through an anaerobic baffled reactor and associated anaerobic filters and then through a constructed wetland before the final treated water is used to fertigate a variety of crops such as bananas, rice, sorghum or taro (madumbe).

Tony Carnie

The entrance to the PRG research toilet.

While there is still some way to go, Prof Buckley's team has placed Durban and the PRG firmly on the map as world leaders in the arena of water conservation, wastewater treatment and the potential valorisation of unwanted human 'waste'. He has also shared his knowledge widely and continues to train a new generation of water researchers and 'poop scientists'.

Former PRG student, Dr Sudhir Pillay (now a senior sanitation research manager at the WRC), recalls that he was not particularly charmed when Prof Buckley drove him down to the Amanzimtoti wastewater treatment works in 2003 to suggest that it was an ideal site to embark on his Master's degree. Dr Pillay demurred at first, but as things turned out they chatted further over a few beers later that evening and Dr Pillay ended up working with Prof Buckley and the PRG for 10 years.

"Working with poop was fun and exciting and the PRG was run like a family environment. Chris always had an open-door policy and much of what I learnt was through Chris, either directly or through his vast national and international network."

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WATER ECOSYSTEMS

The slow death of Lake Sibaya

Why is the water level dropping steadily in one of South Africa's most valuable freshwater lakes? And what can be done to stop it from drying up further? Article by Tony Carnie.

Lake Sibaya, named after the Zulu word for ***cattle kraal***, is the country's largest coastal freshwater lake.

With a surface area of more than 60 km^2 and a water depth of 41 m at the deepest point, it has been estimated that Sibaya can hold more water than all three large dams in the uMngeni River system (Midmar, Albert Falls and Inanda dams) or about 44% of the Pongolapoort Dam.

The lake was once an ancient river estuary, before it was cut off from the Indian Ocean by the gradual formation of a coastal dune barrier. Located in the northern part of KwaZulu-Natal, about 60 km south of the Mozambique border, Sibaya lies on a flat coastal plain where most of the surrounding landscape rarely rises more than 100 m above sea level.

But beneath the region's largely infertile and sandy soils there is a vital groundwater aquifer which has helped to sustain local communities and the ecology around Lake Sibaya for millennia. As part of this aquifer, the lake is an almost direct reflection of the regionally-important groundwater table.

Now the lake is in peril, drying out rapidly due to drought, increasing human water demands and the thirsty roots of exotic timber plantations that have been dubbed "money trees".

During the severe 2014-2016 drought, Lake Sibaya's water level dropped quickly – along with that of several other lakes and

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dams in the region. But whereas Lake St Lucia and local dams have improved gradually since the drought, Sibaya has not risen – and is still dropping.

According to Van Rensburg, the level of the lake reached the lowest recorded level in 2014 and has continued to decline since then. Van Rensburg, the coordinator of the Grasslands-Wetlands-Forests Node of the SA Environmental Observation Network (SAEON), says the main section of the lake has dropped over five meters over the last decade when historic fluctuations were only between one and three meters. Because of the surface area of the lake, even a small drop in water level equates to a large volume of water lost.

Having separated from the main lake for the first time in living memory in 2015, the southern basin – which supplies Mbazwana and Sodwana Bay – has now dropped even lower than the main lake.

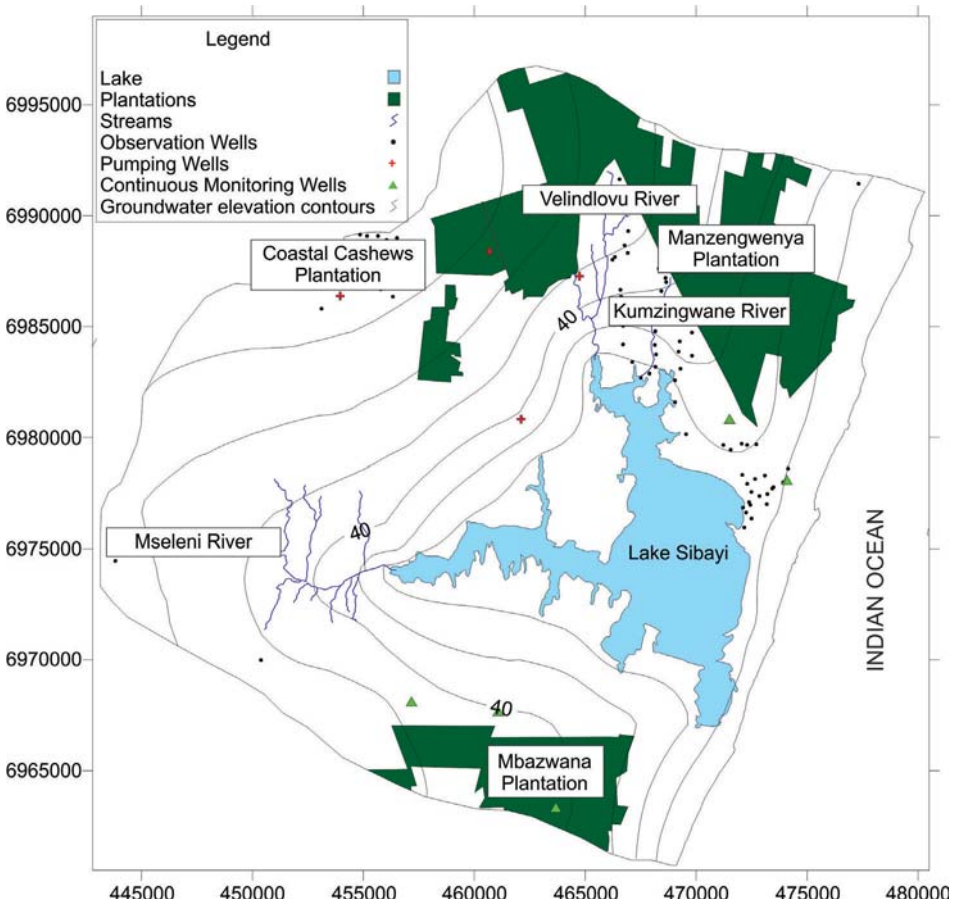
One of the main reasons for this, explains Van Rensburg, is because Sibaya is almost entirely dependent on local rainfall and groundwater recharge. Unlike open river estuaries (which receive both seawater inflow, and freshwater from surrounding rivers) Sibaya has no large perennial rivers that import water into the system from upper catchments. If it does not rain locally, there is no recharge to the system.

Located in quaternary catchment W70A, the total catchment area for the lake is estimated at 530 km^2, of which 60-70 km^2 is taken up by the lake itself. The surrounding human population has also increased significantly in recent decades, although recent studies by Prof Jeff Smithers of the University of KwaZulu-Natal suggest that water abstractions for human use are considered to be modest.

In a study published in 2017, Smithers et al. suggested that (other than drought) a major cause of Sibaya's recent water loss can be linked to depletion by water-guzzling gum and pine plantations.

The first State forestry plantations in the Sibaya area were established in the 1950s and now cover at least 23% of the catchment. Studies show that between 2001 and 2014, the level of Lake Sibaya dropped from close to 20 m above sea level to nearly 16 m above sea level – its lowest level since the commencement of record keeping more than 50 years ago and simulations going back to 1914.

Smithers and his colleagues also modelled the hydrology back to 1986. The results indicated that approximately 35% of the drop in lake levels since 2001 could be attributed to the impact of afforestation, although they noted that there was some uncertainty regarding the exact history, extent and impact of afforestation in the catchment. In contrast, the results indicated that the impact of domestic abstractions on lake levels had been 'negligible'.



Jannie Weitz

The first State forestry plantations in the Sibaya area were established in the 1950s and now cover at least 23% of the catchment. Hydrologists have suggested that at least 5km2 of plantations be removed to protect the lake's water resources.

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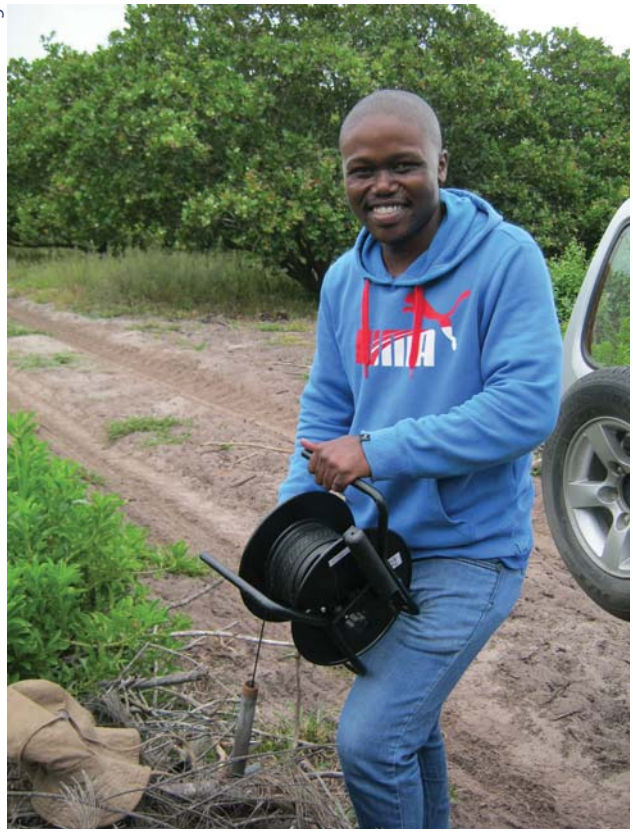
Sue van Rensburg



University of KwaZulu-Natal PhD student, Mlu Shabalala, onducting groundwater use management studies on early growth macadamia and eucalyptus plantations in relation to grasslands.

"The major cause of the drop in the level of Lake Sibaya since 2001 is postulated to be the 10-year period of significantly lower than average rainfall which lasted from 2001 to 2011," said Smithers. Subsequent analysis (Blamey et al) have shown that 2015/2016 was the driest year on record for the region.

A yield analysis demonstrated that at 2014 levels of water use from timber plantations and domestic abstractions, no sustainable additional yield was possible. The 2015/16 drought and subsequent erratic rainfall has exacerbated this situation.

Smithers suggested that at least 5 km^2 of forestry should be removed to provide for additional domestic abstraction. Several other studies in the region have also highlighted the significant impact of timber plantations on local water resources.

In 2018, Prof Molla Demlie of the University of KwaZulu-Natal (UKZN) reported that the large primary aquifer on South Africa's north-eastern coastal plain was under stress from domestic water abstraction, irrigation, commercial forests and reduced rainfall linked to climate change. Prof Demlie suggested that removing water-intensive commercial plantations from the recharge area of the catchments and halting over abstraction of the freshwater lakes were some of the solutions needed to avert serious environmental impacts.

Further studies by hydrogeologist Claudia Brites in the Nyalazi plantation near Lake St Lucia suggest that deep-rooted gum trees use more than twice as much groundwater compared to locally indigenous trees, while hydrologist Brian Rawlins reported that gum and pine plantations around St Lucia could reduce the lake's groundwater inflow by as much as 30% during periods of extreme drought.

More recent modelling studies by UKZN hydrologist, Jannie Weitz, warned that further severe depletion of groundwater around Sibaya could lead to salt-water intruding into the lake from the Indian Ocean.

SAEON's Sue van Rensburg has also voiced concern that climate change may be exacerbating the problem due to reduced rainfall in the catchment in recent years. Van Rensburg started visiting Sibaya regularly from 2014, capturing a set of time-series images which graphically illustrate the declining water level and gradual separation of the southern basin from the main lake.

Van Rensburg, a former regional ecologist for the Hluhluwe-Imfolozi Park who also spent two years working with communities around Serengeti National Park in Tanzania, is determined to help find a sustainable solution before it is too late: "Our job is to do science with and for society to ensure a more sustainable future"

She sees the emerging water crisis as an important research opportunity to understand the relative impacts of land-use, water abstraction, weather, climate change and sea-level change on one of the country's most important coastal aquifer systems.

Sue van Rensburg

SAEON technician, Siphiwe Mfeka, downloads groundwater data from a monitoring sensor. Working in collaboration with various stakeholders, SAEON has established a network of groundwater monitoring sites which it maintains to determine trends in ground water dynamics and how this links to lake level, climate and different land uses in the region.

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There is a very real need to provide economic opportunity in the region, she says, particularly in the north, where poverty levels are high. But she questions the sustainability of recent initiatives to reignite forestry expansion amid the alarming Sibaya water decline.

Over time, working with several collaborators including the Department of Water and Sanitation, commercial forestry and scientists, SAEON expanded its activities into the northern section of the coastal plain and from 2014 onwards, and has also provided logistical support to a Water Research Commission (WRC) project aimed at assessing the hydrodynamics of the Sodwana Bay system.

In 2015 node staff started working in the Vazi pans area, facilitated through a WRC project run by SAEON's Prof Colin Everson, which focuses on understanding alternative agroforestry systems and plant water use. "In May 2017, I called an informal meeting of invited experts in groundwater modelling who had insight into the Sodwana-Sibayi-Vazi-Kosi systems, including experts from the Department of Water and Sanitation," she notes. "The intention was to determine if there was consensus of what might be happening in the system and if there was a case for solid long-term observation by SAEON in the area."

But because of the extended drought and water loss, problems emerged in gathering reliable data after several monitoring stations and the only lake water level gauging station became stranded above the receding water line. SAEON has stepped in with temporary monitoring systems to help ensure a continued record.

Sue van Rensburg

Student, Josephine Magolego, and Sue van Rensburg of SAEON collecting water temperature samples from Lake Sibaya.

Van Rensburg notes that poverty levels around Sibaya are amongst the highest in the country and because the soils are poor for agriculture, there appear to be limited options for economic growth.

"It is therefore imperative when initiating work in the area to ensure there is community buy-in at the outset. The socio-economic context and concern regarding the potential impacts of alternative land uses such as forestry, which many see as the only major source of income, in my view necessitates a multi-disciplinary collaborative approach if we are to see traction in response to our work."

To this end, SAEON and the Isibusiso Esihle Science Discovery Centre (a home-grown science centre close to Vazi pans), hosted an informal workshop inviting relevant stakeholders and interested experts from different disciplines including hydrology, sustainability, resources economics and horticulture.

The workshop began by listening to the voices of community members and industry operating in the area and there was unanimous concern regarding the decline in the water table and the role that plantations may be playing in this in conjunction with the drought.

"The main request was for scientists to work together with industry and community members to understand trends, but more importantly, to provide guidance on alternatives: 'We know there is a problem, but we cannot remove the trees without alternatives being in place. Please work with us to find alternatives,' was the message that emerged."

Apart from the lake itself, impacts have also radiated out into the surrounding wetland areas, including dried-out pans where crocodiles, fish and hippo were once common.

"Changes in groundwater dynamics at a regional scale will consequently have impacts for both the wetland and the terrestrial systems. The vegetation is a rich mosaic of different grassland, forest, savanna and thicket communities and hosts a high number of endemics," she explains.

Large areas of unique peatlands have also dried out, with extensive fires adding to the damage. The peatlands in this section of Maputaland, estimated to be around 7 000 years old, play a vital role in retaining moisture from heavy rainfall and releasing it gradually. And as these unique, natural sponges and wetlands dry out, Van Rensburg says it becomes more difficult to map and accurately delineate buffer zones and land which should be off-limits to timber expansion.

While the National Water Act specifically details streamflow reduction activities, she believes these provisions do not cater adequately for impacts on groundwater-driven systems such as Sibaya. Ideally, she says, policies should be revised to take account of the unique hydro-ecological nature of coastal systems and climate change viability.

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Sue van Rensburg

This time-series sequence of images illustrates the rapid decline in water levels in the southern basin, Banda Banda Bay, of the lake since 2014

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Other potential solutions to land-use dilemmas, she suggests, could include greater community involvement in wildlife, marine and coastal tourism ventures. "Tourism will not make everyone rich. But it can provide a sustainable living for more people in the vicinity of the iSimangaliso Wetland Park World Heritage Site. This region has so much to offer and there is no reason why it should not become a rival to Kruger National Park."

According to the national Department of Environment, Forestry and Fisheries, the Mbazwana and Manzengwenya plantations are still classified as a State Forest but the biological assets were transferred to the Tembe, Mbila, Mabaso Development Trust by the Department of Agriculture, Forestry and Fisheries in April 2016.

The community trusts then formed Tembe Mbila Mabaso Forestry (TMM), to manage the plantations. TMM Forestry took over the management of the plantations and were currently carrying out all operations related to harvesting, silviculture and forest protection.

Responding to questions from ***the Water Wheel*** on what action had been since 2017 to implement the recommendation to remove at least 5km^2 of plantation forests from the Sibaya catchment, department spokesman Albi Modise said that TMM Forestry was well aware of the situation around Lake Sibaya.

"The plantations were established in the 1950s and the Department of Water Affairs and Sanitation are currently dealing with this issue . . .TMM is in the process of planting macadamia trees on 3 000 hectares of land as these trees use far less water than Eucalypts, hence the change in land use will be beneficial to Lake Sibaya."

He added that SAEON was also on board with TMM and had established a monitoring site on the first area planted with macadamias trees.

"They will establish the water use of the trees and try to provide an evidence-based approach to understanding trends to work out relative impacts of climate change. They will be establishing a site in new Eucalyptus plantings as well so that the water usage between the two different crops can be proved scientifically."

"TMM survives on timber sales and no grant funding is available to manage the plantations. For this reason, the company is intending to utilise all the available timber whilst managing the plantations in an environmentally sustainable manner."

Modise said the plantable area in the Manzengwenya plantation was 13 000 ha and that removal of 5 km^2 of timber would make this unit uneconomical for a timber plantation. TMM was also exploring alternative water-efficient crops, along with cattle farming and tourism.

Van Rensburg emphasises that Maputaland is a unique area requiring unique treatment and that part of the solution will depend on building a common vision, unlocking the region's ecotourism potential, combined with innovative, profitable, and climate-smart agricultural systems.

"We are moving into a new era where old rules, past trends and methodologies may no longer be appropriate. Exploring solutions as a collective with all parties represented and using social learning processes may be an important approach for ensuring long term success."

Sue van Rensburg

Banda Banda Bay, southern basin. Mlu Shabalala, UKZN PhD student on his first trip to the region gains an understanding of how important his work is to provide evidence-based decision support for water-wise land use for the region.

Sue van Rensburg

High and dry. A Department of Water and Sanitation gauging station at Banda Banda bay is now stranded above the receding water level.

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HYDRAULIC FRACTURING

Fracking and earthquakes: Taking stock of seismic risks in the Karoo

What does seismic risks and hydraulic fracturing have in common? The latest research in Leeu-Gamka in the Karoo provides some interesting results that should inform local shale gas development plans and practices, according to the scientist involved. Jorisna Bonthuys reports.

Efforts to extract shale gas resources in South Africa have been under intense public scrutiny in recent years.

The government has been looking into hydraulic fracturing or 'fracking' in the Karoo as a way to broaden South Africa's energy mix. This has been met with push-back from lobby groups and environmental organisations that are concerned about its impact on agricultural water resources and long-term socio-economic prospects in the region.

There are also concerns about the impact of such plans on the country's already high per capita carbon footprint in the context of the current climate crisis and South Africa's international obligations to reduce its fossil fuel dependency.

Government and energy companies are reportedly still contemplating their next moves in this regard. At the moment no applications for shale gas rights can proceed until the necessary technical regulations are promulgated by the Minister of Environmental Affairs, Janse Rabie, Agri SA's Head of Natural Resources, indicated.

And while legal battles were underway in 2019 about the Department of Mineral Resources' fracking regulations, a Cape

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Town researcher generated new knowledge about seismic risk and geohazards in the southern Karoo.

Melody Finn believes these results should be taken into consideration when future fracking plans are considered. Not only is the debate about fracking about the potential risks of groundwater contamination and the use of fossil fuels: there are seismic risks involved too.

Fynn received her Masters Degree in the Department of Geological Sciences at the University of Cape Town on this subject. Her study, titled ***Micro-seismic Observations in Leeu Gamka, Karoo, South Africa,*** has provided new insights into our understanding of microseismic activity in the interior of the country.

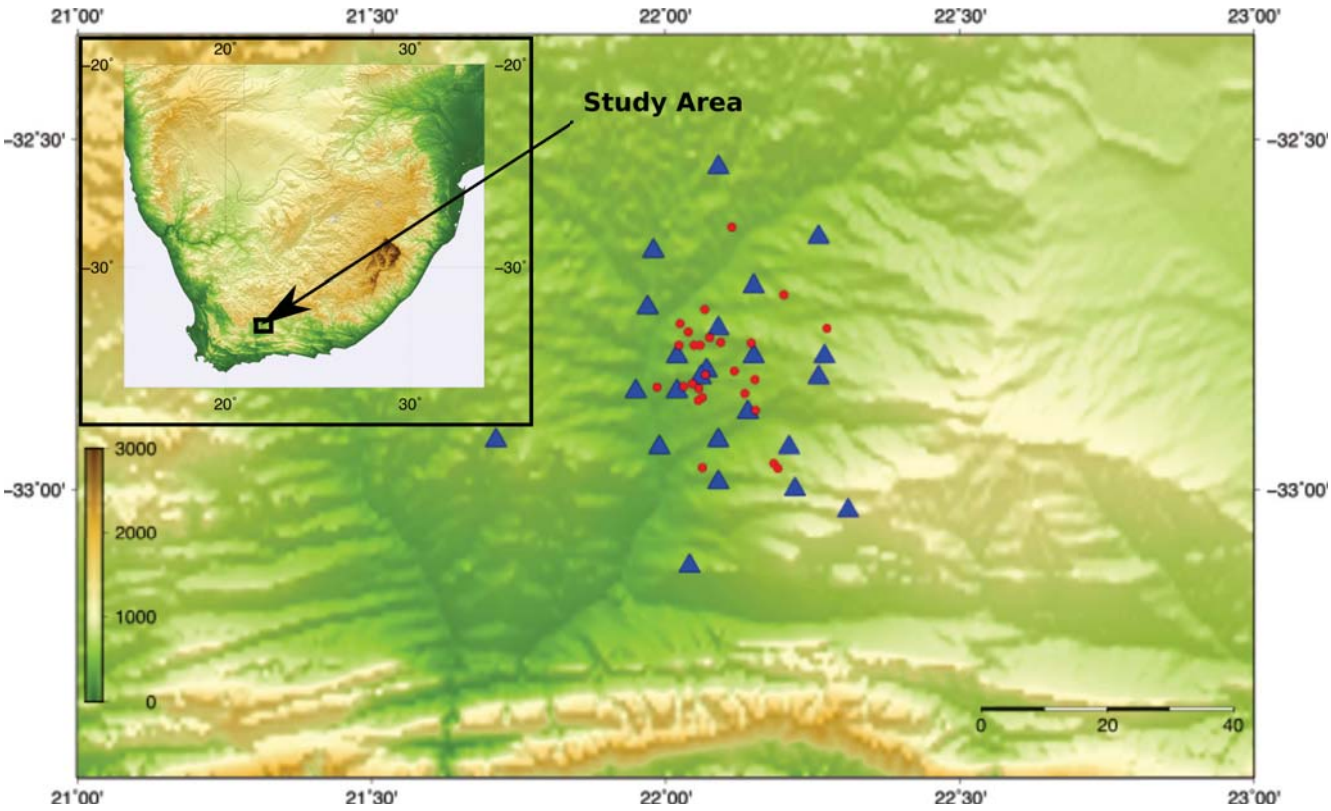
This study is important because the area she focused on is of economic interest to those interested in shale gas exploration.

Tectonic setting

The International Seismological Centre catalogue reported 27 localised anomalous seismicity in the Leeu-Gamka region between 2007 and 2013, with local magnitudes up to ML4.5. These small quakes occurred in a region that is considered as tectonically stable, and far from major tectonic plates. Leeu-Gamka's "seismic swarms" occur in a region which shows little evidence for previous earthquake activity or a fault segment that reaches the surface.

Fynn wanted to understand what caused these swarms. She also wanted to investigate the depth of the earthquake, the orientation of the structure along which the earthquakes are occurring and its source mechanism.

She deployed an array of seismometers in Leeu-Gamka, covering an area of 60 km x 65 km on private farm land based on the previous seismicity recorded in the region.



Melody Fynn

An illustration of the study area with the station locations as blue triangles .

These instruments were installed by digging a 30-50cm deep hole. After three months, the instruments were collected from the field. The data, which had been logged with GPS signals for accurate timing, were analysed.

Seismic swarms differ from earthquakes that are followed by a series of aftershocks in that there is no obvious mainshock in the sequence.

Fynn identified a total of 106 earthquakes from March-June 2015 in the Leeu-Gamka area. Interestingly, almost all of these events happened in the same small area (75% of the epicentres fall within a one square kilometre block).

She then calculated an average hypocentral depth of approximately 6km for the earthquakes, assuming a depth to the base of the Karoo of 5 km. This places the earthquakes just below the base of the Karoo, in the Cape Supergroup. The magnitudes of the earthquakes recorded range from -1.5<ML<0.4.

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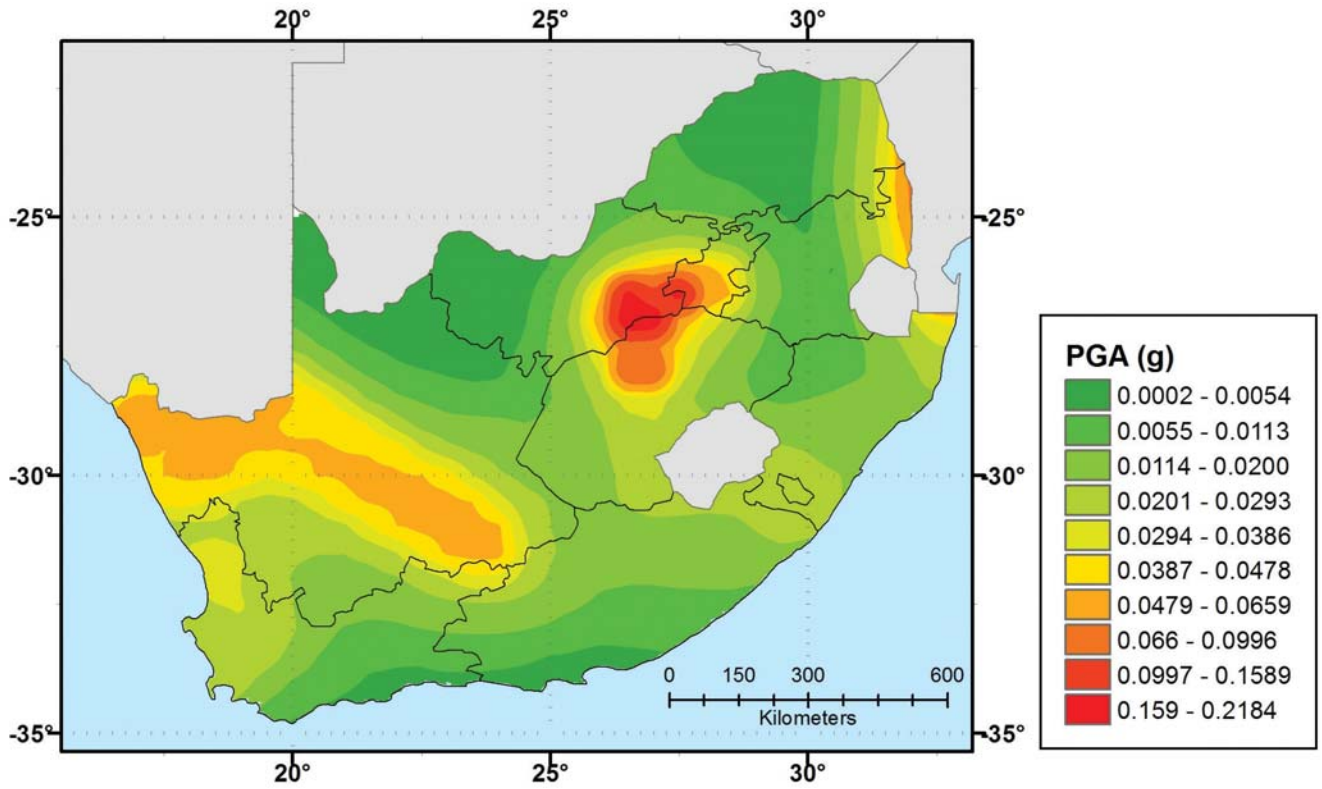
Fynn's work showed there is an active NW-SE strike-slip fault in this area, consistent with the distribution of the earthquakes. The presence of such a structure has implications for shale gas exploration in that wastewater pumping in an area with active faults could trigger larger and more frequent earthquakes, as seen in case studies in the central states of America, in particular, Oklahoma.

To understand this risk, we have to consider seismicity in the region.

Council for Geoscience)



Seismic hazard map of South Africa.

Spotlight on seismicity

Seismic stresses produced by relative tectonic plate motions result in frequent earthquakes at plate boundaries, where more than 90% of natural seismicity occurs. These are the most widely studied earthquakes and are relatively well-understood, Fynn points out.

"By contrast, large earthquakes in the interior of continents, known as intraplate seismicity, occur far from plate boundaries, are rare and are poorly understood. Surface evidence of ruptures is also generally absent during these quakes in the study area and makes them harder to study. South Africa falls within this region type."

Although far less common, earthquakes located far from plate boundaries are still capable of releasing large amounts of seismic energy and are often located on pre-existing structures. The potential energy that can be released on intraplate structures should not be underestimated, Fynn says.

"The essential concept of plate tectonics is that stress builds up on faults over time until the frictional strength of the clamping forces holding the fault together is exceeded, releasing energy in the form of an earthquake," Fynn explains. "It is, therefore, important to understand the conditions in which intraplate earthquakes might occur, especially those areas whose inherent stress conditions may be affected by human-induced activities."

Sporadic earthquakes sometimes occur as a single seismic event on an old fault that has not recently been active, she says. "This seems to be a characteristic that most stable continental regions share." This means that intraplate earthquakes can occur in regions where seismicity was not recorded before and no surface evidence for strain accumulation is observed.

The ML6.3 earthquake in Ceres-Tulbagh that occurred on 29 September 1969 is such an example. This event resulted in at least 12 deaths and considerable damage to infrastructure in the northern Boland. Interestingly, the towns of Ceres and Tulbagh have continued to experience regular seismicity after the quake and its aftershocks.

Southern Africa is generally classified as a stable continent region, bounded to the northeast by the East African Rift System (This is an active continental rift zone where the African plate is in the process of separating into two separate plates: The Nubian plate which is moving towards the west relative to the Somali plate, which is moving towards the east). Although this structure is not well defined, it is linked to much of the seismicity in Mozambique, Zambia, Zimbabwe, Namibia, Botswana and South Africa according to a recent article in the ***Journal of African Earth Sciences***.

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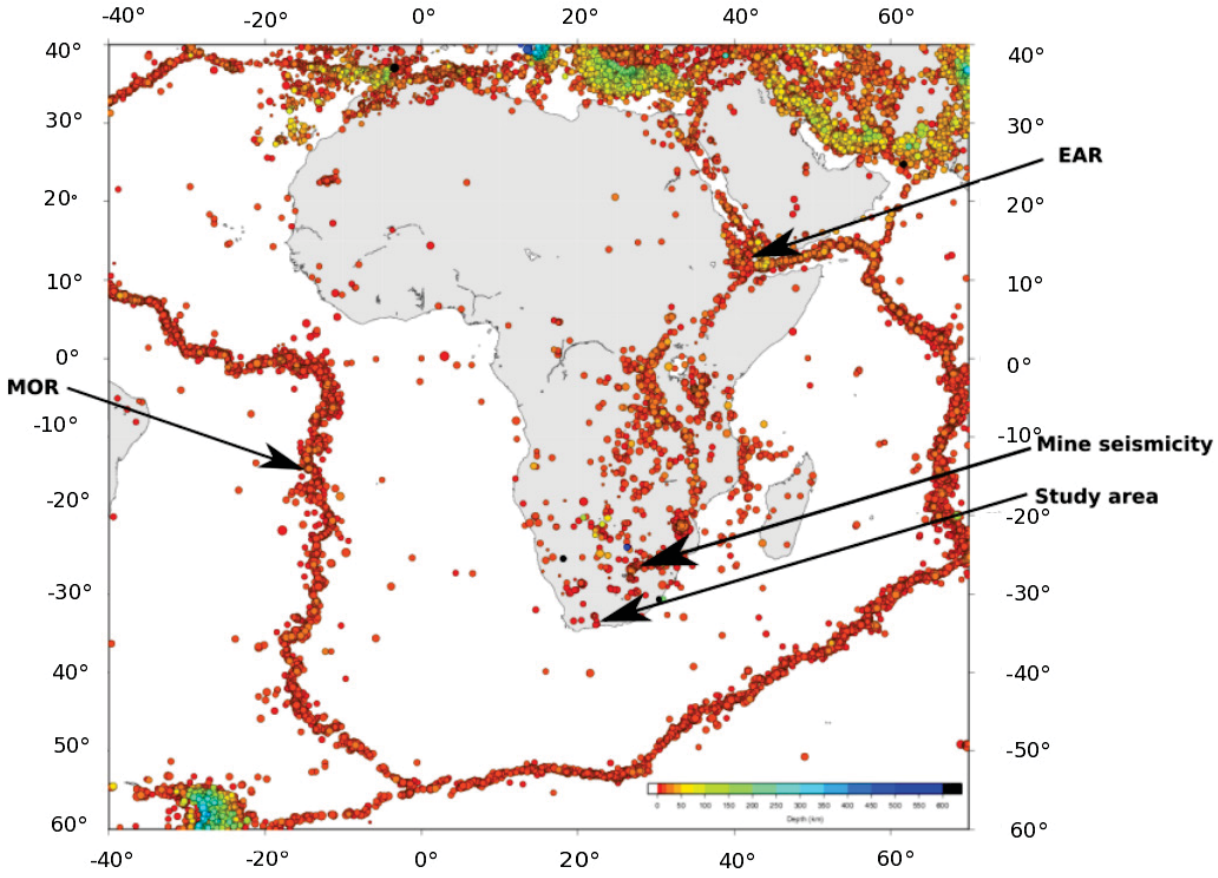

Melody Fynn

Map illustrating the plate boundaries.

Although massive earthquakes do not happen often in South Africa, it has happened according to geological evidence. The largest recorded earthquake in southern Africa is located at the southernmost extent of this system, in south-western Mozambique. The MW7 earthquake was recorded on 22 February 2006 and was unusually large considering that the earthquake occured at a divergent plate boundary, which typically produces events with smaller magnitudes.

"There are many, many smaller quakes and examples of rumblings underground – you just have to listen in the right place," according to Fynn. A total number of 22 089 earthquakes were recorded by the South African Network between 1996–2016.

Most of the seismicity recorded in South Africa is mining-related, but occasionally, clusters like the Augrabies cluster in the Northern Cape, the Drakensberg, Ceres-Tulbagh and quite unexpectedly in Leeu-Gamka, are observed and are of tectonic origin.

The stress region of the study region is according to Fynn influenced by the southern extension of the East African Rift System and the so-called Wegner Stress anomaly along the western coast of Southern Africa. These regimes are largely responsible for earthquakes of a tectonic source in South Africa and are mainly observed in the western regions of the country, including Ceres-Tulbagh and Augrabies.

Until the Tulbagh quake occurred, intraplate regions such as the Western Cape were conceived as effectively rigid and subject to no tectonic loading, except at distant boundaries.

The recurrence time for large earthquakes in individual parts of an intraplate seismic zone may be very long, measured on a scale of millennia rather than centuries, Hartnady says. "Consequently, the historical and instrumental seismic record yields an inaccurate view of the long-term seismicity, and seismic hazard analysis requires additional, scientific tools."

In the early understanding of the African plate, the Western Cape is far from an active plate boundary, explains Dr Chris Hartnady from Umvoto Africa. Hartnady, a former professor at the University of Cape Town, is involved in efforts to improve early warning systems for earthquake hazards in South Africa.

"It is, however, located close to the rifted ocean-continent margins that formed during the break-up of the Gondwanaland supercontinent, between 180 million and 135 billion years ago," he says. "So the western and southern parts of the province are riddled with major faults related to this episode of the supercontinent breakup."

In South Africa, the map of seismicity is dominated by mining regions due to two factors. "Firstly, natural or tectonic earthquakes are relatively rare in South Africa due to its location far from the plate boundary zones," Fynn says. "Secondly, seismic monitoring is concentrated around the mines due to the potential risk of earthquakes to mining." This means that more smaller earthquakes are recorded around the mines

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than elsewhere and this leads to an artificially high density of seismicity if all events are considered, she says. Fynn plotted all ML>4 earthquakes in southern Africa.

The largest mining-related earthquake to be recorded in South Africa was a ML5.5 and occurred near Orkney on 5 August 2014 in the KOSH ((including Klerksdorp, Orkney, Stilfontein and Hartbeesfontein) mining district. The region is quite active with more than 8 000 events recorded between 1971 and 2014 as well as about 150 events of magnitude greater than or equal to MW4.

Lessons from Oklahoma

Since the 1960s, the link between wastewater injection and seismicity has been documented.

This has been seen extensively in Oklahoma, also a previously seismically quiet region, where large earthquakes (>ML5) have been linked to the disposal of wastewater injection with the source locating within a few hundred meters of wastewater injection wells. In 2014, Oklahoma recorded more earthquakes than California, situated on a major active fault and known for its geohazards and seismic risks.

A relationship between increased seismicity and injection of wastewater has also been widely reported in Colorado, Ohio, Arkansas, Texas, New Mexico and China and seems to lead to larger magnitude earthquakes than those said to be related to fracking.

The pumping of wastewater, associated with the process of hydraulic fracturing, into a seismically active region can reactivate dormant faults, increase the seismicity on active faults or induce larger earthquakes than previously experienced or expected.

Research shows an increase in seismicity due to wastewater injection can happen because the pumped fluid causes an increase in pore-pressure which reduces the effective normal stress (or clamping forces) on the fault.

Seismicity can be triggered by changing the pore-fluid pressure at depth. "Faults usually remain locked by the pressure of an overlying column of rock and injecting fluids can counteract the pressure, making the frictional failure of rocks more likely," Fynn says.

A precautionary approach

Hartnady believes a prudent approach to groundwater-resource development requires micro-seismic monitoring in areas that undergo low levels of natural earthquake activity or if wellfield development has the potential to trigger induced seismicity.

Temporary deployments of seismic monitoring arrays have recently been undertaken in the Western Cape to demonstrate ongoing micro-earthquake activity following the 1969-1970 Tulbah-Ceres seismicity and the 2009-2011 Leeu-Gamka earthquake swarm.

Perturbations of stress may be a result of an increase in pore-pressure at earthquake source depths, or from local changes in secondary stresses, for example, surface loading and unloading. In the Karoo, these secondary stresses could originate from unloading caused by excessive borehole water extraction or in the case of possible fracking activities, the pore-pressure could be increased by waste-water injection.

It is also possible that natural seismic swarms can be attributed to fluid overpressure, Fynn points out. Some researchers argued that fluid pressure at depth plays a key role in earthquakes occurring by lowering effective stress on highly stressed fault segments close to shear failure.

Earthquakes can also be triggered by loading and unloading of the crust by surface or groundwater. Research showed that changing the local stress by extracting water from a shallow aquifer likely caused the ML5.1 earthquake near Lorca, Spain in 2011.

This is important for an area like Leeu-Gamka Fynn says. "Earthquakes greater than >ML3 associated with fluid injection are almost always associated with the injection of large volumes of wastewater, and not necessarily the deliberate, controlled formation of fractures to liberate the gas during the fracking process."

The depths of the earthquakes was a key research outcome, Fynn says. The location of the seismicity will prove to be important if fracking should start in the region, particularly if the wastewater produced is re-injected into the subsurface to a similar depth of the active fault.

Providing a baseline study of seismicity and identifying active faults in a region being considered for shale gas extraction is vital.

What this study has revealed, is that there is an active fault in the region with a NW-SE striking surface, capable of generating an earthquake of ML4.5, the largest observed within the period between 2007–2013. "I can say with some degree of confidence that the earthquakes in the Leeu-Gamka region are a consequence of reactivation along a pre-existing fault," Fynn says.

The active part of the fault identified starts at a depth of approximately 6 km, a critically stressed zone within the Cape Supergroup, and could further be exacerbated by wastewater injection near this depth if this method is adopted for disposal.

The disposal of wastewater produced by fracking merits further study, Fynn adds. Studies are also needed to examine earthquake swarm processes and their potential for reactivating inactive faults or unidentified faults in a particular region, she concludes.

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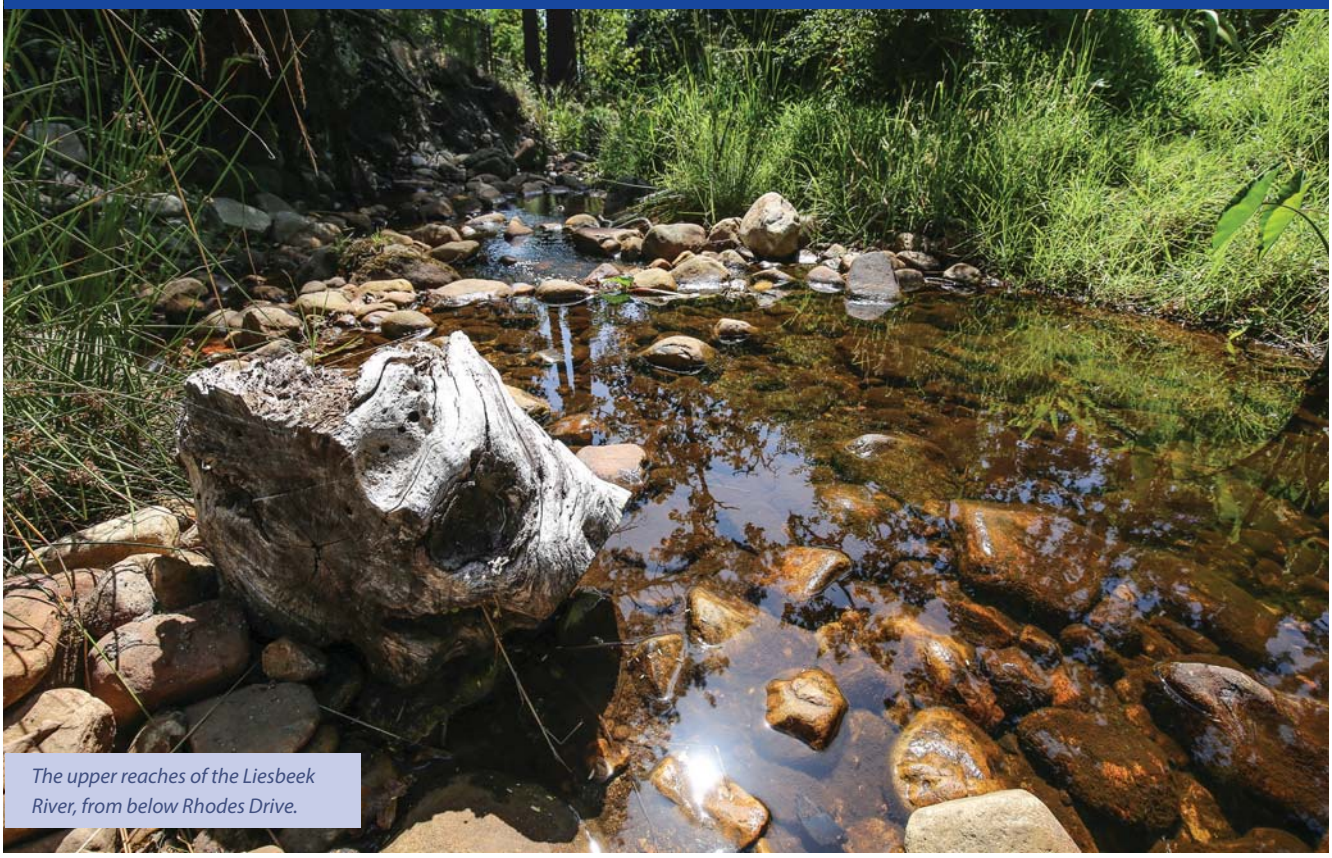
RIVER HERITAGE

Liesbeek – The people's river of Cape Town

Urban river, the Liesbeek, has been transformed after action by the residents of the City of Cape Town. Petro Kotzé reports.

All photographs by Petro Kotzé



The upper reaches of the Liesbeek River, from below Rhodes Drive.

People have followed rivers for centuries. Today still, the origin of many cities can be traced back to a stream that allowed people to settle, and flourish. Another common trait of today's cities is the severe pollution of the streams that run through them. As development continued, the pristine rivers that the cities' establishment and expansion were built on, often paid the biggest price.

Cape Town is no different. Yet the Liesbeek, a river that supported much of city's early development, is now following a different trajectory. Once described as utterly unfit for human use, it has become the cleanest urban river in South Africa. This is according to Dr Kevin Winter of the Future Water Institute at the University of Cape Town. For him, the Liesbeek is a living laboratory and, lessons from the river's recovery is now circling out far beyond the basin, as he lectures on the topic locally and abroad.

As a specialist in Water Sensitive Urban Design, the Liesbeek offers Dr Winter a good example of how conservation of green infrastructure such as rivers, can be applied to solve modern day urban challenges, including stormwater management and climate adaptation. Over and above this, the river is also a prime example of residents retaking ownership of an urban river for a better quality of life.

Himself a Cape Town native, Dr Winter says that there is much more to the streams that run through our cities. "Our rivers need

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to become recognised as heritage and national assets."

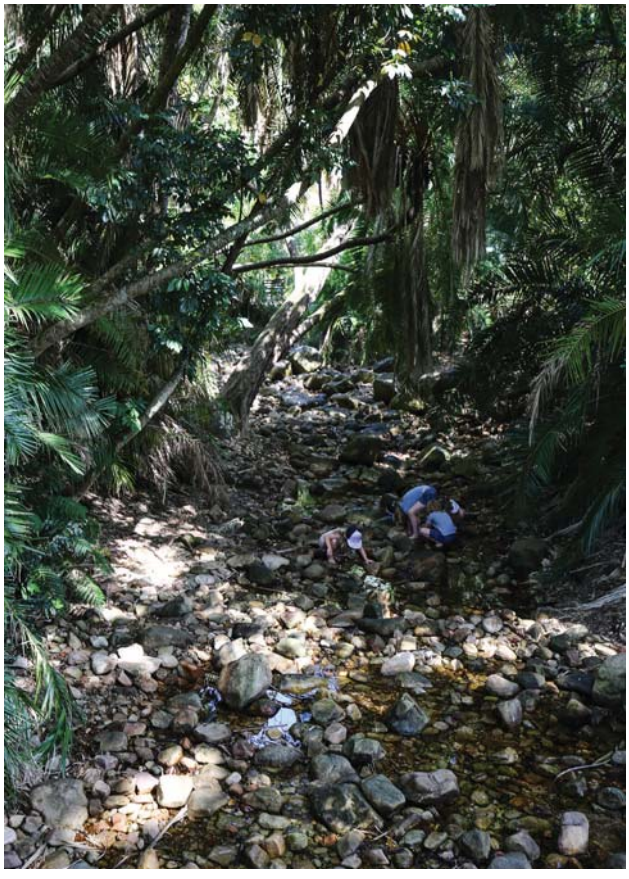
For this, the Liesbeek is a strong contender. Following the river from source to mouth provides glimpses into the past of the city that blossomed on its banks, snapshots of how it developed from there and a possible preview into a future where people turn to face a near-forgotten urban stream, once again.

The river's source

The source of the Liesbeek is on the eastern slopes of the iconic Table Mountain. Due to the angle of the slope to the prevailing southwesterly, the moisture trickles down into streams that run year-round, unusual for a city that depends on winter rains.

You can meet the streams on their way down. The easiest is to meander up the mountain slopes through the Kirstenbosch National Garden, via the Smuts track and the Yellowwood trail, making your way under the foliage of some of the last remaining pockets of Afromontane Forest (or, mountain forest of Africa). Though lush with yellowwoods, stink woods, hard pear and red alder, the forest is but a whimper of its formidable former self. Jan van Riebeeck noted in his diaries that the eastern slopes of Table Mountain, stretching down to the Liesbeek itself, were covered by forests "so dense from the top to the bottom, close to the river, that no opening could be found."

Today it's easy to spot the four amber coloured streams that flow through the garden to form the Liesbeek. The Vaalkat Stream



Kids play in the Skeleton Stream as it runs through the Kirstenbosch gardens.

Dr Kevin Winter, head of the Future Water Institute at the University of Cape Town.

joins the Nursery Stream and eventually, the Skeleton. These are joined by the Window stream, and all of them rush downward towards Rhodes Drive. It's not marked but between the fence of the main parking lot, and the manicured lawn that marks your entrance to the garden, a big tunnel runs under Rhodes Drive, spitting water out on the other side into Bishopscourt.

This then, is the Liesbeek. Today, it's a river born from a culvert, to run to the suburbs.

The Upper Liesbeek River

When Jan van Riebeeck arrived the Liesbeek was still wild. Full of fish and large eels, the river's banks were visited by plenty of roe, eland, hares, ducks and partridges. Others noted tracks of lions, "tigers", "wolves" jackals and very large baboons.

Once, hunter-gatherers came to enjoy the bounties that the river offered but the Dutch too, depended heavily on it in their early years of settlement. Yet, they pillaged the resources instead. The yellowwoods, rooiels and wild olives were the first to disappear, but the destruction of the forests along the Liesbeek was eventually near complete.

Today, the Liesbeek here wears a thin cloak of shrubs and trees, decorated with Arum lilies and fern trees. The air is permeated by pine, a whiff of the exotic oaks and cluster pines introduced by the Dutch and the British. The destruction of the trees would forever alter the river. Their roots would have protected the

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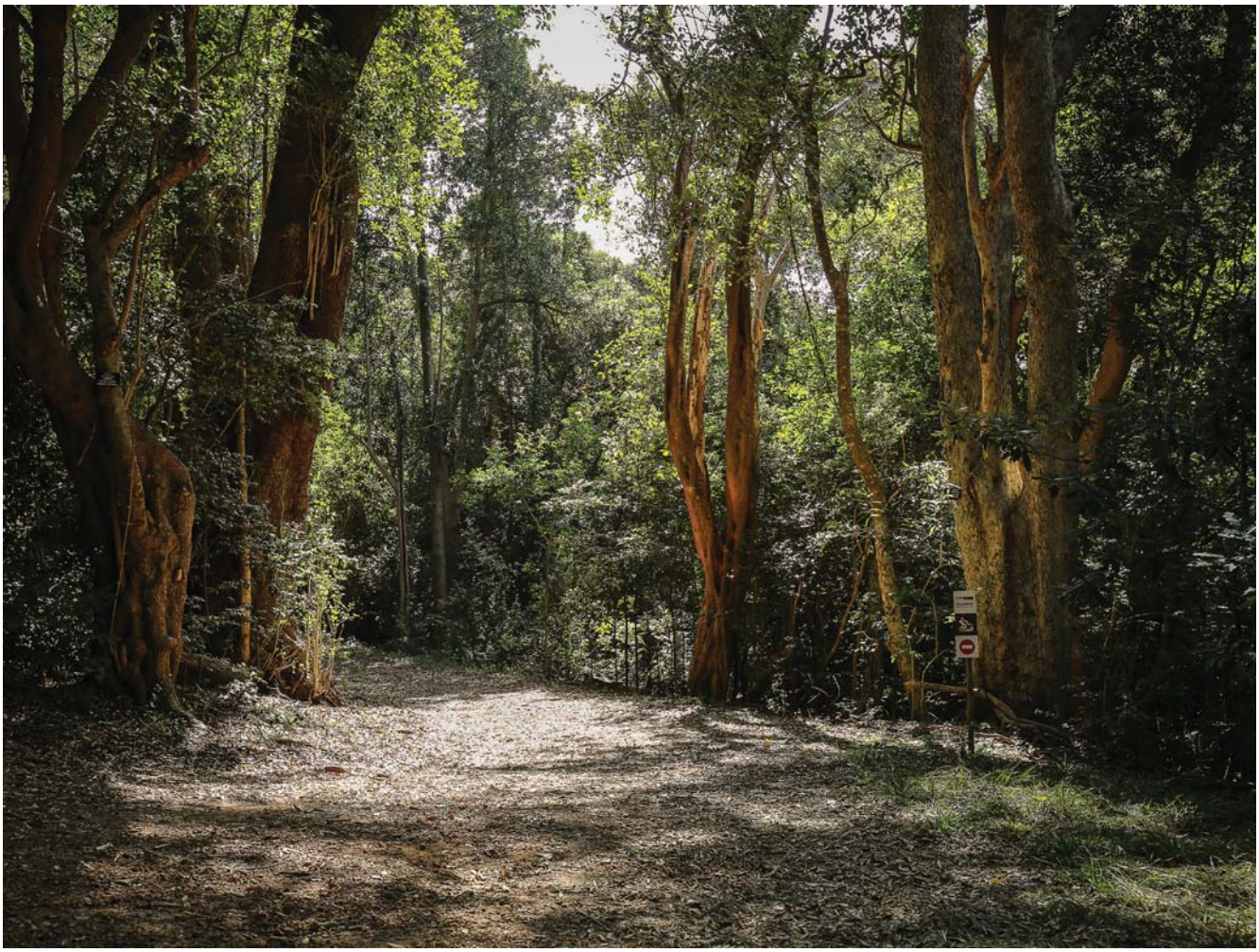

Pockets of Afromontane Forest remain protected in the Kirstenbosch Gardens.

riverbanks from erosion, and provided food for many animal and micro-organisms. In comparison to their gradual shed of leaves from spring to summer, exotics drop theirs quickly in autumn, affecting food inputs into the river, and altering its flow with their foreign water needs.

Today, visitors are mostly hikers and dog walkers who let their pets cool down in the bubbling stream. It's not accessible all the way, but with only a bit of effort you can squeeze through the plants to follow the crisp water as it tinkles along over smooth, brown pebbles. Along the way, you will find hidden riverbank gardens, fenced off sprightly green lawns and lovingly tended beds that must be for private use alone.

It's an old tradition. Somewhere around here, on the slopes of Bishopscourt lies Van Riebeeck's farm; apparently his garden was regarded as the best in the British Empire outside of Britain. He would have tapped water from the Liesbeek for it, a tradition that must have continued judging by the pipes from the properties into the river.

Eventually you emerge close to Kirstenbosch Drive again, reaching the road by clambering onto an embankment. At closer inspection it harbours a stormwater pipe. It's only a small opening but, in the life of the Liesbeek, it represents a big transformation.

Stormwater and the Liesbeek

Except for the loss of riverine vegetation, the roads and pavements that were eventually constructed led to more problems for the Liesbeek. The hardened surfaces reduce the volume of water that infiltrates to the soil and groundwater. Instead, contaminated runoff is discharged to the river rather than giving natural systems time to absorb and process the pollutants.

Dr Winter explains that this leads to what is called the "urban stream syndrome" – roughly described as the consistent altercation of a stream's form, flow and function until the ecological services eventually collapse. Symptoms include higher-than-usual spikes in river flow during rainfall due to the water channeled in from the streets; an increase of concentrations of nutrients and pollutants; changed channel shape; and a decrease in species diversity, while select species start to dominate.

Yet, the Liesbeek here is still a lovely sight. A little bit further down, Riverside Road hugs its banks for an easy walk onwards. The aptly named Moss and Thistle streets Holly and Garden roads add to the pleasant atmosphere, but much of the joy of the walk from here is thanks to a group of volunteers called the Friends of the Liesbeek.

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The river wins new friends in Cape Town

The Friends of the Liesbeek River is a group of local volunteers whose aim it is to create an awareness of the importance of the Liesbeek as a green corridor in an urban setting. They also work to rehabilitate, enhance, and conserve it and its environs. They started in the early nineties amidst public calls for the restoration of the Black and Liesbeek rivers.

From small beginnings, they now employ a permanent team to keep the river clean from litter and alien vegetation as much as possible, says chairperson Phil McLean. This is constant work. Each week, he says, they still pick up at least 62 bags of trash along a stretch of the river downstream. However, their effort has completely changed the fate of the Liesbeek. If it was not for their work, the river would still have been little more than a conduit for trash, with overgrown banks that became no-go zones to residents.

Thanks to the friends, you can now enjoy a pleasant and safe walk along the river – they rallied for the construction of the pedestrian trail. It's a relaxing walk, quiet even on weekends. Since residential development began, much of the upper Liesbeek was, and remains, fairly elite, with large plots. Now the river vegetation is a mix of popular garden varieties; a lovingly tended Bromeliad garden on one side, an embankment thick with Boston Ferns on the other.

A delightful example of residents taking ownership of a river is the Upper Liesbeek Garden, not far upstream from the busy M3. Driven by a local resident, the overgrown banks were transformed with tree trunk benches and flowerbeds. Crabs, tadpoles and butterflies now dart between the water and the plants, and the space is enjoyed by a variety of people.

Just up the embankment, the sound of a babbling brook is replaced by the buzz of traffic. It marks the real start of what some describe as the most devastating action that can be done against a river. From here, the Liesbeek is canalised.

Taming the Liesbeek

The difference between the highest and lowest points of the Liesbeek's catchment is 1 079 m. When it rains, stormwater rushes to the river down this steep gradient, resulting in floods. City engineers responded by canalising small sections to send water as quickly as possible out of the city and keep residents safe. The practice continued until almost the entire river (about 70%) was canalised, except for about two kilometres below Kirstenbosch and a few other short stretches.

Still, the Friends of the Liesbeek was determined to take the river back. As it slips under the M3 it emerges cascading into Paradise Park. McLean says that this another of the achievements that they are immensely proud of, after taking huge initiative to upgrade the space. Before, it was overgrown, creating "a place that security guards did not even want to cycle through," he says. On this weekend, it's full of kids and grownups soaking up the sunshine.

Further away from the playpark, just around the bend and hidden from the noise of the M3, people are lounging in the shady riverbanks. Kids play in the shallow waters of the canal, treehouses hang over banks and groups are picnicking along the shores. From here, the river disappears into the suburbs. From over a fence you can see the water run past the Vineyard Hotel's lush riverbank garden, but otherwise it's not that easy to follow it through the suburbs anymore.

Instead, Dr Winter says it's best to tackle it on scooter, which allows you to slip through the grinding Cape Town traffic. By the time you hit Newlands, few people must be aware that the Liesbeek exists close by, though there are signs. The famous Newlands Brewery was born from the water of the Liesbeek. The beer was first brewed on its banks, but later operations moved to Newlands, today the oldest commercial brewery in South Africa.

At Rondebosch the river runs past the back of the Riverside Mall. Once, Van Riebeeck noted the presence of tiger, lion and a large wolf at Rondebosch, but today the banks are bare except for traffic, pedestrians and pavement.

Dr Winter explains that when the mall was redeveloped ten years ago, The friends (as registered interested and affected parties) attempted to influence the developer to redesign the existing shopping centre so that the shop frontage faced the river. Siting cost constraints, they decided otherwise, placing the parking entrance and deliveries next to the water instead. "It could have been a triumphant re-think, but the developer missed the chance ….big time!" says Dr Winter. It shows. Along the banks,

Downstream of the Liesbeek Garden, towards the M3.

Paradise Park.

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The Liesbeek River as it flows through Rosebank.

broken bottles are only some of the trash lying around, and a lone shopping bag drifts downstream with a pair of ducks. McLean says this stretch of the river is one of their biggest headaches, as a lot of litter is generated here in the commercial area.

Onwards to Rosebank

Though motorists whizzing past along Liesbeek Parkway are probably unaware of it, Rosebank features the best example of the living lab that the Liesbeek has become. A strip of artificial wetlands have been constructed along the river. Dr Winter explains that the project is an example of how natural infrastructure can be used to manage stormwater quality to the benefit of the environment.

Polluted stormwater is fed through a biofiltration wetland before it enters the Liesbeek, removing nutrients, pollutants and heavy metals in the process. Except for looking much better than a tarred pavement, and providing a natural environment for many species to thrive, Dr Winter says that the system also works very well. The wetlands are doing a robust job of treating the stormwater to a suitable quality before releasing it into the river.

Here too, Capetonians are enjoying the river again, walking along its edge to soak up the last of the disappearing sun. "We underestimate the role of ecology in people's enjoyment of the river, and in bringing nature back into the city" says Dr Winter. That's part of the reason why some residents are pushing back, against developments that are pushing ahead.

An example is the Two Rivers Urban Park, located below Rosebank and Mowbray where the Liesbeek meets the Black River at Observatory. Dr Winter explains that the location of the development is unsuitable, and is likely to impact flood levels of the river.

However, the river's right is now at least partially protected by the very residents of the city that developed around it. McLean says the Friends of the Liesbeek now has over 1 000 supporting members, on whose behalf they lobby for the conservation of the river through responsible development.

Eventually, the Liesbeek empties into Table Bay at Paarden Island, after its nine kilometer journey from source to sea. It would have followed this route for millions of years. It's only recently, as the city developed, that it faced such big changes, as with many other urban rivers around the world. Still, says Dr Winter, there is hope in the Liesbeek. "It's an urban river that's a good example of what others can be like too."

Sources

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- *Re-Using water in the Liesbeek River, Cape Town by Tom Sebastiaan Krul*
- *The changing landscape of the Liesbeek River Valley - An investigation of the use of an Environmental History approach in historical research and in classroom practice by Jean Botario*
- *Friends of the Liesbeek website, http://fol.org.za/*

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BULK WATER SUPPLY

The balancing act of Gauteng's water security

To secure water for Gauteng in the long term, some important actions are required in the short term. Petro Kotzé investigates.

Alastair Mclachlan

"It's not a crisis, but one thing is for sure, it can't be business as usual," says Timothy Nast, Gauteng Provincial Government Chief Director of the Planning Division, in reference to the province's water security.

Gauteng's water supply has always been precarious, but outside of prolonged droughts, a supply has always been secure. Perched on the divide between the Limpopo and Orange river basins, the province itself is home to few streams. Apart from the 15 million or so residents that call it home, a constant and secure water supply to Gauteng is also critical because the province supports the bulk of our country's economy.

To ensure this, water is imported via the highly engineered Integrated Vaal River System (IVRS). This collection of dams, rivers, pipelines and canals supports the quarter or so of all South Africans that reside in the Gauteng City Region (GCR) as well as 50% of the country's GDP (water is also supplied to a substantial proportion of the economic activity in the Crocodile-Marico and Upper Olifants catchments). ESKOM, SASOL, mines and vast urban settlements all tap from the IVRS.

Why Gauteng doesn't run out of water

Gauteng is thus water secure because it taps water from beyond its borders. The IVRS's system of pipes and infrastructure imports water from five different river basins, across six provinces and

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Lesotho. It includes water from the uThukela River in KwaZulu-Natal (stored in the Sterkfontein Dam), the upper uSuthu in Mpumalanga and, through the Lesotho Highlands Water Project (LHWP), the Senqu River (a tributary of the Orange). In total, the system includes a collection of fourteen dams.

The storage capacity alone is enough for Gautengers to hardly feel the pinch of droughts. The 9 300 Mm^3 per annum that the IVRS keeps is six years of Gauteng's water supply. The dams (excluding Bloemhof, which is downstream of Gauteng) store nearly five years of the average flow in the Vaal River. The vast spread of the systems further reduces risk. It's unlikely, for example, that all 40 000 km^2 that it covers will be affected by drought simultaneously. (In comparison, the Western Cape system that Cape Town taps from stores less than two years of average flows with a catchment area of just 803 km^2.)

Still, the demand being placed on the system is ever increasing, and with plans for more water to be added severely delayed, the resilience of the IVRS is now being scrutinised.

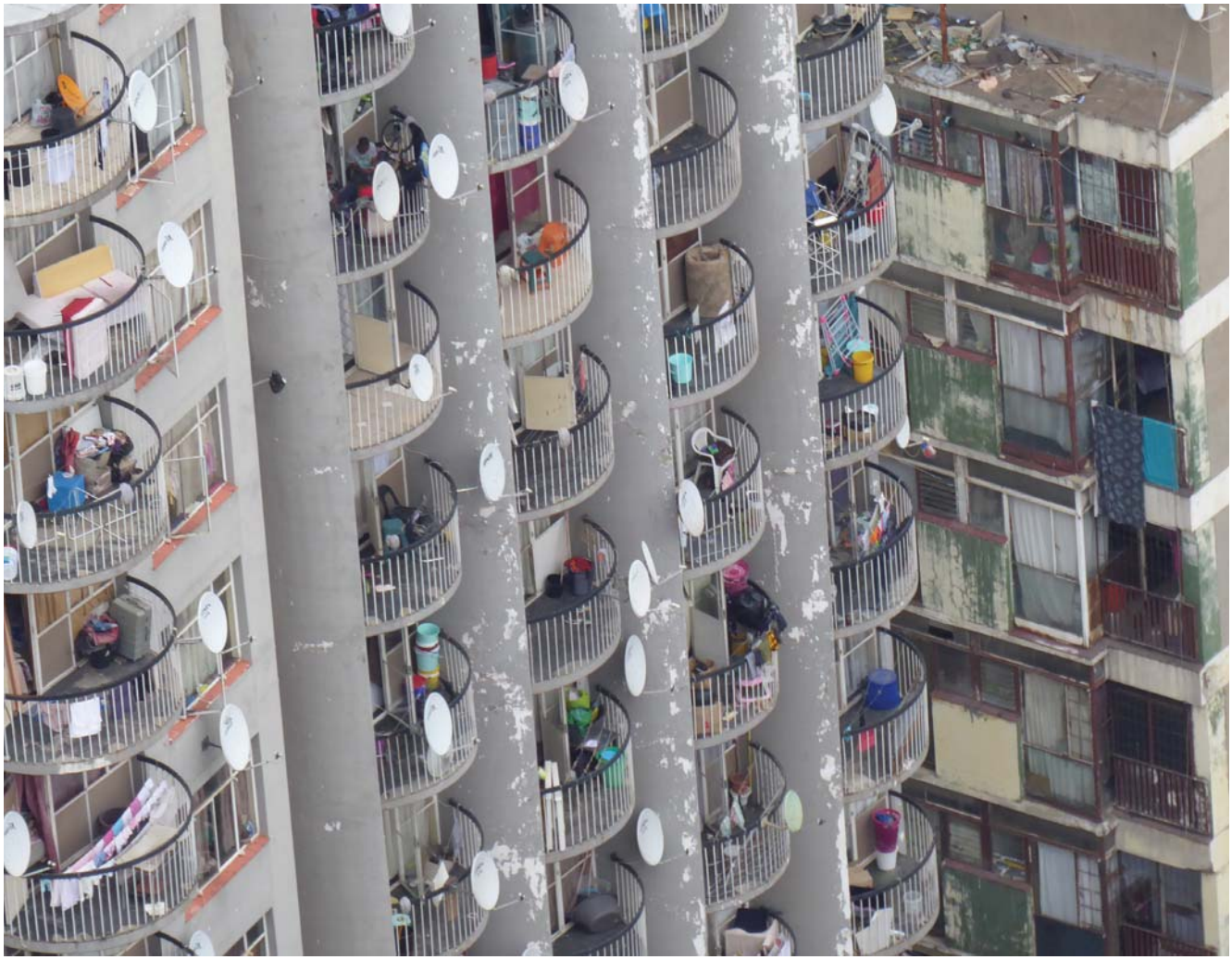
A resilient system under threat

"We are facing a situation where available bulk supply is capped and the population continues to grow," says Nast. In fact, the province sees the highest growth in South Africa. Between 2008 and 2018 natural population growth and in-migration pushed 3 392 495 more people into Gauteng.

To cater for increasing demand, more water for the IVRS will be added during phase 2 of the Lesotho Highlands Water Project. More specifically, additional water is to be supplied from the Polihali Dam, which is set to be constructed on a tributary of the Orange-Senqu River in Lesotho. This should ensure adequate water for the region until 2030. However, though planned to be completed in 2018, construction of the dam has now been pushed back to 2026 after which it will need to be filled with good rains before being of use.

A further challenge in the mix is that the system relies on variable and unpredictable climate. Multiyear droughts are not unfamiliar to Gauteng resident, but the threat of climate change adds more risk to the scenario.

"Other than in times of drought there has generally been no concern for water," notes Nast. While there is no immediate danger of shortages, the mentioned supply and demand challenges has led to discussion about water security for Gauteng is now taking place in times of apparent plenty.



Jaco Roets

Between 2008 and 2018 Gauteng grew by 3,4 million additional people.

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"In the longer term, Gauteng must work to build a more resilient community that can live comfortably within its available water resources and manage the risks that it faces."

In 2018, the Premier requested a project to understand urban water challenges in the GCR, what long-term water security entails and how it can be achieved. Though Provincial Government is not responsible for water supply, its role as coordinator of functions across the province, and responsibility for disaster risk management, has urged them to turn their eyes towards the water.

Conducted by the Gauteng City Region Observatory (GCRO) and a team of water specialists from Pegasys Consulting and the Wits School of Governance in close consultation with Provincial Government representatives, the result is the ***Water Security Perspective for the Gauteng City-Region***, released in November last year. For the first time, the Provincial Government has put forward ideas," explains Nast.

The goal of the perspective is to achieve water security for the GCR. For the project purpose, security is defined as "the reliable availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies."

A plan for sustained water security

"We took a very deliberate approach," says project coordinator and GCRO senior researcher, Gillian Maree. The perspective's proposed plans and solutions are not revolutionary or new, but what sets it apart from existing water management plans for the province is that it crosses hydrological and administrative boundaries. It looks at water security from the perspective of a city region as a whole, she explains. "For this, the Provincial Government has the best view of the complexity of how the city region functions."

The perspective calls for a balance between short-term and long-term priorities. Immediate priorities include ensuring that Polihali Dam is completed on time. Until then, the province will be at risk of supply shortages if, or when, a prolonged dry period next takes place. In the meanwhile, water consumption must be kept at sustainable limits, and water use must be restricted as soon as drought risks looms.

In the longer term, Gauteng must work to build a more resilient community that can live comfortably within its available water resources and manage the risks that it faces. This will entail buy-in from city planners and architects. People need to understand the urban water cycle, and the impact of their behaviour on it. Then, all residents must be afforded access to safe and reliable water supplies and sanitation services.

Maree says that the core of the plan is encapsulated in five identified critical issues and programmatic areas of intervention. The five critical issues are as follows:

Mark Lewis

Pollution from Gauteng is contributing to the eutrophication of the province's dams.

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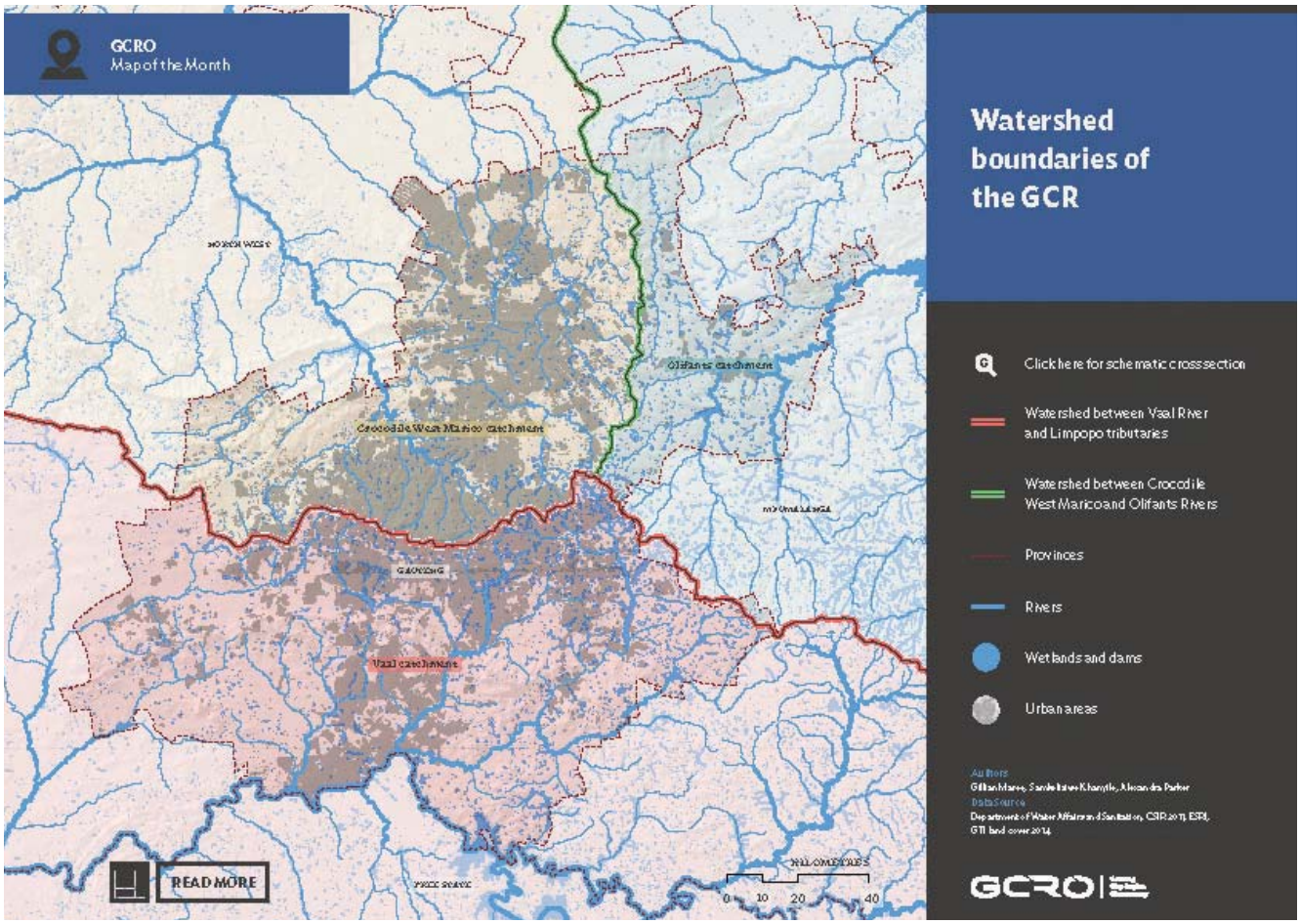

The watersheds that feed Gauteng's water system.

1. **Supply and demand:** On the demand side, Gauteng's per-capita water use must be reduced, as must losses in the municipal water distribution system. Everyone must be prepared for restrictions at times of drought, and urban planning must drive towards water efficient cities. On the supply side, the IVRS must be effectively monitored, operated and maintained to sustain reliable bulk water supplies. The system infrastructure must be further developed, and the Vaal River Reconciliation Strategy updated as a priority. The water mix must be diversified with potential sources such as groundwater, wastewater re-use, treated acid mine drainage, and rainwater harvesting.
2. **Institutions:** Institutional weakness and possible failure at all levels is a threat to water security. National and provincial government must support and regulate municipalities for the provision of water supply and sanitation services.
3. **Stormwater management:** Urban planning and development must take account of the management of stormwater to reduce flooding risks and health hazards as well as water supply and wastewater disposal requirements. In the long term, the goal must be to make Gauteng's cities greener and more sustainable.
4. **Water quality:** Cities are a major source of water pollution, much of which is due to improperly managed wastewater infrastructure. While the four largest municipalities will have to make 95% of the water savings to balance supply and demand, smaller municipalities must focus on improving their wastewater treatment which is a disproportionately large source of pollution.
5. **The way forward:** The strategy proposes an action plan as a more structured programme to address the longer term goals and five programmatic areas of intervention.

The perspective then goes ahead to specify five programmatic areas of intervention that will require action in the short term, but will necessitate ongoing support and effort. These will also require cooperation across institutions and partners in the GCR:

1. **Reduce water demand:** Available water must be allocated between municipalities and other users and programmes put in place to keep consumption within these limits.
2. **Manage variability to prepare for water scarcity:** Water availability must be managed so users can be alerted and take action if there is a threat of scarcity. For this, the IVRS must be maintained and updated. Operating rules and plans need to be put in place and agreed to by all water institutions before they are needed.
3. **Invest in alternative water sources and tools for water conservation:** To reduce risk, more water must be made available by diversifying sources of supply. These could include groundwater, rainwater, stormwater, reuse of wastewater and treated acid mine drainage.
4. **Manage water quality to limit pollution and achieve environmental goals:** Pollution from Gauteng is contributing to the eutrophication of the province's dams, reducing their value for recreational purposes. Updated

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water quality modelling is required to guide policy interventions and wastewater disposal strategies to reduce and increase the volumes of reusable water.

5. **Effective institutions for water security:** Many of the challenges to creating water security in the GCR relate to the performance and capability of the complex set of institutions with water related mandates. The perspective sets out a programme of action that municipalities, water boards and water utilities should take to build strong institutions that will ensure water security.

The new route is not without speedbumps

Although the proposed solutions are not groundbreaking, they can be seen to be so in the context of Gauteng, says Nast. The challenges in implementing these solutions are many, however.

For one, there are different silos where water management takes place, Nast explains. For example, there are no forums where one can engage directly with municipalities on what they are doing to reduce consumption, and what their plans are. "We have to look differently at how we do this," he says.

The challenges at municipal level is another serious aspect. While some municipalities are well off and do a fair amount of planning, says Nast, some at the other end of the spectrum are near collapse. "There comes a point in which the mismanagement of the water justifies intervention." Furthermore, the financing for water infrastructure and management should also be looked at. "Is water priced correctly?," he asks as example.

Yet, changing consumer behaviour might be the biggest challenge for Gauteng. "It's not just about building dams," says Nast. "In the long run the key is the use of water, not the supply." But, he continues to say that it will be difficult to motivate for the kind of change they are looking for regards water use behaviour, especially since water supply at the moment seems flush. Unless there's a major drought, he thinks it will be tough. "The key is communication, and education."

Regardless of the difficulties, it's integral that the recommendations should see implementation now. "Planning for water scarcity is important to supply a degree of certainty." Nast explains that the ideal would be to be able to notify residents when dam levels are low, for them the lower their water use accordingly. Once drought hits, the window for such rational decisions have closed.

"With any disaster like a drought you have to make unpopular decision before the impact hits," agrees Maree. You have to plan your way in and out of drought. Due to the storage capacity of the IVRS, the time period before the impact of drought hits in Gauteng is five to six years. Maree notes that this is longer than a political term, making implementation difficult, as a governing party would have to make unpopular choices about water, but not necessarily reap the benefits.

Taking the plan forward

According to the stipulated action plan there is an enormous amount to do, says Maree. "Yet, because there is enough water at the moment, water concerns have been placed on the back burner again."

"The one encouraging sign, however, is that this is being picked up in a cooperative way, and that there is real concern whether this is being implemented." Yet, she sees the real positive as something else. "It's not about how many projects and polices we have on water security, but how we make sure that water is on people's minds all the time when they're making decisions."

The strategy can be seen as proof of that. "There has certainly been a shift. Water is something that is now being taken much more serious on high levels."

The Katse Dam is part of the Lesotho Highlands Water Project, which feeds Gauteng.

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SOIL SCIENCE

Regional soil information for hydrological modelling in South Africa

Johan van Tol and George van Zijl explore the importance of regional soil information for hydrological modelling in South Africa.

Soils act as a first order control on hydrological processes by partitioning rainfall into overland flow or infiltration. The fate of the infiltrated water (e.g. storage, deep drainage, lateral flow etc.) is largely determined by soil properties and their spatial distribution. Although hydrologists agree that soils play a very important role in the hydrological functioning of landscapes, they often lack the skill to interpret existing soil information.

This problem is heightened by the fact that soil data has mostly been generated for agricultural purposes, such as land potential and fertilizer requirements, with little effort to make the soil data user-friendly for non-soil scientists. The consequence is that soil information is often misused in hydrological models and soil parameters are often only used for calibration of hydrological models.

With enhanced computing power, spatially distributed hydrological models are capable of handling details of landscape heterogeneity better. Some models (e.g. SWAT) couple seamlessly with GIS interfaces, such as ArcMap and QGIS. The models typically rely on layers of the terrain, land use and soil information to delineate Hydrological Response Units (HRUs). The assumption is that a HRU is an area with homogenous hydrological response.

Terrain and land use data are freely available at an adequate scale for most hydrological modelling purposes in South Africa. Soil information, on the other hand, is typically not readily available for direct parameterisation of most models. Distributed models require not only the spatial distribution of the soils but also important soil properties which will determine the hydrological response of soil units. These properties include mostly physical properties, such as particle size distribution (% sand, silt and clay), depth of different soil horizons, hydraulic conductivity

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of the soil horizons and soil water retention characteristics. In more complex models, chemical properties of the soils are also included to determine nutrient uptake or the fate of pollutants from point and non-point sources.

Hydrological soil information for South Africa

In South Africa, the only soil database that covers the entire country is the land type database. A land type is an area demarcatable at 1:250 000 scale with similar climate, geology and consequently soil distribution patterns. A total of 7 070 land types have been delineated between 1972 and 2006. Each of these land types are accompanied by a land type inventory (see example in Figure 1).

The land type inventory present the typical soils occurring on various Terrain Morphological Units (TMU's) (Figure 1a), gives an indication of the relative coverage of the TMU's in relation to the total area of the land type as well as the relative coverage of the soils covering the various TMU's (Figure 1b). The soils presented in the land type inventory reflect the soil series as in the first edition of the South African Soil Classification System (1977) – or the 'red book'. More than 30 years ago, Prof Roland Schulze made a remarkable effort to establish the hydrological response for each of these soil series.

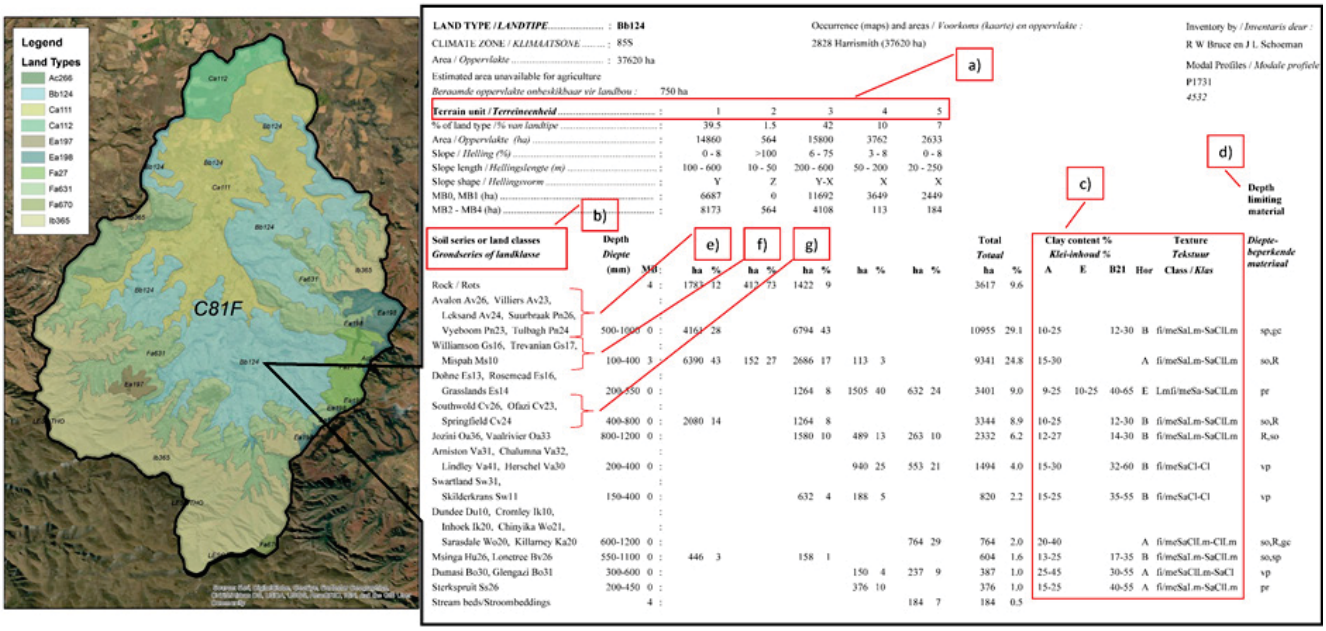

Figure 1: Example of land types covering quantenary catchment (C81F) and the inventory for land type Bb124.

The land type inventory further provides estimated clay percentages and texture class for the A, E and B1 horizons of the different soil forms (Figure 1c) as well as description of the nature of the layer which will restrict root penetration (Figure 1d).

At this stage, land type information are mainly being used in 'lumped' format as presented in the South African Atlas of Agrohydrology and Climatology (Schulze et al., 2007). In this format, the land type is considered as a single unit, with average parameters representing the entire land type (in the Atlas the hydrological parameters are mainly those which are used in the ACRU model). Although treating land types as lumped entities is certainly useful for large scale modelling, we believe that this invaluable database can be used for so much more, permitted that certain limitations are addressed.

Limitations of using land type information for hydrological modelling

The land type survey was essentially done with agricultural potential in mind. The observation depth was limited to 1 200 mm. When a root limiting layer was observed, deeper layers were not described. In hydrology, the nature of the soil/bedrock interface plays a very important role in the hydrological response. This requires that land type data is carefully interpreted before direct incorporation for modelling purposes.

The majority of land types were described using the 1977 edition of the soil classification (the 'Red Book') and the remainder with the 1991 edition (Blue Book). Both of these editions are no longer in print creating a knowledge gap for upcoming modellers in terms of the data that they are using. The newest edition of soil classification was published in 2018, with a strong emphasis on soil as a natural entity (i.e. not only agriculture). Although this is a complete paradigm shift in the way soil scientist describe soils, it will require a dedicated effort to re-interpret existing soil information for hydrological purposes.

It is important to note that a land type is not a soil polygon but depicts soil distribution patterns. Considerable variation can therefore occur between soils on different terrain units.

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Significant variation within a specific terrain unit is also possible – therefore, merely identifying terrain positions to disaggregate land type is not sufficient. In the example of land type Bb124 (Figure 1), TMU 1 is dominated by 3 distinctly different soil associations. A total of 28% (Figure 1e) of this terrain position are occupied by soils with plinthic layers (see Figure 2a), 43% (Figure 1f) by shallow soils (Figure 2b) and 14% (Figure 1g) by freely drained soils (Figure 2c). The hydrological response of these soil groups will differ considerably, where lateral flow at the soil/bedrock interface is likely to be dominant on the plinthic soils (Figure 2a), overland flow due to storage excess on the shallow soils (Figure 2b) and vertical drainage and recharge on freely drained soils (Figure 2c).

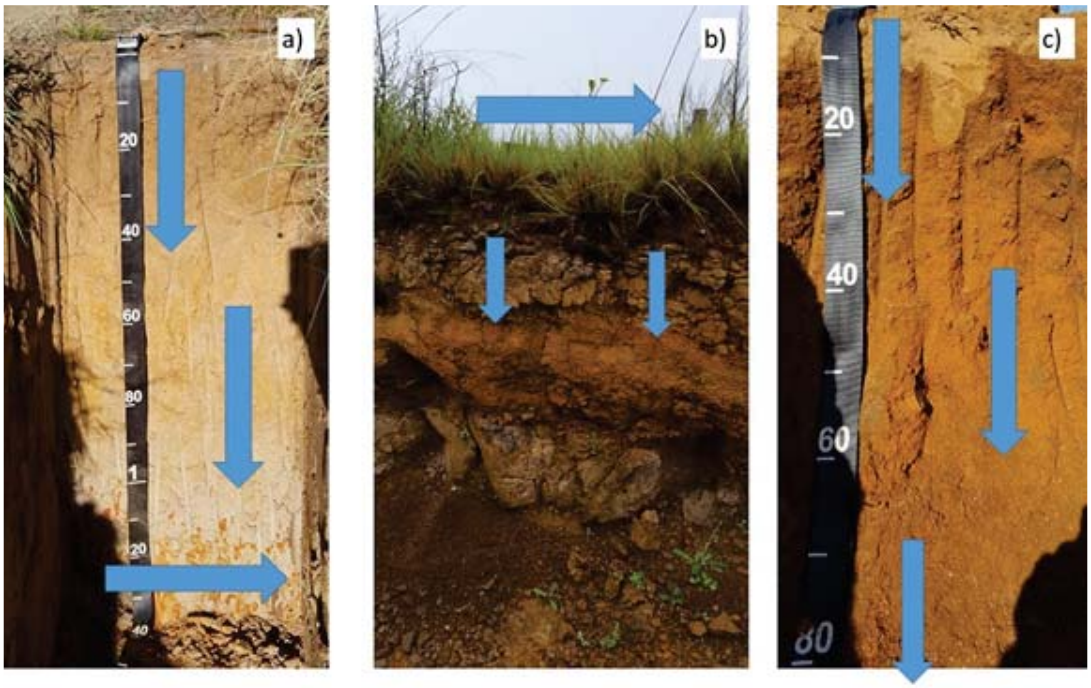

Figure 2: Soils occurring on a single terrain unit in land type Bb124 a) interflow soils, b) shallow responsive soils and 3 recharge soils. The variation in hydrological response emphasise the importance of accurate disaggregation of land type information for hydrological purposes.

Hydrological soil information for South Africa

The advances in Digital Soil Mapping (DSM) have paved the way for remapping soil legacy data at finer scales and better accuracy. In the past few years significant progress has been made to map soils through machine learning, expert knowledge and disaggregation of land types approaches into soil polygons, also for hydrological purposes in South Africa. These approaches also allow for the creation of soil associations/groups with similar hydrological response. A great advantage of the DSM derived maps are that a measure of uncertainty accompanies them, which could be built into the models.

There is a need to use the DSM methods to create user-friendly hydrological soil maps for the whole of South Africa. Such maps should also be accompanied by hydrological properties of the dominant soils for parameterisation of a range of hydrological models. These properties should either be directly measured or derived from locally developed PedoTransfer Functions (PTF's) which is applicable for our environmental conditions. These maps must also be accompanied with dedicated field campaigns where the accuracy of the maps are determined (for quantification of model input accuracy) and description of the nature of the soil/bedrock interface.

Sustainable water resource management in the highly variable water regime of South Africa becomes increasingly important as the demand for this resource increase. Accurate hydrological modelling to forecast the impacts of climate and land use change on this resource are pivotal to sustainable management. In this day and age, we simply cannot allow that the efficiency of modelling output is jeopardised by outdated, inadequate soil information, while new methods exist with which the spatial distribution of soil classes and properties could be accurately determined, together with the accompanying uncertainty on the distribution.

Examples of DSM-related projects for hydrological purposes in South Africa are:

Disaggregation of land types:

- *Flynn, T., van Zijl, G.M., Van Tol, J.J., Botha, C.C., Rozanov, A., Warr, B., Clarke, C., Comparing algorithms to disaggregate complex soil polygons in contrasting environments. Geoderma 352, 171-180.*

Expert knowledge:

- *Van Tol, J.J., Van Zijl, G.M., Riddell, E.S., Fundisi, D. 2015. Applications of hydropedological insights in hydrological modelling of the Stevenson-Hamilton Research Supersite, Kruger National Park, South Africa. Water SA 41, 525-533.*

Machine learning:

1. *Van Zijl, G.M., Van Tol, J.J., Tinnefeld, M., Le Roux, P.A.L. 2019. A hillslope based digital soil mapping approach, for hydropedological assessments. Geoderma. https://doi.org/10.1016/j.geoderma.2019.113888*

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SANITATION

New construction standard paves the way for non-sewered sanitation

A successful workshop held in Pretoria last year drew much needed attention to a new standard, which is blazing a trail for non-sewered sanitation systems. Article by Akin Akinsete.

Delegates at the sanitation workshop, held in Pretoria in November last year.

The inaugural SANS 30500 awareness workshop was held on November 19, 2019 in Pretoria. The workshop targeted policymakers in the South African national government departments (including, among others, the Department of Water and Sanitation, department of trade and industry, and the Department of Health) as well as other national bodies such as the South African Bureau of Standards (SABS) and the national regulator for compulsory standards (NRC).

The purpose of the awareness workshops is to familiarise stakeholders within the sanitation sector with the SANS 30500 standard, provide insight into how the standard can impact and benefit the sanitation value chain and industry, and to create a forum where the views and expectations of stakeholders can be shared and discussed. The Pretoria workshop is the first of many planned workshops, which will target other tiers of government, such as provincial, municipalities and metros, and other actors in the sanitation value chain, such as consulting engineers, manufacturers and suppliers, and held in different location across the country.

The workshops are aimed at fostering a better understanding and appreciation of the SANS 30500 standard, create an enabling environment for conversations around how the

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standard can benefit the current sanitation landscape and most importantly provide a platform for inter-departmental and inter-governmental collaboration that will be required to promote non-sewer sanitation systems (NSSS) as a viable alternative to the current sanitation paradigm.

The workshop concept is a collaboration between the Water Research Commission (WRC)'s sanitation programme, the South African Sanitation Technology Evaluation Programme (SASTEP) and the South African Bureau of Standards (SABS). The Department of Water and Sanitation, as the sector leader, is also providing technical support. The workshops are framed to provide an overview of the standards and to sensitise the sanitation community on how the standard can contribute to alleviating current sanitation problems and challenges and enable a conducive environment for dialogue and the development of holistic approach that takes into account, available technologies, policies and regulatory framework that can be harnessed in providing dignified, clean, hygienic sanitation solutions for all.

The South African Sanitation Technology Evaluation Programme (SASTEP) is an initiative funded by the Department of Science and Innovation (DSI) and the Bill & Melinda Gates Foundation (BMGF), with the WRC providing the programme, implementation and support services. SASTEP is focused on the commercialisation, localisation and industrialisation of innovative sanitation technologies, including NSSS. The SASTEP model involves creating a platform that enables commercial partners i.e. entrepreneurs, SMMEs and manufacturers in the sanitation sector bring innovative solutions to market.

The SASTEP platform, through research and its extensive WRC networks, looks to foster enabling policies and regulations, provide technology validation and advisory support and matchmaking with institutional investors such as the IDC, PIC and incentive programmes within the likes of the dti. The adoption and implementation of the SANS 30500 standard is central to the SASTEP initiative and considered a key strategic tool for enabling and regulating the new sanitation technology platforms. The inclusion of the standard in the national building regulation (NBR) and promulgation of enabling policy by relevant government department would galvanise manufacturers, suppliers and end-users and enable the adoption of NSSS, creating market access and eventual commercialisation and industrialisation of NSSS technologies in South Africa.

The standard is titled "SANS 30500 - Non-sewered sanitation systems – Prefabricated integrated treatment units – General safety and performance requirements for design and testing". It is a voluntary, international product standard, published in October 2018 and it was adopted "as-is" by the South African Bureau of Standards (SABS) on May 17, 2019. The second country to do so after Senegal. The standard specifies technical requirements, test methods, and sustainability considerations for NSSS. It outlines criteria for the safety, functionality, usability, reliability, and maintainability of the system, as well as its compatibility with environmental protection goals.

SASTEP Programme Manager, Akin Akinsete, addresses workshop delegates.

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WRC Executive Manager, Dr Valerie Naidoo, provided an introduction to South Africa's move towards innovative non-sewered technologies.

The standard is comprehensive and written to ensure SANS 30500 NSSS certified technologies are robust and provide regulators and policy makers with assurance that they are safe and provide positive health and environmental outcomes. SANS 30500 certified technologies can meet basic sanitation needs and promotes economic, social, and environmental sustainability through strategies that may include minimising resource consumption (e.g. water, energy) and converting human waste to safe output. The standard provides safety and performance requirements for the following outputs:

- Safe solid discharge or reuse
- Safe liquid discharge or reuse
- Air emissions
- Odor
- Noise

The knowledge disseminated through the SANS 30500 workshops to various stakeholders in the sanitation value-chain, including policy makers, regulators, manufacturers, suppliers and end-users. will assist in creating consensus around sanitation products and solutions and an understanding of how they fit into solving current sanitation challenges.

Addressing the challenges of inadequate and unhygienic sanitation is a priority of the South African government and several subsidies are provided to ensure the provision of improved sanitation facilities in poor and disadvantaged communities. The ventilated improved pit (VIP) toilet or its equivalent is the most deployed solution due to its low capex, robustness, and environmental impact.

This system is not without problems that stem from misuse, high filling rate, lack of maintenance due to lack of ownership from communities and users as a result of low user acceptance by users, who aspire and clamour for waterborne sanitation. waterborne solutions connected to a city-wide reticulation network also poses a challenge due to its high implementation and operating cost as well as high resource intensity.

Next generation non-sewered sanitation systems (NSSS) therefore provides a bridge between the conventional pit latrine and waterborne solution. As many of the NSSS technologies are novel there is a need for standards, testing, and validation of these technologies. Therefore, to unlock the benefits of NSSS, there is a need to enhance local capacities and strengthening the skills and training on the next generation technologies, the workshops are therefore a much-needed platform for dialogue amongst relevant stakeholders.

The workshop commenced with Dr Valerie Naidoo from the WRC giving an introduction of SASTEP and South Africa's move towards innovative non-sewered technologies. In her presentation she laid out the objective of the programme, the benefits of including NSSS to the current sanitation technology toolbox and the desired policy and regulatory shifts required to unlock the benefits of the standard and NSSS technologies.

This was then followed by Iris Mathye from the Department of Water & Sanitation (DWS). She gave an overview of the South African sanitation legislative landscape and its relevance in supporting innovative technologies including NSSS. She further highlighted her department's commitment and strategies

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towards the inclusion of improving non-sewered sanitation solutions in their technology mix. She also touched on the National water and Sanitation Master Plan, the Industrial Policy action Plan (IPAP), the National Sanitation Integrated Plan and the National Faecal Sludge Management (NFSM) Strategy, which if well managed and implemented would bring about much need shift in the sanitation realities in South Africa.

Mathye further reiterated how NSSS can play a crucial role in achieving the department's strategies. The DWS' National Sanitation Integrated Plan, a 10-year road map, includes a focus on acceptance of innovations and industrialisation of sanitation. The adoption and industrialisation of sanitation solutions will assist the DWS in responding and meeting its target for the United Nation's Social Developmental Goal (SDG) target 6.2 on safely managed sanitation on the entire sanitation service chain.

Dr Konstantina Velkushanova from the University of KwaZulu Natal, who was part of the team that developed the manuals and material for the workshop, gave an overview of the SANS:30500 standard. She reiterated the many benefits of the standards such as that policymakers can rely on global expert opinion to ensure safety of the product for its citizens without spending its own time and money. Secondly, manufacturers will have a blueprint to use to create a product that meets international guidelines, making market entry easier and lastly, the standard will increase user confidence in the product, since it reflects a consensus of regulators, manufactures, and users from across the world. She also illustrated the procedure for certification of the non-sewered systems using the SANS:30500.

A panel discussion was held at the workshop to address aspect of certification such local readiness for certification, availability of necessary infrastructure within South African to support testing and certification and the role of stakeholders in supporting the implementation of the standard. Also discussed were timeline for the testing and certification of new technologies, and their market availability in context of support and preparation of the local government bodies to facilitate and incorporate the certification processes.

The panel included Rudolph Opperman (NRCS), Reza Shah, (SABS), Valarie Naidoo (SASTEP) Tina Velkushanova (UKZN), and Iris Mathye (DWS), and it was moderated by Kay Naidoo (SABS). Rudolph Opperman from the national regulator for compulsory standard (NRCS) mentioned that they are currently working to get the standard incorporated into the national building regulation (NBR). This was followed by a question and answer session from the attendees to the panellists.

There was an agreement after the workshop that there should be an acceleration of the implementation of the certification plan by the SABS and that the sector, led by the DWS, should promote acceptance of the standards and the adoption of NSSS technologies. The recommendation made at the workshop was compiled by the SASTEP team who will engage with the relevant stakeholder on the next steps and actions.

The next workshops will be held in 2020 targeting other stakeholders. The stakeholder groups, dates and venues will be announced on the WRC and SABS' website and other platforms.

For more information on the workshops, contact the SASTEP Programme Manager, Akin Akinsete at Email: akina@wrc.org.za

Iris Mathye from the Department of Water and Sanitation.

WRC Research Manager, Dr Sudhir Pillay, SASTEP Commercialisation Manager, Charmaine Twala, and SASTEP Programme Manager, Akin Akinsete.

The discussion panel at the sanitation workshop included Dr Valerie Naidoo (Water Research Commission), Reza Shah, (SABS), Tina Velkushanova (UKZN), Rudolph Opperman (NRCS), and Iris Mathye (DWS).

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The knowledge generated by the WRC generates new products and services for economic development, it informs policy and decision making, it provides sustainable development solutions, it contributes to transformation and redress, it empowers communities and it leads various dialogues in the water and science sectors.

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