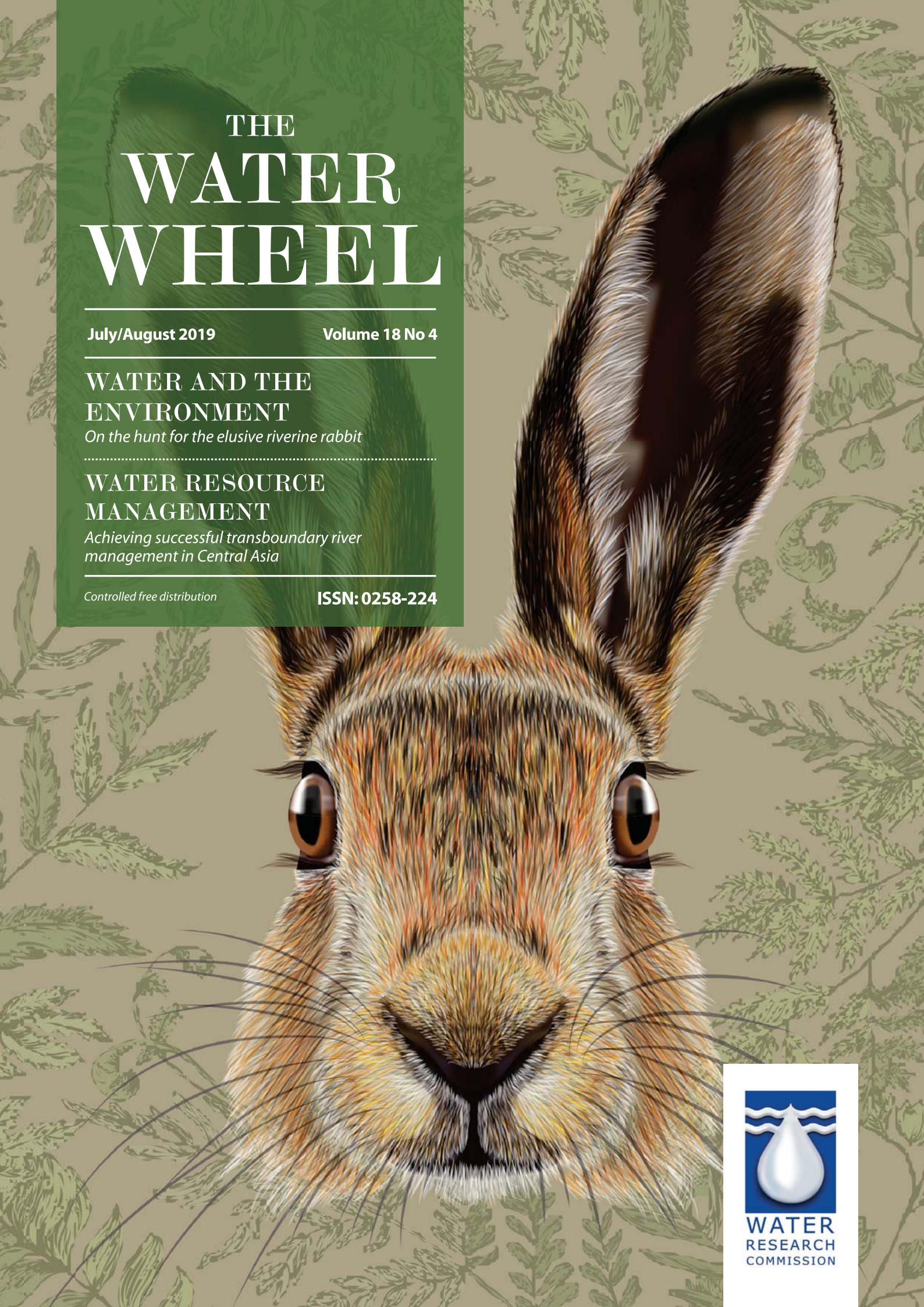

THE WATER WHEEL

July/August 2019 Volume 18 No 4

WATER AND THE ENVIRONMENT

On the hunt for the elusive riverine rabbit

WATER RESOURCE MANAGEMENT

Achieving successful transboundary river management in Central Asia

Controlled free distribution

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WATER RESEARCH COMMISSION

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WATER RESEARCH COMMISSION

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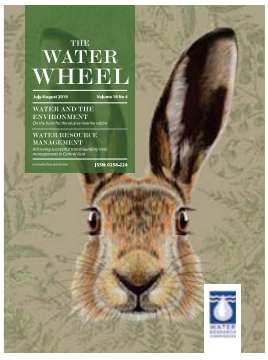


The elusive riverine rabbit remains one of South Africa's least understood creatures. Now its habitat is threatened. See story on page 12.

FLUID THOUGHTS

WRC CEO, Dhesigen Naidoo

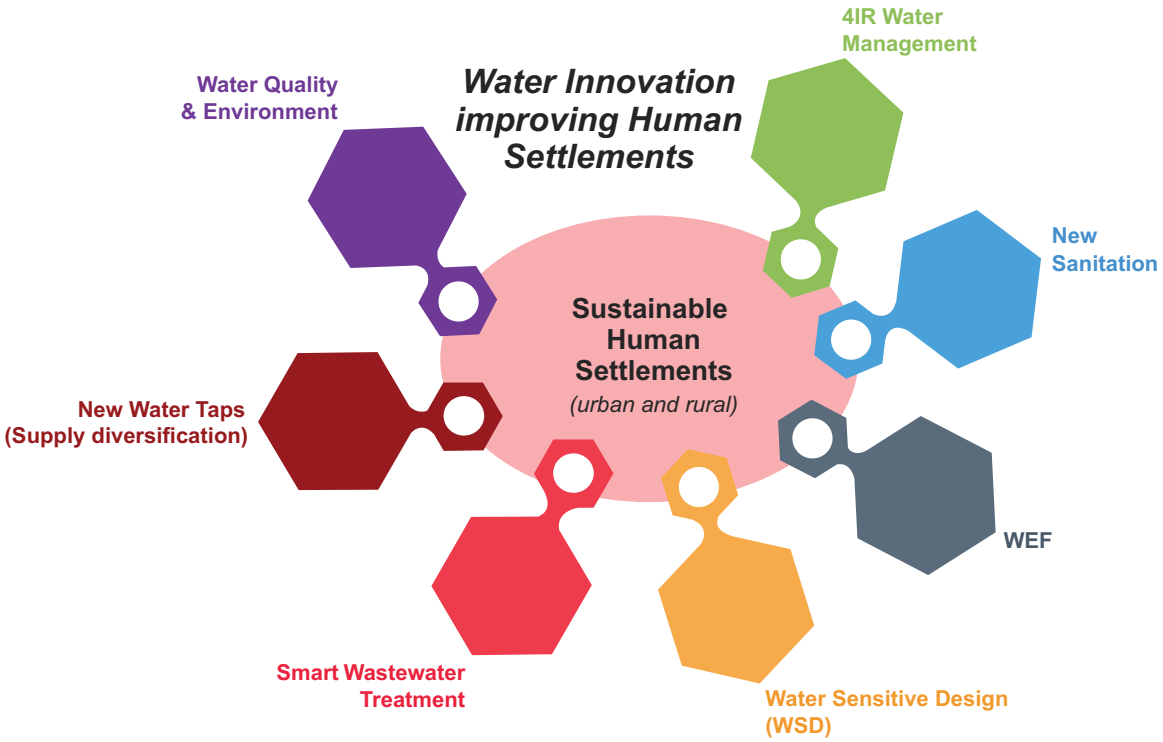
An integration decision of note

At the heart of South Africa's water woes lies our continued inability to utilise the water we already have innovatively, effectively, efficiently and with the right levels of efficacy.

This is not in any way discounting the vagaries of climate change and the increased frequency of extreme weather events. The extended El Niño cycles, including the frequent low impact ones, have certainly had an accumulative effect – especially in our ability to timeously recover sufficiently between dry spells. These are real, and represent the new boundary conditions for our water planning, and perhaps this is where we have been wanting. It should, of course, be informing not only water planning, but overall development and economic planning.

The promise in the new Cabinet portfolio in the form of Human Settlements, Water and Sanitation under the stewardship of Minister Lindiwe Sisulu may hold the key. The reconceptualisation of human settlement from single developments, such as the appropriately lauded Cornubia and Cosmo City to city and region-wide planning represents the theatre of change. We need to bring to bear the now considerable repository of new water knowledge and incredible water and sanitation innovations into designing all new development on the basis of water sensitive design (WSD).

It is an area of strength for the highly productive South African water science and technology community of practice, steered and supported by the Water Research Commission, which is rated by the ISI (International scientific indexing) as being in the top twenty globally. WSD, combined with game-changing technology, will not only ensure a water secure future for South Africa, but also set us on a pathway toward a low carbon economy and a sustainable development future.



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These interventions include direct contribution areas of research and innovation toward realising sustainable human settlements, interventions to enhance both water access as well as resource (water and financial) efficiency. They include New Sanitation, innovations in water quality and the environmentally sensitive water development, a fundamental diversification of water-supply options, smart – beneficiation oriented and decentralized (localised) wastewater treatment, innovative WSD, embracing the water-energy-food nexus and fully implementing a 4th Industrial Revolution approach to water and sanitation management.

Taking advantage of our water science and technology asset will not only significantly enhance our water security. If done correctly, the net result will also be in increased energy and nutritional security, with concomitant improved health security. In addition, and if the correct investments are made, we can industrialise our water and sanitation innovations and produce for a global market as envisaged in the Industrial Policy Action Plan (IPAP). This, in turn, significantly changes the risk profile of water financing and investment as more private sector participation – through large corporates as well as start-ups and co-operatives – are enabled.

There is a significant convergence in all global analyses that from an economic, social, environmental, political and security viewpoint the increase of water scarcity on the back of decreased availability as well as deteriorating water quality is a crowning global crisis. These solutions, therefore, promise to mitigate and eventually solve the local and global water crises have far-reaching implications. If we don't accelerate the adoption of these new solutions, we have the unwelcome prospect of living out the World Economic Forum (WEF) 2019 ***Global Risk Perception Survey's*** connectivity analysis. It first reminds us that water has been consistently in the top 5 global risks in terms of impact from 2012 to 2019, having been the number one risk in 2015. It further connects the water crisis risk not only to natural disasters, biodiversity loss and ecosystem collapse and our collective Climate Change inaction; but is also a critical factor in the failure of global and regional governance, interstate conflict, the fiscal crisis and unemployment.

We need to bring to bear the now considerable repository of new water knowledge and incredible water and sanitation innovations into designing all new development on the basis of water sensitive design (WSD).

The possibilities are compelling. We stand at a turning point for the South African development narrative – one that has the dual and mutually reinforcing opportunity to simultaneously improve the quality of life for the poorest of the poor while creating fertile ground for industrialisation and entrepreneur development in South Africa, Africa and the developing world. It will announce a step change in water management for the 21st century.

WATER DIARY

Water governance
27-39 August
The Water Institute of Southern Africa is hosting a training course on water governance, in the Western Cape.
For more information,
Visit: www.wisa.org.za

World Water
25-30 August
Hosted by the Stockholm International Water Institute, World Water Week will be held in Stockholm, Sweden, with the theme 'Water for society – including all'.
For more information,
Visit: www.worldwaterweek.org

Research and development
11-13 September
The Water Research Commission will be hosting its fourth biennial Symposium at the Sandton Convention Centre.
For more information,
Visit: www.wrc.org.za

Groundwater
20-23 October
The 16th Groundwater Division Conference and Exhibition will be held in Port Elizabeth under the theme 'Conservation, demand and surety'. *For more information, Visit: www.gwd.org.za*

Emerging contaminants
4-8 November
The second African Conference on Health Effects of Endocrine Disruptors will be hosted by the University of Pretoria at its Future Africa Campus.
For more information, Visit: www.up.ac.za

Large dams
6-8 November
The annual conference of the South African National Committee on Large Dams (SANCOLD) will take place at Kopanong Hotel and Conference Centre, Benoni.
Visit: sancold.org.za

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NEWS

Scientists draw attention to environmental risks of nanomaterials

Some of the most common household products, including sunscreens, hair relaxers, lotions and cleaning detergents, contain engineered nanomaterial ingredients that, when released into the environment, have the potential to cause nanopollution.

This is according to scientists from the CSIR who, along with colleagues from the University of Johannesburg, the Nelson Mandela University and the Sefako Makgatho Health Sciences University, have conducted a study on the subject. This was reported to be the first local study in which nano-enabled products were identified and prioritised (qualitatively and quantitatively) according to their likelihood for nanopollution in Africa.

Studies point to sunscreens as the main concern, recording a release factor above 90% due to the likelihood of the product releasing engineering nanomaterials into water systems during bathing and/or swimming.

"Engineered nanomaterials are considered a case of contaminants of emerging concern because their environmental behaviour differs from their larger-sized counterparts and, thus, their risk management does not fit well into the existing environmental risk assessment frameworks," explains CSIR senior researcher and study leader, Dr Melusi Thwala.

The studies were conducted to improve understanding of the potential sources of engineered nanomaterials into the environment under a consortium funded by the Department of Science and Technology. Products included in the study were limited to those containing engineered nanomaterials as indicated on the product label.

A total of 264 nano-enabled products were identified, spanning six product categories, namely health and fitness, electronics and computers, home and garden, appliances, automotive and food and beverage. The health and fitness category dominated, making up over half of the identified products.

Production and use of nano-enabled products are increasing, and experts are concerned about the increased likelihood of environmental release across the product lifecycle, predominantly during use and disposal, especially in light of the current information gaps with respect to the implications of nanopollution.

Overall, the current findings indicate that most identified nano-enabled products, especially those in the health and fitness category, are likely to release engineered nanomaterials into the environment with relative ease, with water resources being the most likely immediate recipient.

Concern is also expressed regarding the fact that over 90% of the identified products exhibit a medium to high potential for nanopollution. It is recommended that South African authorities in the environmental regulation sector establish the means through which sources of nanopollution could be identified, and their extant established.

Source: CSIR

Merged departments welcome new ministers

Minister Sisulu being sworn in.

The newly merged departments of Human Settlements and Water and Sanitation welcomed their new ministers in June. The new department is being led by Lindiwe Sisulu. The department now has two Deputy Ministers, Pamela Tshwete and David Mahlobo.

Sisulu served as Minister of International Relations (2018-2019), having previously served as Minister of Human Settlements. She has also served as the Minister of Public Service and Administration, Intelligence, Housing and Defence and Deputy Minister of Home Affairs.

The ministers spent their first month in office receiving briefings from the management of the newly-formed department. The briefings sought to, among others, highlight areas of priority over the next few years, and identify challenges facing the department to deliver on its expectations. A strategy workshop was also held to assist alignment of the two departments.

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Young water professionals to meet in Durban in October

The Young Water Professionals division of the Water Institute of Southern Africa (WISA) is holding its sixth biennial conference at the Durban International Conference Centre from October 20 to 23.

Organised under the theme 'My Water, My Business', the national conference will explore a wide range of water and sanitation issues, and the conference organisers are encouraging young professionals to attend and make presentations.

Conference chair, Lindelani Sibiya, has also commended Umgeni Water for its commitment to investing in future leaders by providing anchor sponsorship.

Sibiya notes that this is the first time the conference will be held in KwaZulu-Natal, in the hope of making its easier – financially and logistically – for young professionals from rural-dominated provinces to attend and empower each other through the conference. He hopes the meeting will assist "bright young minds" to share knowledge, build confidence, promote research and also allow younger professionals to hone their public-speaking and networking skills. Umgeni Water CE, Thami Hlongwa, said he and fellow "elders" in the water sector believed it was critical for younger leaders to step up and take responsibility for challenges facing the water and sanitation sector. "For example, we should be looking beyond the era of flush toilets, in which up to 12 litres of potable water is used to flush away 150 ml of pee," says Hlongwa.

The organisers also note that the conference comes at a time when several regions have experienced drought.

There will be several sub-themes in the spotlight, including "Water in the 4th industrial revolution, which will include discussions on smart-metering, artificial intelligence, the internet of things and the human resources and skills needed to remain relevant in the 4th industrial revolution

Under the sub-theme of 'Innovative water businesses and opportunities', presentations will focus on sustainable financial models to fund new water infrastructure, and understanding profits and losses in the bulk water and sanitation business.

There will also, be a special session on 'Water scarcity', with a specific focus on recent droughts, water-saving technologies, desalination and strategies for cities to survive drought.

Under 'Sanitation solutions', debate will focus on encouraging behaviour change, water-smart toilets, emerging pollutants and the circular economy.

The fifth conference theme, 'Ecosystems management' and restoration of the natural environment; will explore the importance of healthy ecosystems in ensuring water quality and quantity.

A number of technical tours have also been planned after the main conference ends.

For more information about the conference and registration, contact the project manager, Bongiwe Dube, at Tel: (031) 303 9852 or Email: bongiwe@confco.co.za.

Sponsorship and exhibition queries can be directed to Sanele Mazibuko at Tel (079) 313 7486 or Email: sanele.mazibuko@umgeni.co.za

Minister calls on municipalities to prioritise maintenance

Minister of Human Settlements, Water and Sanitation, Lindiwe Sisulu, has called on all municipalities to prioritise maintenance of water and sanitation infrastructure to prevent pollution of dams and rivers.

The minister made the call after receiving a briefing from Acting Director of Water and Sanitation, Squire Mahlangu, on the situation of water shortage being experienced by the town of Mahikeng, in North West, in June. The minister has directed the Acting DG to submit a national report on the state of water and sanitation infrastructure and the maintenance programme by municipalities.

"We want to understand the state of our water and sanitation infrastructure, we want to work with municipalities to ensure that there is ongoing maintenance and modernisation of infrastructure to avoid pollution," noted Sisulu.

The minister also directed Mahlangu to submit a report on funding allocated to municipalities and expenditure trends to discuss with premiers and mayors. "The Department of Human Settlements, Water and Sanitation must grow capacity to monitor all our sources of water, dams and rivers, focusing on maintenance and prevention of pollution. Modern technology and a strong inspectorate should be able to assist us," Sisulu said.

On the Mahikeng water situation, the Minister has directed Deputy Minister, Davi Mahlobo, to lead a team to come up with urgent measures to address the water disruption in the area.

Source: SA News

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GLOBAL

Antibiotics in some world rivers exceed 'safe' levels

Concentrations of antibiotics found in some of the world's rivers exceed 'safe' levels by up to 300 times, the first ever global study has discovered. The project was led by the University of York.

Researchers looked for 14 commonly used antibiotics in rivers in 72 countries across six continents and found antibiotics in 65% of the sites monitored. Some of the world's most iconic rivers were sampled, including the Chao Phraya, Danube, Mekong, Seine, Thames, Tiber and Tigris.

Metronidazole, which is used to treat bacterial infections, including skin and mouth infections, exceeded safe levels by the biggest margin, with concentrations at one site in Bangladesh 300 times greater than the 'safe' level. In the River Thames and one of its tributaries in London, the researchers detected a maximum total antibiotic concentration of 233 nanograms per litre (ng/l), whereas in Bangladesh the concentration was 170 times higher.

The most prevalent antibiotic was trimethoprim, which was detected at 307 of the 711 sites tested, and is primarily used to treat urinary tract infections.

The team said that the 'safe' limits were most frequently exceeded in Asia and Africa, but sites in Europe, North America and South America also had levels of concern showing that antibiotic contamination was a "global problem". Sites where antibiotics exceeded 'safe' levels by the greatest degree were Bangladesh, Kenya, Ghana, Pakistan and Nigeria. The study revealed that high-risk sites were typically adjacent to wastewater treatment systems, waste or sewage dumps, and in some areas of political turmoil, including the Israeli and Palestinian border.

Prof Alistair Boxall, Theme Leader of the York Environmental Sustainability Institute, said: "The results are quite eye opening and worrying, demonstrating the widespread contamination of river systems around the world with antibiotic compounds. Many scientists and policymakers now recognise the role of the natural environment in the antimicrobial resistance problem. Our data show that antibiotic contamination of rivers could be an important contributor.

"Solving the problem is going to be a mammoth challenge and will need investment in infrastructure for waste and wastewater treatment, tighter regulation and the cleaning up of already contaminated sites."

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Mozambique cyclone a 'wake up call'- UN weather agency

The havoc caused by cyclones Idai and Kenneth across Mozambique is a 'wake-up call' for vulnerable countries to build resistance against further high-impact tropical storms, coastal flooding and intense rainfall linked to climate change. This is according to the World Meteorological Agency (WMA) Secretary-General Petteri Taalas.

A WMO fact-finding mission to Mozambique in May recommended disaster-risk-reduction priorities to strengthen the country's early warning systems and reduce damage due to weather, climate and water-related hazards.

"Mozambique needs to build resilience," noted Taalas in a message to an international pledging conference to secure support for reconstruction. "Although the number of tropical cyclones globally is expected to reduce in the future, the number of most intense tropical cyclones (category 4 and 5) associated with more rainfall, will increase in a warming climate."

Taalas further asserted that future sea level rise "will exacerbate the impact of storm surge on coastal regions" and raise flooding concerns, "particularly for low-lying cities such as Beira", which was inundated by cyclones in March and April. It also draws attention to Mozambique's vulnerability to floods from both rivers and sea. The fact-finding team said that a US$27 million investment is needed to strengthen meteorological and water-supply sectors. This includes reconstruction, rehabilitation and modernisation of infrastructure and equipment, land surveys for flood-risk mapping and satellite rainfall estimation and training.

The cyclones and subsequent flooding killed more than 600 people, injured an estimated 1 600, affected more than 1,8 million ha and caused an estimated US$773-million in damages to buildings, infrastructure and agriculture.

Tiny fish are a big deal in Africa's lakes and rivers

Small freshwater fish around Africa offer a large and under-recognised opportunity to boost food and nutrition security, according to a new Food and Agriculture Organisation (FAO) working paper investigating an array of species and related livelihoods that too often are undervalued.

Small pelagic fish, generally processed, sold and eaten whole, account for three quarters of the total inland fish catch of the continent, but because of their low economic value they are not given the attention they deserve. Yet, their unparalleled production rate, and simple technologies used for their capture, make them ideal in nutrient-deficit regions.

Take Lake Victoria, the largest lake in Africa, where the introduction of Nile Perch fostered a lucrative although bust-prone industry. Yet catches of ***dagaa*** – an endogenous sardine like cyprinid captured on moonless nights – actually contribute more to fisheries output by weight and in terms of regional food security.

Ensuring that these vital 'vitamin fish' are accessible and available for human consumption hinges on "profoundly social, economic and political" transformation in areas ranging from governance to marketing, the report says. The fish in question are often seen as "trash fish", and catching them is often illegal due to rules drawn to protect higher-value and larger fish species.

"The largely unmanaged shift of many African fisheries towards small species may in fact represent a shift to more balanced harvesting," rather than a sign of overfishing of species higher up the food chain, noted Jeppe Kolding, a professor of biology at the University of Berger in Norway and lead author of the technical report. It suggests that potential catches of small species in Africa's lakes and rivers could be sustainably increased – a significant opportunity to tackle Africa's hunger and nutrition challenges.

Africa is the only continent with large, natural tropical lakes, and boasts around 1.3 million km^3 of freshwater resources. Its small fish species consist of mostly zooplankton feeders, such as herring and minnows, which weigh only a few grams and are less targeted than larger species, such as breams, carps and perches.

While small, they reproduce their own biomass at twice or more the pace of their fancier peers, reaching rates of five times per year and higher. As a result, from an ecosystem perspective, the fishing pressure on most of them is only a fraction of that on rivals higher up the trophic ladder that draw the attention of fisheries managers and policy-makers, and drive a pessimistic narrative about unsustainable fishing in African freshwaters.

FAO recommends efforts to compile better catch statistics, recognise the neglected socio-economic and nutritional importance of small pelagic fish, and encourage revised regulatory frameworks to promote balanced fishing patterns through a shift towards lower trophic levels.

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NEW WRC REPORTS

The application of ecotoxicity and activity system analysis of salt management to water resource protection and use: Sector specific guidelines for agriculture, mining and municipal wastewater

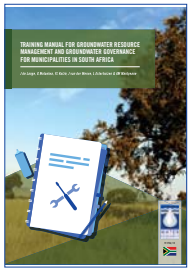
Freshwater salinisation in South Africa is on an increasing trajectory, with elevated levels of sulphate, sodium and chloride ions in many of the country's rivers, causing increased electrical conductivity and changes in ion composition. The problem of freshwater salinisation is intractable and desalination, though an effective treatment technique, it is expensive in terms of cost and energy consumption. This project investigated ways of effectively managing salinity risk to water resources by combining traditional science methods with those of social sciences in order to develop water quality guidelines and management practices for salinity. The project combined ecotoxicological and cultural history activity theory research techniques in the light of new trends in water research.

Report no. 2462/1/19

Factors influencing under-utilisation of smallholder irrigation schemes and opportunities to improve the schemes' productivity in Limpopo Province, South Africa

In South Africa and the Limpopo Province, in particular, a significant amount of investments has been made into small-scale irrigation schemes over the last 20 years. However, the majority of these schemes are considered to be underperforming or underutilised or failed cases. For this reason, the Water Research Commission (WRC) instituted a study to investigate the causes of the under-utilisation of the smallholder irrigation schemes in Limpopo Province and the possible interventions that can turn these schemes into profitable enterprises. A participatory action research approach was adopted and a comprehensive tool to carry out the assessments was used to conduct the study.

Report no. TT 787/19



Training manual for groundwater resource management and groundwater governance for municipalities in South Africa

In order to establish sound groundwater resource management within towns and municipal areas, the development of a training manual on groundwater resource management and groundwater governance for municipalities is of utmost importance. A training manual can be extensively used for capacitating municipal officials, technicians, managers and decision-makers, as well as communities where villages and towns are partially or solely reliant on groundwater resources. The objectives of this project were thus to undertake a training audit of national skills of municipalities and education institutions; to develop a training manual on groundwater resource management and groundwater governance for municipalities in South Africa.

Report no. 2447/1/19 (main report), TT 790/19 (training manual)

Assessing the impact of erosion and sediment yield from farming and forestry systems in selected catchments of South Africa

Natural ecosystems provide key functions for the sustainable economic development of societies. However, in many regions of the world, in particular in developing countries, such landscapes have suffered extensive degradation with consequential negative implications for ecosystem health, potentially jeopardising the capacity of ecosystems to deliver various life-supporting services. The primary aim of this project was to improve the understanding of the processes of erosion and sediment yield for different combinations of land uses (e.g. grassland, woodlands, agricultural crops, orchards and forest plantations) and scales for traditional and commercial agricultural production systems at selected sites within catchments for further application and extrapolation.

Report no. TT 788/19

Ecosystem process and function of temporary wetlands: Baseline data for climate change predictions

Ephemeral wetlands are well adapted to cyclical drying and wetting conditions that include wide ranges in temperatures. With the advent of global climate change, it is important to better understand the ecological function of these systems by drawing from existing knowledge on how to better predict and manage permanent wetland systems with a view to understand how they cope and adapt to these climatic changes. This project was designed to attempt to address gaps in knowledge such that it feeds into current water quality models that are designed to predict changes associated with global climate change by making them more robust.

Report no. 2348/1/19

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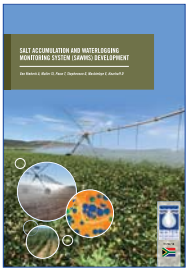

Salt accumulation and waterlogging monitoring system (SAWMS) development

Crop production in irrigated areas is often negatively affected by salt accumulation and waterlogging. Excessive accumulation of salt in the plant root zone has a deteriorative effect on vegetative growth, resulting in reduced crop yield and barren soil and ultimately leading to a decrease in agricultural production. It has been estimated that 18% of South Africa's irrigated land is either moderately or severely salt-affected or waterlogged. Salt accumulation and waterlogging are closely linked as rising water tables prevent salts from being leached. Conventional methods for monitoring salt accumulation within irrigation schemes involve regular field visits to collect soil samples, followed by laboratory analyses. Remote sensing has been proposed as a less time-consuming and more cost-effective method for monitoring salt accumulation, as satellite image cover large areas on a regular, timely basis. The aims of this project, which lead to the establishment of the Salt Accumulation and Waterlogging Monitoring System (SAWMS) were to develop a system that automatically analyses multi-temporal satellite imagery to identify areas within cultivated fields that are likely affected by waterlogging or salt accumulation; dissemination information about waterlogged and salt-affected areas to end-users through the development of a Web-based application; and demonstration, apply and evaluate the system in suitable irrigation schemes.

Report no. TT 782/18

Sentinel-3 validation for water resources protection

The *Sentinel-3 validation for water resources protection*, hereafter referred as S3VAL, project aimed to provide measurements that support the quantitative collaboration and validation of the satellite remote sending Sentinel-3 Ocean and Land Colour Instrument for water quality monitoring applications in water bodies and near-coastal waters of South Africa. the Sentinel-3A satellite was launched on 16 February 2016 and once fully operational will provide an unprecedented ability to observe the Earth's land and water surfaces for environmental applications.

Report no. 2518/1/19

To download a free copy of these reports
Visit: www.wrc.org.za.

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WATER AND THE ENVIRONMENT

On the hunt for the elusive riverine rabbit

The story of the riverine rabbit – a rare and elusive mammal found mostly in the upper central Nama Karoo – is intertwined with historical land use practices, agricultural prospects and future livelihoods. Jorisna Bonthuys explores the link between this ecological indicator species and dryland seasonal rivers and their riparian zones.

Courtesy EWT

The riverine rabbit can grow to a size of around 52 cm and has large ears. It has a dark brown band running along the side of the lower jaw upwards to the bottom of the ears.

The riverine rabbit (***Bunolagus monticularis***) has kept researchers guessing for more than a century.

This elusive animal is notoriously difficult to find and monitor in the vastness of the Karoo. Nowadays, camera traps are employed to determine its presence or lack thereof in the landscape. New technology is capturing them in novel places.

First discovered near Deelfontein in the Karoo in 1902, it took 27 years before the rabbit was rediscovered in 1929. A further specimen was taken in 1939. In 1949, only four specimens were found in donga-like seasonal rivers near Calvinia, namely the Fish and Rhinoceros rivers. The species was first discovered in the Western Cape in 2003.

With only a small population left in the wild, the species is of conservation concern, says Cobus Theron from the Endangered Wildlife Trust (EWT). He is the programme manager of the EWT's Drylands Conservation Programme.

Scientists are still trying to understand this species' distribution and population dynamics. This kind of information is vital to ensure resilient landscapes in the face of increasing land use pressure and climate change. "The riverine rabbit is not only important from a biodiversity point of view. It is also considered

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an indicator species for the riparian shrubland associated with the seasonal drainage systems of the Karoo," Theron explains. "Their absence along sections of the seasonal rivers in the Nama-Karoo and Succulent Karoo indicates river systems under stress."

Riverine rabbits are short-lived and have a very low breeding rate, making them particularly vulnerable to environmental changes in their habitat. Projections of future temperature change show significant temperature increases across their distribution range. The risk of more frequent extreme events, including more floods and more droughts, is also increasing. More frequent drought events, like the recent multi-year drought, are becoming the new normal in the region due to unfolding climate change. At the same time, the extent, duration and seasonal distribution of rainfall is changing.

The future is going to be hotter and drier in the semi-arid regions of the country, and this could affect the species' survival rate.

The secret life of riverine rabbits

Until recently, it was believed that these critically endangered animals only occur in the riparian zones along the seasonal rivers of the Karoo (particularly the Nama-Karoo). The majority of the riparian shrub typical to their habitat are found near the Klein/Sak River, the Ongers River, Brak River and Riet/Klein River.

However, in May this year, the EWT confirmed that camera traps captured a population of riverine rabbits on the western side of the Baviaanskloof in the Southern Cape. Somehow this population managed to go entirely undetected until recently. This comes after ornithologist and conservation scientist, Alan Lee from Blue Hill Escape Farm, discovered a dead riverine rabbit on a gravel road in December 2018.

This population represents a completely new distribution of the species not anticipated by any previous population modelling. Bonnie Schumann, EWT's Nama-Karoo coordinator in the Drylands Conservation Programme, describes this as a "historic find", with the closest confirmed sightings of the southern population having been more than 250 km to the west.

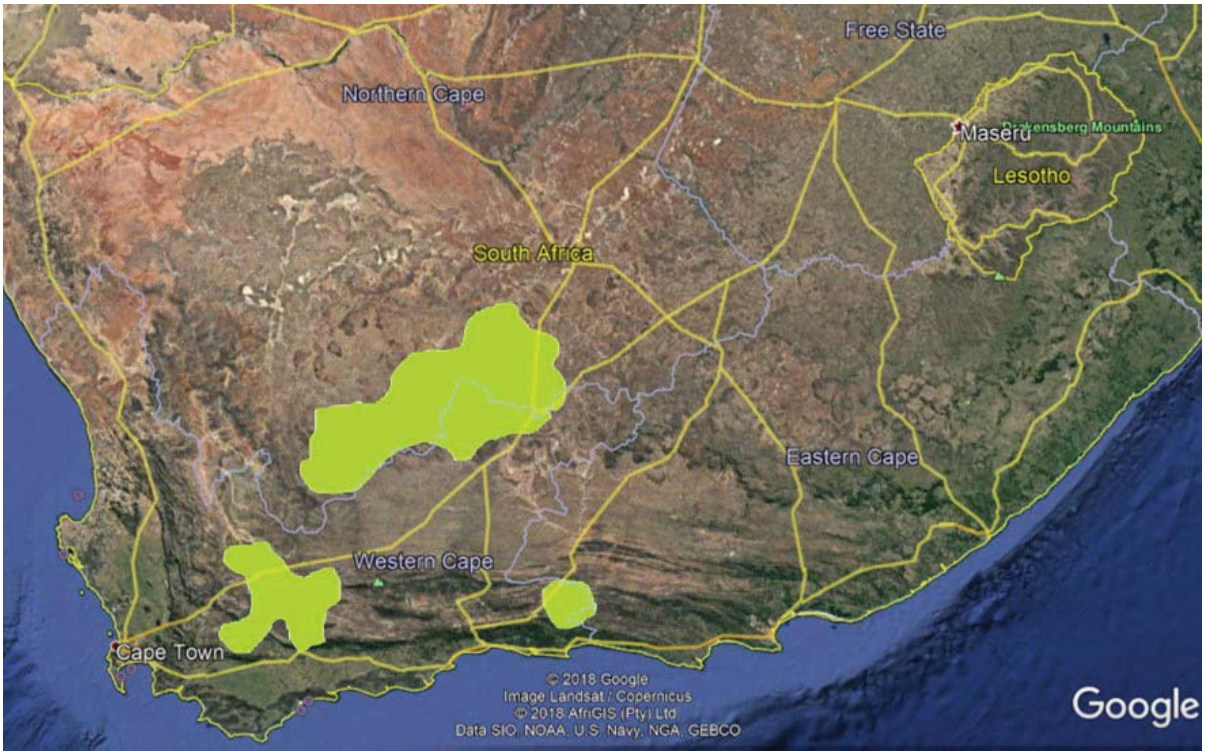
"This find is unexpected and redefines scientific understanding of the distribution of the species," Theron adds. "It also demonstrates that their elusiveness is part of their survival strategy."

The EWT, along with CapeNature, will now incorporate the findings into their conservation strategy and engage landowners to help ensure the riverine rabbit and its habitat receives attention.

Land use and habitat loss

Several studies have drawn attention to the destruction of the riverine vegetation as a reason for the species' absence from large tracts of its former range. This is because two-thirds of its habitat has been fragmented or destroyed in the past 50 years as a result of anthropogenic disturbances.

"It is estimated that approximately 68% of the species' original habitat was destroyed during the first part of the 20th century."



Courtesy EWT

The riverine rabbit occupies a small habitat in parts of the Western and Southern Cape.

Courtesy EWT

An example of the type of healthy riparian habitat along seasonal river beds in the Nama Karoo that provides habitat for the critically endangered riverine rabbit.

Courtesy EWT

A previous unknown population of riverine rabbits has been discovered in the Baviaanskloof.

In earlier decades, the species' range was known to extend from Calvinia in the west, to near Richmond in the east. However, they have disappeared from large parts of this range. They now occur mostly from Williston to Victoria West, including the areas around Carnarvon, Fraserburg and Loxton.

The riverine rabbit is the only indigenous burrowing rabbit in Africa. The animal depends on the availability of deep and soft alluvial soils for their survival. These soils are attractive to land users for the cultivation of crops as suitable agricultural soils and access to reliable water sources, which are a scarce commodity in the region.

It is estimated that approximately 68% of the species' original habitat was destroyed during the first part of the 20th century due to extensive wheat cultivation in an area known for its water scarcity. Most of the altered habitat comprises cultivated lands, historic lands, impoundments, eroded areas, and salinised patches. Recovery of these areas is extremely slow, taking several decades, as riparian zone vegetation will only establish after sporadic above-average rainfall years, or not at all if the degradation is very severe.

The species survives in the dense and often fragmented vegetation in the districts of Victoria West, Beaufort West and Fraserburg, in riparian zones along the seasonal rivers. Most of the remaining riverine rabbits' habitat is found to be associated with a network of rivers, including the Sak, Klein Sak, Riet and Klein Riet rivers.

Building resilient landscapes

Farming practices have a significant impact on the long-term resilience of the landscapes in which riverine rabbits are found. During the recent multi-year drought, considered the most severe drought in about a century, stresses on habitat have increased due to grazing pressure.

While the Nama-Karoo is characterised by largely intact diverse natural rangelands used primarily for extensive livestock production, the EWT points out that there is a need to halt and reverse existing degradation and adopt the most effective management practices to counter increased climatic uncertainty.

"We need to buffer the ability of the natural environment to withstand shocks. Furthermore, protecting the ecosystem services and goods that people benefit from is critical," Schumann emphasises. In the case of the semi-arid regions, the cost of habitat degradation is very high compared to maintaining natural veld and healthy riverine corridors. "It is much cheaper to keep remaining habitat intact than try to restore it in these areas," she says.

Theron believes more emphasis is needed to ensure sustainable land use and development planning to protect nature's ability to provide vital ecological goods and services that humans derive from nature. This requires sound management of the natural infrastructure, including rivers, streams and riverbeds that trap, clean and deliver water and help to recharge groundwater resources.

Healthy river ecosystems are not a luxury, but the basis for sustaining livelihoods in these semi-arid regions, Theron says. Water availability in the area is severely limited, and shale gas development (including hydraulic fracturing) and other mining practices also pose a significant threat to water resources. "In the Karoo, water is considered 'liquid gold'", he says. "Many communities are entirely dependent on limited groundwater supplies for their livelihoods."

Non-perennial rivers and their riparian zones provide many ecological goods and services, including natural flood control and replenishing groundwater resources. These systems enhance the ecological functioning of water catchments and provide critical habitat for fauna and flora, according to Jeanne Gouws, CapeNature's freshwater ecologist. Connectivity between aquatic ecosystems, and between aquatic ecosystems and the surrounding terrestrial landscape in functioning natural corridors, is essential for supporting the fauna of the region, including their need to feed, breed and migrate.

Seasonal rivers are particularly vulnerable to changes in

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hydrology, as they are adapted to brief periods of inundation and flow, explains Kate Snaddon from the Freshwater Research Centre in Cape Town. While rainfall drives the inundation period of the aquatic ecosystems in the area, surface-groundwater interactions are thought to be important for sustaining them.

The seasonal rivers of the Karoo are highly dependent on groundwater discharge, which occurs at springs and when groundwater recharge (through precipitation at higher elevations) allows the water table to intersect with river channels. The upper reaches of the Salt River (Beaufort West), the Kamdeboo, Sundays and Brak Rivers (De Aar) are all good examples of these groundwater-fed watercourses, Snaddon points out in a recent publication.

Towards sustainable land use

Most of the efforts to ensure sustainable land use practices and conservation efforts related to riverine rabbits occur on privately and communally owned land. This is because these mammals occur in working commercial livestock farming landscapes, making it imperative to integrate interdisciplinary priorities to ensure the survival of this iconic species and the riverine habitats it depends on.

The EWT's Drylands Conservation Programme recently embarked on a project in partnership with the United Nations Development Programme and the Department of Environmental Affairs to promote sustainable land management in the Karoo.

Responsible natural resource management ensures the integrity of ecosystems and the continued provision of ecosystem services to current and future generations, Theron says. This should include a major focus on agricultural land use practices.

Over 80% of South Africa's land is used for agriculture with livestock farming being the dominant rural land use, according to the EWT. Approximately 1.5 million hectares of land in South Africa is degraded, resulting in the loss of vital ecosystem services and productive land.

The strategy for conserving riverine rabbits and their habitats incorporates an integrated management approach that considers the functioning riparian ecosystems on a landscape scale. Four riverine rabbit conservancies covering 360 000 hectares are currently in existence.

Farm-scale habitat management can contribute to both conservation and sustainable land use, Schumann emphasises. The effective management of livestock within camps inhabited by riverine rabbits, for instance, requires frequent rotations with adequate rest periods to allow regrowth of vegetation. Efforts are also underway to ensure ecological benefits at scale in this region.

About the riverine rabbit

- This elusive animal is found mostly along seasonal rivers of the upper-central Nama-Karoo. It is considered the rarest mammal in Southern Africa.
- The riverine rabbit (***Bunolagus monticularis***) is an indicator species of the state of river health and riparian vegetation in its rangeland.
- Soon after the discovery of this species in 1902, it became known as the 'pondhaas' ('pound rabbit' in English) after Captain GC Shortridge, curator of the Kaffrarian Museum in King William's Town, offered £1 for each rabbit brought to him.
- The riverine rabbit – a mostly nocturnal and often solitary species – is the only burrowing rabbit in Africa. Its lifespan is about four years.

Source: www.capenature.co.za and www.ewt.org.za.

"Implementing sustainable management has the potential to not only improve agricultural production and the conservation of biodiversity but also sustain livelihoods in this arid ecosystem indefinitely," Theron concludes.

For more information, contact Theron at cobust@ewt.org.za or visit www.ewt.org.za.

Repeat photography shows habitat changes in the area of the Droërivier about 27 km southeast of Calvinia, in the Northern Cape, over recent decades. The 'original' photograph was taken by Dr Margaret Levyns in about 1926. The 'repeat' photograph was taken by Prof Timm Hoffman and Hana Petersen on 9 September 2015.

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WATER INFRASTRUCTURE

Mzimvubu Water Project – bane or boon for the Wild Coast?

Extreme challenges of sedimentation and erosion are casting shadows on the potential success of the planned Mzimvubu water project. Article by Sue Matthews.

Bennie van der Waal

On 18 February the then Minister of Water and Sanitation, Gugile Nkwinti, launched the 'advanced infrastructure' project for the Ntabelanga Dam, which forms part of the massive Mzimvubu Water Project, estimated at just over R15 billion at 2017 prices. This initial phase simply entails construction of access roads to the site of the future dam on the Tsitsa River and adjacent water treatment works, at a budgeted cost of R113 million.

According to a ***City Press*** article by Lubabalo Ngcukana published a few days before the launch, Nkwinti had said that funds had not yet been allocated for the dam itself, nor for the smaller Lalini Dam downstream. In fact, National Treasury and Cabinet had not yet approved the Lalini Dam as it would generate minimal hydropower, compared with the touted 1 600 MW from the Mbokazi Dam on the main stem of the Mzimvubu River. A feasibility study for the latter was about to begin, despite the fact that the Mbokazi Dam had been 'taken off the table' during previous screening exercises because of its high cost and environmental impacts, as well as its limited potential for domestic water supply, agricultural development and job creation.

Nevertheless, the same article reported that President Cyril Ramaphosa had announced during an African National Congress (ANC) rally in January that the Mzimvubu Water Project would become a priority if the party won the May election. This would not be the first time that the project has been used for electioneering. When former President Jacob Zuma launched the Mzimvubu Water Project with a sod-turning ceremony on 11 April 2014, he concluded his speech by saying: "please

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go and vote during the elections on the 7th of May, for these achievements to be consolidated."

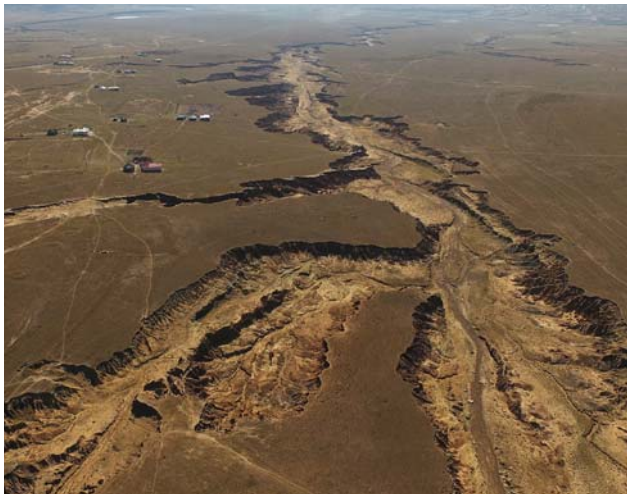
It is notable that Zuma's 'launch' took place six months before the publication of the final report on the Feasibility Study, commissioned by the Department of Water and Sanitation (DWS) and conducted by consulting firm Jeffares & Green. The process commenced in January 2012 with an Inception Phase, followed by a Preliminary Study and then the full Feasibility Study, which culminated in the publication of the final reports in October 2014. The study built upon three earlier ones, although the first of these – Republic of Transkei Mzimvubu Basin Development, dated 1987 – focused only on the Mbokazi Dam and included the ludicrous concept that up to 90 million m^3 of water would be exported on an annual basis to the Arabian Peninsula by tanker. The other two studies, completed in 2010, focused on water resources and the business case for water-related opportunities, respectively.

Two weeks after Zuma's sod-turning ceremony in April 2014, the environmental impact assessment (EIA) process for the Mzimvubu Water Project kicked off with the publication of a background information document. The EIA, conducted by ILISO Consulting, involved separate applications for dam construction, electricity generation and roads. The final scoping report and plan of study for the EIA were submitted to the Department of Environmental Affairs (DEA) on 20 June 2014, and had been accepted by 15 July. The final EIA Report was issued in February 2015, and by mid-June of that year DEA had granted environmental authorisation. A water use licence application (WULA) process ran concurrently with the EIA, and that too was completed by February 2015.

Subsequently, DWS commissioned more detailed designs and operational plans for the dams, as well as the study to determine water resource classes and resource quality objectives for the Mzimvubu catchment. A number of scenarios for dam operation were considered as part of this study, which revealed that the proposed hydropower plants could not run at maximal capacity during the winter months – resulting in elevated baseflows downstream – without compromising the ecological health of the river and estuary. The proposed Classes and RQOs were gazetted for public comment in November 2018.

Clearly, though, Phase 1 of the Mzimvubu Water Project, which entails construction of the Ntabelanga Dam, water treatment works and bulk distribution system, is considered a done deal subject to funding being available, and the Chinese government has expressed interest in assisting with this. But scientists and

David Henning



Erosion gullies would contribute enormous quantities of sediment to the Ntabelanga and Lalini dams.

Vuyo Ntamo

Rhodes University doctoral candidate, Laura Bannatyne, shows Anavuyo Ndaba how to use a clarity tube.

The bulk water-supply scheme

The Ntabelanga Dam and associated treatment works would supply potable water to a population of more than 500 000 people, projected to increase to at least 725 000 people by 2050. Some 2 860 ha of high-potential irrigable land in the vicinity have been identified, although 85% of this is 17-32 km away over hilly terrain, necessitating major pumping and distribution systems with significant energy requirements. A hydropower plant at the dam wall would generate some electricity, but to offset energy costs the Lalini Dam and hydropower scheme were proposed. Releases from the Lalini Dam would generate hydropower at the dam wall, but would also be piped 8 km to a larger 45 MW installation below the Tsitsa Falls before being discharged back into the river. This electricity would be sold to ESKOM, but the true potential for this remains unclear, given the SOE's ongoing woes. And without hydropower revenue to subsidise raw water costs, the irrigation scheme would be neither viable nor sustainable.

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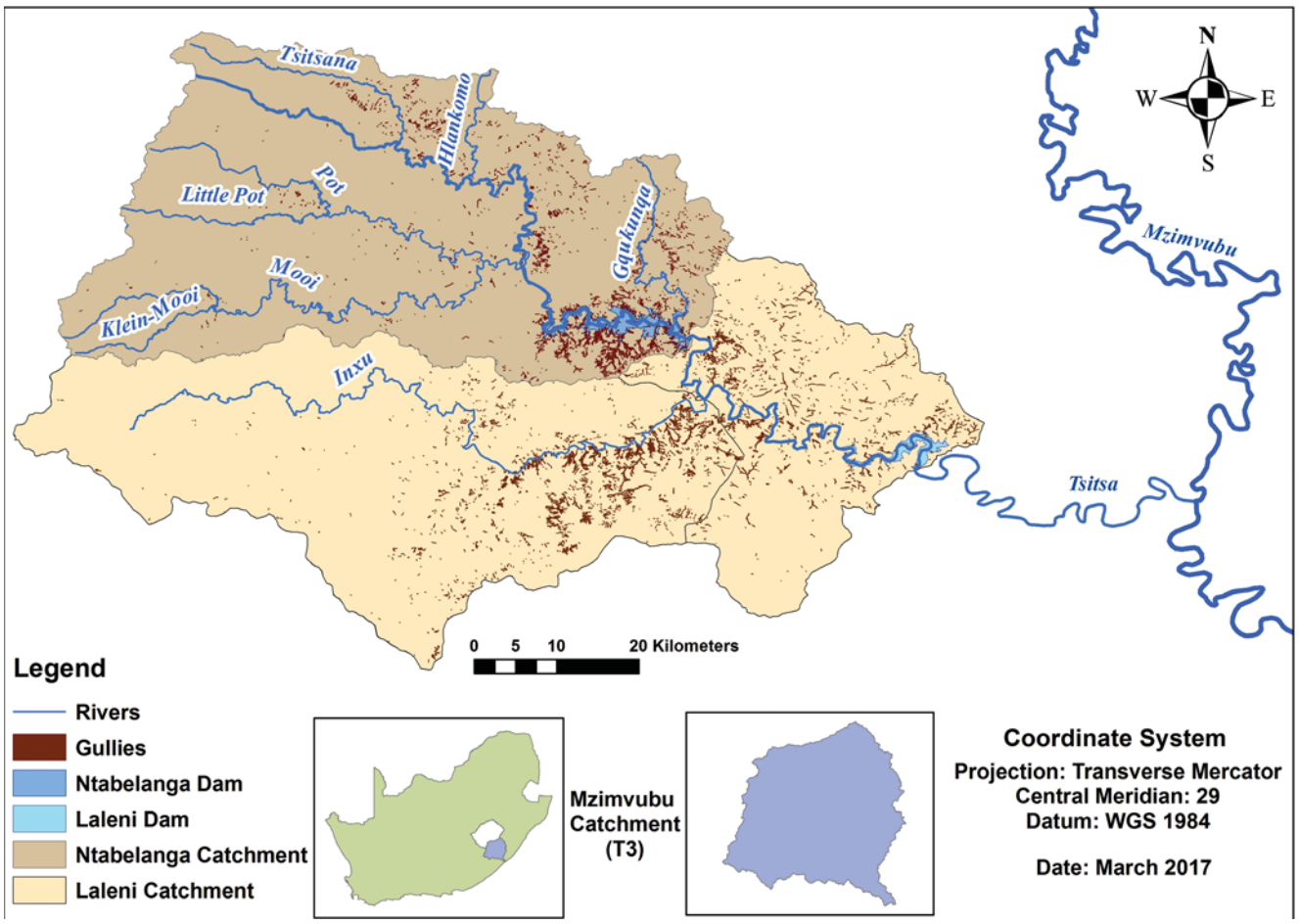

Namso Nyamela

The proposed Ntabelanga and Lalini dams would be built on Tsitsa River, a tributary of the Mzimvubu River that flows into the sea at Port St Johns.

land managers familiar with the terrain are questioning the project's sustainability, given the likelihood that the lifespan of any instream dams here will be severely curtailed by sedimentation.

"When I was contacted more than seven years ago by the feasibility study consultants and they told me the dam sites they had in mind, I almost fell off my chair!," says Dr Jay Le Roux, a soil erosion specialist then based at the Agricultural Research Council's Institute for Soil, Climate and Water (ARC-ISCW), but now at the University of the Free State. "That's one of the erosion hotspots in South Africa, if not the world."

The main report of the feasibility study gives short shrift to the issue, apart from mentioning the large-scale erosion within the catchment, and extremely high sediment loads in rivers. Sedimentation was one of the criteria used to compare potential dam sites, and was assessed using the updated version of the Rooseboom (1992) method developed in the WRC-funded project 'Sediment Yield Prediction for South Africa: 2010 Edition' by Msadala *et al.* (**WRC Report No. 1765/1/10**). The V50 values, representing the predicted volume of sediment accumulated in the dam after 50 years, were calculated to be 35.7 million m^3 for the Ntabelanga Dam and 32.1 million m^3 for the Lalini Dam. This equates to 7.3% of the Ntabelanga Dam's 490 million m^3 storage capacity and 13.8% of Lalini Dam's 232 million m^3 storage capacity.

Dr Le Roux believes these figures vastly underestimate the problem, however, because the methods used to derive them do not take gully erosion into account. As project leader for the WRC-funded study, 'Sediment yield modelling in the **Mzimvubu** River catchment' (**WRC Report No. 2243/1/15**), completed in April 2015, he used ArcSWAT to model sheet-rill erosion as well as SPOT-5 satellite imagery to map erosion gullies, or dongas, and then model gully-derived sediment in a geographic information system (GIS). In a paper subsequently published in ***Land Degradation and Development*** (2017, DOI: 10.1002/ldr.2753), he concludes that the life expectancies of the Ntabelanga and Lalini dams could potentially be as short as 55 and 43 years, respectively, without catchment rehabilitation to slow the rate of sedimentation.

This is because the more than 7 600 gullies mapped in the Tsitsa catchment, where the dams are located, could contribute up to 95% of the total sediment production in that catchment. Some of the gullies are several kilometres long and more than 100 m wide. While poor land-use practices, such as overgrazing, cultivation on steep slopes, and the subsequent abandonment of these croplands, as well as natural events in the form of veld fires, drought and floods have all played a role in the formation of these gullies, it is the highly erodible soils that are most to blame.

"The main causal factor of those big gullies are the soils – they're quite unique, and simply horrible!," says Dr Le Roux. He explains

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that these are duplex dispersive soils, comprised of a shallow topsoil that is relatively sandy and permeable, with a sharp transition to an underlying clay-rich prisma-cutanic subsoil. "When dry the clay feels rock hard, but as soon as it comes into contact with water it simply dissolves, and that fine sediment stays in suspension for a very long time, so it will eventually make its way into the dams and be trapped there."

He points out that his results do not take account of sediment residence time – the temporary deposition within the catchment that may delay the sediments' arrival at the dams – and they represent potential rather than absolute values as the models have not been validated with actual measurements. In an effort to address the latter, follow-up research is now being conducted to estimate the amount of sediment produced by a few selected gullies as they continue eroding.

"Most gullies in the catchment incise very quickly until they reach the bedrock, then the incision processes slow down but the side walls keep slumping and collapsing, losing tons and tons of soil within one rainfall event," says Dr Le Roux. "So we're using drones to create high-resolution digital elevation models, flying the same gullies at about the same time each year, and this should allow us to calculate the volume of soil that is lost as the gully gets bigger. I believe that once we have accurate values for our test gullies, we can extrapolate the data to other gullies and calculate how much sediment they deliver."

This work is being conducted with Dr Bennie van der Waal from Rhodes University, and a number of postgraduate students. In addition, a PhD student supervised by Dr Van der Waal, Laura Bannatyne, is measuring suspended sediment in rivers within the Tsitsa catchment with the assistance of 'citizen technicians' hired from the local communities. She began this research in December 2015 for her MSc, and described the methods used and challenges experienced during the first wet season in a 2017 paper in ***Water SA***.

Individuals living near the monitoring sites have been trained to collect water samples from the river bank and record other information about the river using a combination of basic sampling equipment and smartphones. The water samples are later analysed in the Rhodes' laboratories for electrical conductivity and turbidity, before being evaporated to derive the suspended sediment concentration. In the first seven months alone, approximately 4 000 samples were collected by the citizen technicians.

This was supplemented by flow measurements and sampling done by researchers wading across the entire cross-section of river channels, in a range of flow and turbidity conditions, to provide width- and depth-integrated data on suspended sediment concentrations. In addition, continuous depth data was obtained from Solinst pressure transducers installed at nine sites, discharge data was collated from the two DWS gauging stations in the area, and five-minute rainfall data was provided by six rain gauges installed throughout the catchment.

"More than 90% of the sediment is carried in the highest 10% of flows, so these flows must be targeted for sampling," says Bannatyne. The citizen technicians routinely sample each morning and afternoon, but increase the sampling frequency when they observe a rise in water level to monitor both sides of the flood hydrograph. Of course, the very highest flows are

Laura Bannatyne

Citizen technician, Khanyisa Nogaga, takes a sample from the Tsitsa River using a plastic jar on the end of a sampling pole.

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unsafe to sample for both citizen technicians and researchers, requiring adjustment of suspended sediment load and yield estimates.

"In other places around the world where suspended sediment data is still being collected, it is typically done using fixed probes or pump samplers," she adds. "In the Tsitsa catchment we could install one probe at the DWS weir at Xonxonxa where there was a power supply and a structure to house it. That probe would give an idea of overall catchment suspended sediment load and yield, but no spatial insight into the areas contributing most sediment to the system. Unfortunately, the probe was twice destroyed by lightning, almost immediately after installation and then again the following year after it had been repaired."

Bannatyne has continued this research for her PhD, although the original 11 sites have been reduced to seven, and more than 20 000 samples have now been collected and analysed. The project is funded by DEA's Natural Resource Management (NRM) programme, which is rolling out extensive rehabilitation and erosion-prevention works in the Tsitsa catchment. It is anticipated that Bannatyne's dataset – besides providing information on the likelihood of the dams' lifespan being compromised by sedimentation – will assist NRM decision-makers in deciding where they should be directing their efforts.

The NRM funding is channelled through a project that was initiated in 2014 as the Ntabelanga and Lalini Ecological Infrastructure Project (NLEIP), but was renamed the Tsitsa Project in 2018 to reduce the association with the dams. The project has evolved over time to focus on social-biophysical linkages in the catchment, with the aim of addressing the drivers of land degradation. It is coordinated by a team at Rhodes University, with Dr Van der Waal's role straddling both the research and implementation components, as he supervises a number of postgrads while also supporting operations and planning.

"The approach we're following, and it's in line with international thinking, is that it's very expensive to fix an established gully – typically done with huge gabion structures – so instead we try to prevent new gullies from forming," he says. "It's a lot about involving the local communities to help build smaller, soft structures that slow the water down, allowing it to infiltrate and to be stored in the landscape in order to improve the ecosystem services, so the people living there can benefit at the end of the day."

Of course, getting community buy-in takes time, especially since these are mostly communal lands under the authority of a traditional leader. The Tsitsa Project brochure suggests that tangible progress achieved to date is limited, as it states: "At the time of writing (late 2018), we feel we have made a good start and are gradually building trust and are optimistic about improved collaboration."

"We're moving very slowly, but we're trying to build capacity on the ground to be more involved in governance, so people living in a village can have a better say over what is happening and how things are done in their surrounds," explains Dr Van der Waal. "Hopefully, that will have a longer lasting effect than outsiders coming in, building structures and leaving."

When the NLEIP was initiated in 2014, a budget of R450 million over the next 10 years was allocated to the project. Dr van der Waal says he has done a back-of-the-envelope assessment of the scale of work needed in the catchment, and this will not scratch the surface of what is required.

"We need to invest R15 billion over a 10-year period – that's the likely cost to address most of the land degradation in that catchment – and we probably have to invest over 50 years to make a meaningful difference. At the moment we're putting in maybe R10 million per year. So when decision-makers consider the R15 billion estimated cost of the Mzimvubu Water Project, it would be wise to consider a similar budget for rehabilitation, just to protect their investment."

Dr Le Roux agrees with this sentiment. "Given the seriousness of the problem, much more needs to be done – huge restoration works should be underway before a dam is considered. The NRM is only going to be capable of rehabilitating this catchment if they are given lots of funds and capacity to do more work on the ground."

Of course, rehabilitating the catchment will not prevent the dams from silting up, but only extend their lifespan – perhaps by up to 30% according to some estimates, although it is impossible to say. The Mzimvubu Water Project is categorised as a social development project, so it need not 'pay for itself' in financial terms. But can the country really afford R15 billion for upfront capital expenditure on a relatively short-term intervention with limited socio-economic benefits, as well as ongoing rehabilitation and operational expenses that will be blisteringly high, particularly if hydropower cannot subsidise the energy and water costs?

Dylan Weyer

The Tsitsa River winds its way past Shukunxa village.

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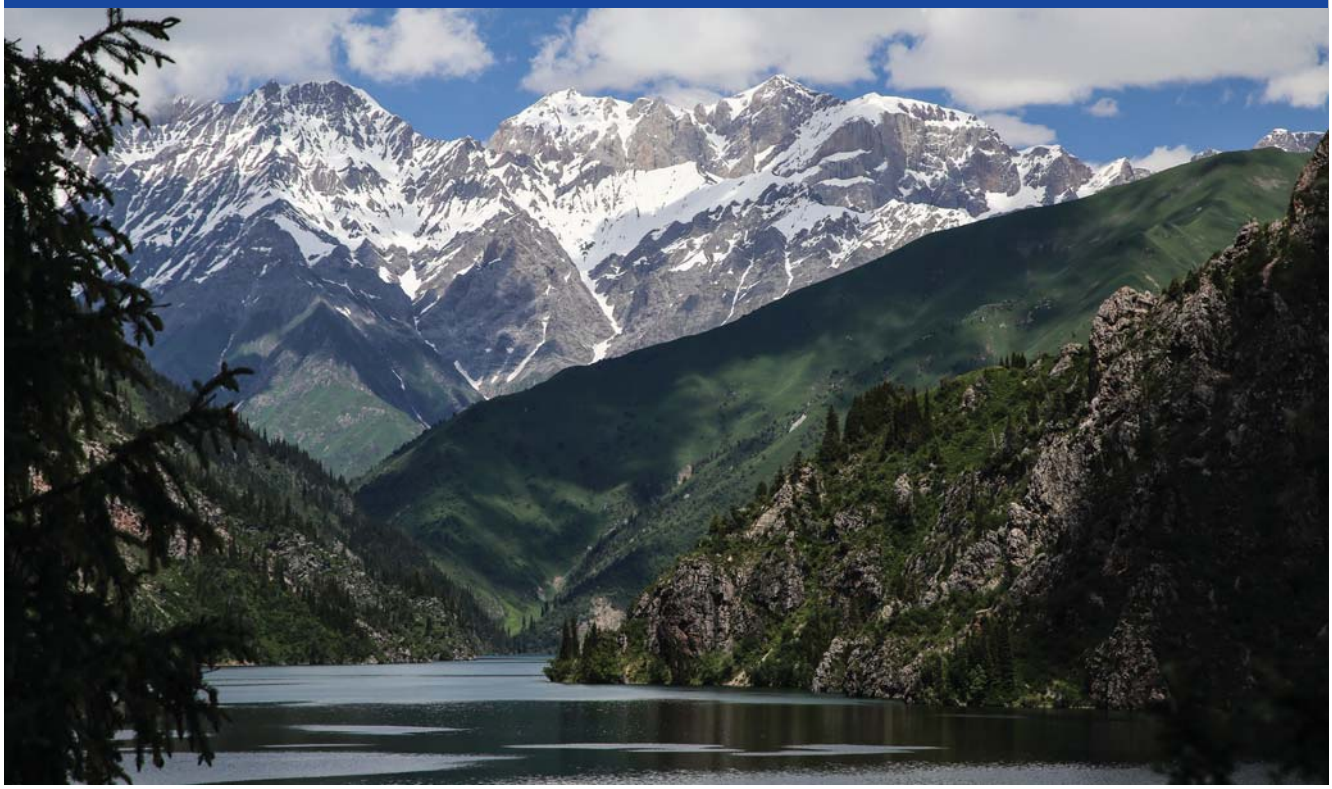
WATER RESOURCE MANAGEMENT

Crossing borders – Achieving successful transboundary river management in Central Asia

Petro Kotzé investigates how a project in Central Asia is using the power of personal relationships to achieve integrated management of transboundary river basins.



All photographs by Petro Kotzé

The rivers of the region are fed by glaciers, rising and falling as snow freezes and melts throughout the seasons.

"For two years there has been almost no conflict with our neighbours in Tajikistan," says Doranbek Mamadiev. "Now I have personal friends across the border." Mamadiev is the chairperson of the Isfara River Small Basin Council (SBC) in Kyrgyzstan, an advisory body that is one of the key outcomes of a project that is trying to foster cooperation in transboundary river basins in Central Asia.

Of course, Central Asia is not the only region where borders have been drawn across rivers. Regardless of their political relations, many neighbouring countries the world over are bound by water. According to the Food and Agriculture Organisation of the United Nations (FAO), international river basins cover 45.3% of the Earth's land surface, and account for roughly 80% of global river flows. In the Southern African Development Community (SADC) region, about 70% of the water resources are shared by more than one country. Nations that share water are not just hydrologically interdependent, but also economically and socially. Though this creates potential for collaboration, it can also result in conflict.

Central Asia is a perfect case in point. Here, water has been the tinderbox that has ignited violent skirmishes. However, the region is emerging as an example of how integrated water resources management in small transboundary basins can be achieved by simple means: the power of personal relationships.

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The Central Asian republics

Prior to the fall of the Soviet Union, the Union of Soviet Socialist Republics (USSR) was a socialist state with a highly centralised government and economy. It was once the largest country in the world, spanning over 100 000 km east to west across 11 time zones, and over 7 200 km north to south. The landscape was made up of five diverse climate zones; tundra (uplands, or treeless mountain tracts); taiga (coniferous forest or boreal forest located below the tundra); steppes (dry, cold grassland); desert and mountains.

When the USSR collapsed in 1991, its fifteen republics were transformed into independent states. Among these were the Central Asian republics of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan, sharing the Aral Basin with Afghanistan in the south (the latter was not part of the USSR).

The region has five main river basins, the two largest by far being the Amu Darya and Syr Darya, followed by the Balkash-Alakol, Ob-Irtysh, and Ural rivers. The area is mostly arid or semi-arid, and the available water is unequally distributed. Most water in the Amu Darya and Syr Darya rivers comes from the melting of glaciers, and coupled with the heaviest rainfall taking place in the high mountains of Kyrgyzstan and Tajikistan, these countries are also the most plentiful endowed with water. These landscapes are ideal for hydroelectricity generation, a vital energy resource in the region.

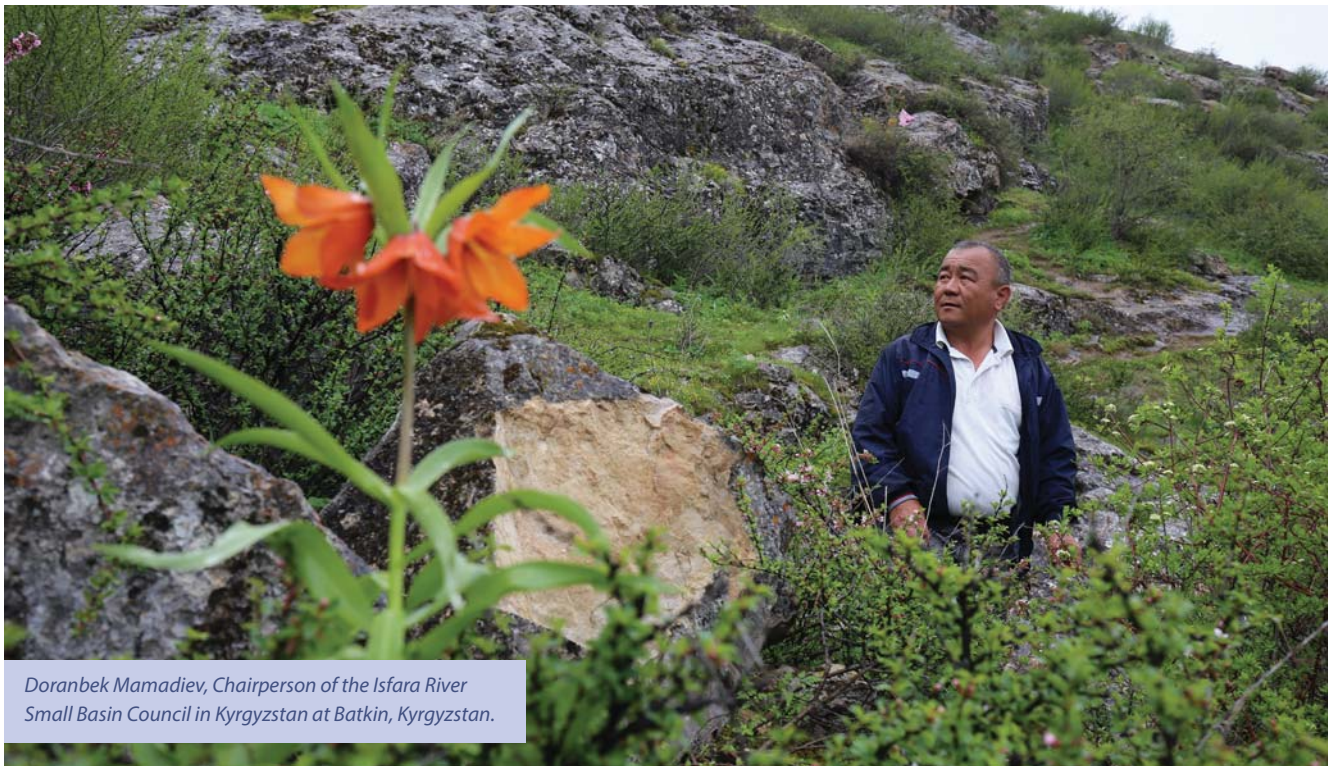
The bulk of the region's water is used for agriculture in countries downstream, in particular water-stressed Uzbekistan and Turkmenistan, where deserts were turned into fertile farmlands during Soviet reign on the back of intensive irrigation schemes. This has allowed Central Asian countries to become major agricultural producers, with large-scale cultivation of water-intensive crops, such as cotton, prioritised for many years.

Scholarship benefits ripple across borders

"I used to only think about our nation's water challenges," says Arif Mamedova. Mamedova is from Turkmenistan, and is studying towards his Master's degree in IWRM at the Kazakh German University, together with other students from across Afghanistan, Kyrgyzstan, Kazakhstan and Tajikistan. The students were brought together here in Almaty, Kazakhstan, thanks to scholarships awarded as part of the Smart Waters project.

"Students are nominated for scholarships by a state body," says Anna Inozemtseva, Deputy Chief of Party of the Smart Waters Project. "They then sign an agreement to return to this state body on completion of their studies in order to bring new knowledge into the institutions," she says. For Mamedova, much has changed since he accepted the opportunity. "I have never had friends from other Central Asian countries, but now I have many." Here, we are all friends, he says. "Now I see the problems experienced in the countries that we share water with too."

This is exactly what the project is trying to achieve with the scholarships, over and above providing a new generation of experts in IWRM. "In the future, these alumni will use their networks to cooperate," says Inozemtseva. "Instead of working in isolation, they will discuss shared problems on water resources management across the Central Asian region."



Doranbek Mamadiev, Chairperson of the Isfara River Small Basin Council in Kyrgyzstan at Batkin, Kyrgyzstan.

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Between them, the five countries have a total irrigated are of some 100 000 km^2 – three times the land area of Belgium. With little water coming from rainfall they are heavily dependent on snow-fed river water for irrigation.

When borders are drawn where once there were none

Management of the river basins was relatively straightforward when the entire region was part of a single country, but when the union collapsed, hundreds of river basins were split between independent nations. The Syr Darya, for example, originates in the Tian Shan Mountains in Kyrgyzstan and eastern Uzbekistan, then flows for over 1 300 miles (2 092 km) through Uzbekistan and southern Kazakhstan to meet the Aral Sea. Within the basin, the fertile Fergana Valley is carved into a patchwork of entwined territories through which a network of irrigation canals flow back and forth between Kyrgyzstan, Tajikistan and Uzbekistan. Except for the larger river basins, over 200 smaller rivers are crossed with international borders.

According to the European Parliamentary Research Service, cooperation continued after the disintegration of the Soviet Union in the form of a number of bilateral and regional agreements. For example, in 1996 Turkmenistan and Uzbekistan established infrastructure-sharing arrangements that allow each country equal share of water from the Amu Darya River. Under a 1998 agreement between Kyrgyzstan, Kazakhstan and Uzbekistan (joined by Tajikistan in 1999), Kyrgyzstan committed to releasing enough water during the growing season from its Toktogul cascade of reservoirs to irrigate crops in downstream countries. In return, Kyrgyzstan would be compensated for the loss of winter hydroelectricity-generating potential in the form of free deliveries of fuel and electricity, and financial contributions towards infrastructure maintenance.

Regardless, cooperation proved much more difficult than during Soviet reign. With weaker regional organisations in place, unable to effectively coordinate water resource management and some borders remaining undefined, water became the spark that ignited violent skirmishes, resulted in border closures and the cutting of electricity and water supplies to neighbouring countries. In 2014, for example, a fight broke out between villagers on either sides of the Kyrgyz-Tajik border after irrigation water from Tajikistan to a downstream area in Kyrgyzstan was cut off. In the Fergana Valley, mobs attacked ethnic Uzbeks living in southern Kyrgyzstan in 2010. Hundreds of people were killed.

The region has experienced a period of stability of late, but the impact of the disintegration of the Soviet Union surged into various other aspects of water resources management. Expertise once freely shared became isolated in select countries, as did the institutions for training new generations of water engineers and managers. Infrastructure such as canals and water pumps, once maintained from a central point, deteriorated without clear authorities appointed for upkeep. Colleagues that once freely collaborated and shared data along river ways were suddenly hampered by international check-points.

This left a variety of water management challenges. Heavy and inefficient water use, especially in agriculture, is putting water supplies under pressure. Intensive agriculture has polluted the region's rivers and soils. The natural environment paid a heavy price, perhaps most clearly indicated in the near-disappearance of the Aral Sea, once one of the world's largest lakes. The Central Asia countries and the Islamic Republic of Afghanistan now face a number of issues in the field of water resources regulation and management. According to the Central Asian Regional Environmental Centre (CAREC), necessities include personnel training and retraining systems, improved irrigation and drainage systems and water legislation as well as strengthened cooperation between stakeholders.

Climate change is set to add more pressure, as the glaciers in the mountains of Kyrgyzstan and Tajikistan are shrinking. An estimated one-quarter of the volume of water stored in glaciers was lost in the second half of the 20th century. These challenges are exacerbated by a fast growing population.

To share water, collaboration and trust are integral

Launched in October 2015 with financial support from USAID, the Smart Waters project is addressing these challenges from a number of vantage points, predominantly aimed at strengthening cooperation in water issues, and introducing modern approaches to integrated water resources management. The project is implemented by CAREC, an independent, non-profit, non-political, international organisation assisting the Central Asia governments in addressing environmental and sustainability challenges.

The Fergana Valley has been described as the agricultural heartland of Central Asia, marked by fertile lands where an array of crops are grown.

At the Namangan market, an array of crops from the fertile Fergana Valley that it is located in is available.

Building bridges in the Fergana Valley

The Fergana valley has been described as the population and agricultural heartland of Central Asia. It's a fertile oasis surrounded by mountains, deserts and treeless steppes, split among Kyrgyzstan, Tajikistan and Uzbekistan. The Syr Darya and numerous tributaries crisscross the valley, allowing abundant cultivation of wheat, cotton, rice, vegetables and fruit. One of the valley's smaller tributaries, the Padshaata, flows through the Namangan region of Uzbekistan and Kyrgyzstan and the basin is one of the Smart Waters pilot project sites.

The two SBCs (from Kyrgyzstan and Uzbekistan) had their third joint meeting this June, following on a first joint meeting in Kyrgyzstan in 2018, and a second in Uzbekistan in May 2019. During this meeting, the basin councils agreed to meet on a regular basis to discuss and resolve joint issues, including matters such as the operation and maintenance of irrigation infrastructure, water accounting and data exchange.

"The meeting was very important," says Saydilla Mehmonov SBC Chairperson (Uzbekistan). "It was the first time that the Kyrgyz side came to the Uzbek side to discuss shared issues." Mehmonov says that though these are not issues that appeared yesterday, there was no platform to try and find solutions until the SBCs were created. "There are no complications such as a border within the SBC," he says. "When you share a table and toasts you become friends; it lifts the barrier between communications."

The meeting was also an opportunity to show the Kyrgyz visitors the water management approaches and technologies practiced in Uzbekistan. In upstream Kyrgyzstan, the mountainous landscape has traditionally been geared towards hydropower generation and stock farming, while downstream Uzbekistan practices large – scale irrigation farming. The delegation visited the Eski yer water reservoir, the Galaba-1 pump station, a greenhouse that implements Korean and Israeli technologies as well as cropland that makes use of large-scale drip irrigation. Masalbek Myrzamamytov, chairperson for the Padshaata SBC (Kyrgyzstan) says the trip showed them how extensive orchards can be managed, and modern technologies such as drip irrigation and greenhouses applied to conserve water. "It's good to see how Uzbekistan is using drip irrigation to achieve higher yield from a small land area," he says. "Upstream in Kyrgyzstan we have deep ravines, limited land for agriculture, and steep slopes which makes pumping water to potential crop fields more expensive."

Myrzamamytov returned the favour when the Uzbek SBC visited Kyrgyzstan this June, shaping the programme around Kyrgyzstan's strengths. "I wanted to show our Uzbekistan colleagues how water and ecology is connected here," he says. The trip included visits to the Sary-Chelek UNESCO Biosphere Reserve and the Padysh Ata Reserve in the western Tien Shan Mountains. "I have never seen an area so little affected by development," said Uzbek SBC member Nematjon Nurmatov. His first time visiting the area, Nurmatov says he is amazed that they could manage to establish protected areas like these. "The Padshaata water is divided between our two countries, and opportunities like this help us to understand why communication is so important to solve problems without giving way to conflict," he says. In this way we can conserve this precious water, says Nurmatov. "My wish is that I can still bring my family here, to see this beauty one day too."

Masalbek Myrzamamytov, Chairperson of the Padshaata Small Basin Council (Kyrgyzstan) during the second joint SBC meeting in Uzbekistan.

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The project is implemented through four components: Capacity building and academic exchange (see sidebar: ***Scholarship benefits ripple across borders***), networking and cooperation, IWRM promotion and support and basin planning.

Introducing IWRM into transboundary river basin management

As a starting point, small transboundary river basins were selected for pilot studies, says basin planning specialist, Ekaterina Sakhbaeva (based in Bishkek, Kyrgyzstan), who was involved with the project from its inception. Guided by international best-practice guidelines, basin management plans for the pilot basins were created, but key to the successes that are being achieved are the creation of SBCs, says Sakhbaeva. (See sidebar 2: ***Building bridges in the Fergana Valley***)

These are local advisory bodies that aim to find the best solutions to water-related problems across borders. Members include a variety of local water use group representatives and experts in fields such as agriculture, the environment, irrigation and local government. The aim is to create an SBC on each side of the border of the pilot sites, and then bring them together around the same table.

Taking the region's history in mind, this is no small feat. "It can take anything from a couple of months, to years," says Smart Waters project manager, Ekaterina Strikeleva. First, the project team approach local government bodies to explain the project aims and, if they are willing to continue, to nominate SBC members. Establishment of SBCs for the Aspara, a 108 km river located in Kazakhstan and Kyrgyzstan, and coordinating joint meetings of the two SBCs took a couple of months, she says. For other basins it can take years.

Strikeleva says the project calls for time and patience. If parties are not initially keen to meet with counterparts across the border, they would approach the goal from a different angle. "We would perhaps invite parties to participate in the same training opportunities first, to meet each other face to face." Over time, she says, once the members are more familiar with each other, the possibility for collaborating on non-controversial cross-border water issues can be introduced, and from there, as the relationships become stronger, bigger issues can be presented.

An irrigation canal fed from the Isfara River that runs through Batkin, Kyrgyzstan.

Once an SBC is established, a basin plan is developed, and location-specific technical needs are identified and addressed. This can includes the establishment of automated water flow measurements devices for fair allocation of water between countries, funding for equipment such as excavators to clear canals, or the creation of GIS maps of basin areas. Council members are also provided with needs-based training on necessary topics.

The feedback from SBC members is resoundingly positive. According to Saidhojaev Narzullo, member of the Isfara River SBC (Tajikistan), the SBC allows them to discuss priorities and develop a plan of action accordingly. "We develop a common vision that allows us to easily priorities actions," he says.

For Hudayberdiev Nuramat, member of the Padshaata River SBC (Uzbekistan) the highlight of the SBC is that it created a platform for people from different fields to come together, including experts in land erosion, ecology, sanitation, maintenance and customs, all somehow related to water. "Whenever a crisis arises there are now specialists from each side to assist," he says.

Achievements that are hard to quantify

Currently, all 13 pilot small transboundary watershed sites are actively involved in local-level basin planning as part of national-level IWRM reforms taking place in all target countries. However, says Sakhbaeva, "it's impossible to measure the impact in quantifiable ways." The people that got involved learned so much, and now have a different world view," she says.

This is perhaps best exemplified in the series of annual river day celebrations that are now being held across the region. Mamadiev says that the Isfara River Day, the first one that was celebrated, is the personification of the changes taking place in the region. "The river used to be a source of conflict. Now we call it the river of friendship."

The Smart Waters project will conclude in September 2020.

Sources

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WATER AND AGRICULTURE

Satellite imagery employed to help conserve irreplaceable agricultural lands

Online system that identifies salt accumulation and waterlogging in irrigation schemes developed in South Africa. Article by Petro Kotzé.

Large pivot irrigation fields are characteristic of the Northern Cape area where the SAWMS was tested and performed well.

"In farming, sustainability is integral; especially economic sustainability," says Dup Haarhoff, head of agricultural services at GWK. The agricultural cooperative and consultancy operates in the semi-arid Northern Cape, where irrigation of fields adjacent to the Orange, Riet, Vaal and Harts river systems allow for the large-scale production of wheat and corn, among others.

The enormous pivot drawn croplands that mark the landscape are signs of the intensive irrigation that farmers here practice, allowing them two planting seasons per year. "Sometimes we harvest a crop, and plant the same fields again within 24 hours, especially when switching between wheat and maize," says Haarhoff. This level of productivity comes at a price. The cost per hectare to farm land here is high and, combined with the value of limited water supplies, room for error in the cut throat business of farming is small.

Haarhoff says that farmers here have to produce at maximum capacity. Mistakes cost time and money, and one that can potentially decrease a cropland's yield, is allowing for salt accumulation and waterlogging. A new online monitoring system recently developed with support from the Water Research Commission (WRC) will help prevent this by allowing agricultural producers to zone in on the proverbial needles in the haystack – relatively small areas in large irrigation fields that are underperforming due to the mentioned soil conditions. Dubbed the Salt Accumulation and Waterlogging Monitoring System (SAWMS), the easy-to-navigate online interface places specialist analysis of high-resolution satellite images a click away from farmers and agricultural advisors.

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Salt accumulation and waterlogging in South Africa
Salt accumulation is when excessive salts, or combinations of its ingredients (such as chlorides, sodium, calcium and magnesium) collect in soil or irrigation water. Waterlogging is closely related and occurs when the groundwater level is too high and saturates the soil, potentially preventing the leaching of salts. These conditions can have a negative impact on plant roots, and consequently, plant growth and crop production.

Crops in affected fields that are sensitive to the accumulation of salt can lead to immense losses of revenue

Internationally, the problem impacts large swaths of landscapes. Reportedly, as much as 34% of Argentina is salt affected, as is 33% of Egypt, 30% of Iran, 26% of Pakistan and 23% of the United States. In South Africa, an estimated 18% of irrigated land is either moderately or severely affected. Earlier WRC studies found 6.3% of nine irrigation schemes in South Africa were severely affected. This seems insignificant in comparison to international cases, but the value of the land affected in South Africa makes it a serious concern. According to the Food and Agriculture Organisation of the United Nations (FAO), land available for irrigated agriculture in South Africa is only 1.2% of the country's land area (about 1 464 000 ha), with about 1.1% (1 334 562 ha) under irrigation. Conservation of every single hectare of this scare resource is integral, and failing to do so leads to multiple consequences.

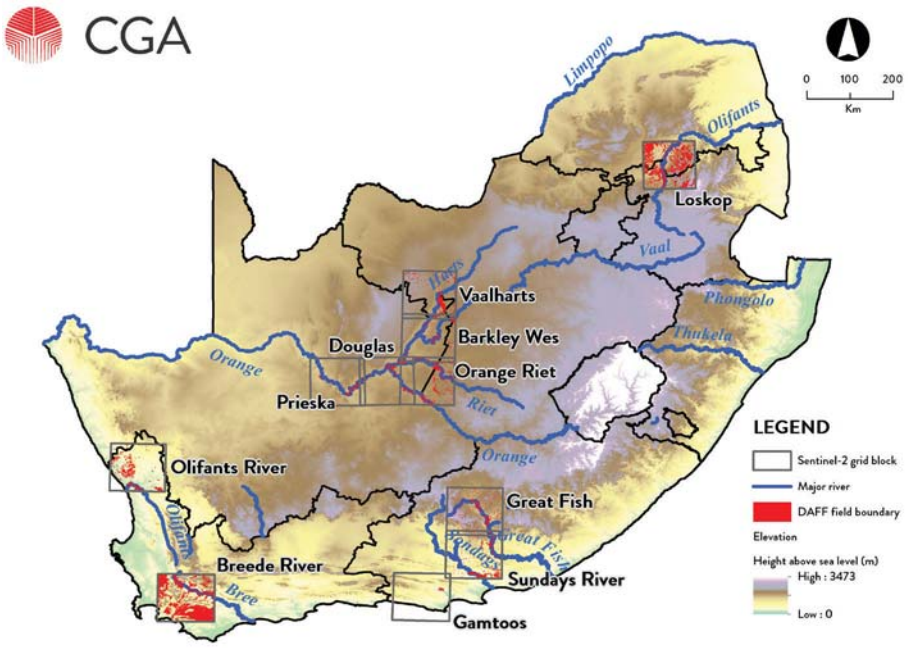
Crops in affected fields that are sensitive to the accumulation of salt can lead to immense losses of revenue, says Haarhoff. Of particular concern in the Northern Cape is the impact on pecan nut trees, a high-value crop increasing in popularity. "Pecan nuts are some of the most sensitive to salt accumulation," he explains.

The problem is potentially set to increase as farmers are working ever more efficiently with limited water supplies. Haarhoff says that producers increasingly have to look at the output they can achieve per millimeter of water yet, conversely, this carries a risk to soil conservation. "If you focus more on water use efficiency, you can lose sight of leaching requirements, leading to the build-up of salt under certain circumstances."

To manage areas affected by salt accumulation and waterlogging, monitoring is required. Conventionally, this entails regular field visits to collect soil samples for laboratory analyses. As some affected areas in large irrigation schemes can be as narrow as 1 – 2 metres, the use of remote sensing has been suggested as a less time consuming and more cost-effective method. The SAWMS employs a technique called within-field anomaly detection (WFAD), found to consistently outperform a series of other remote sensing and geospatial modelling techniques evaluated for the purpose in a previous WRC project (***Methodology for monitoring waterlogging and salt accumulation on selected irrigation schemes in South Africa***, published as **WRC report no. TT 648/15** by the Stellenbosch University and the Agricultural Research Council).

Detecting anomalies in agricultural fields with the help of high-resolution satellite imagery
The principle behind WFAD is that areas within an agricultural field that consistently under-perform over time in comparison to the rest of the field, is likely related to soil factors, explains Prof Adriaan van Niekerk, Director of the Centre for Geographical Analysis at the University of Stellenbosch. Prof Van Niekerk is an expert on the development of geographical information systems (GIS) and remote sensing techniques to support decisions concerned with land use, bio-geographical, environmental and socio-economic problems.

The technique essentially identifies 'spots' of plants that underperform in comparison to the rest of the field (anomalies),



Geographical distribution of the irrigation schemes and agricultural areas where the SAWMS was applied.

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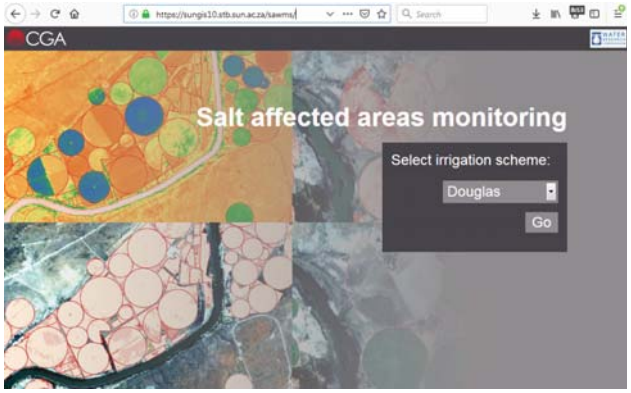
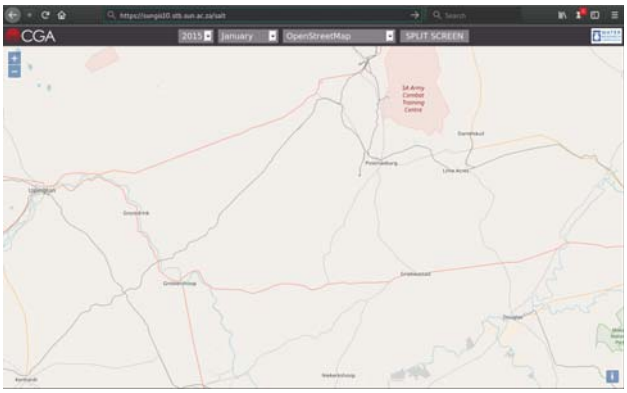


The landing page for the SAWMS.



Graphical user interface when web application is first loaded.

over several growing seasons. To do this, the WFAD makes use of the normalised difference vegetation index (NDVI) derived from high resolution satellite imagery. The NDVI is a commonly used remote sensing technique to help identify vegetation and provide a measure of its health and vitality. In general, healthy and dense vegetation reflects a lot of near-infrared light but very little red, as this is absorbed by the abundant chlorophyll (high NDVI). On the other hand, sparse or unhealthy plants contain less chlorophyll, and shows up more red on the satellite images (low NDVI).

Prof Van Niekerk explains that a low NDVI is most often related to a lack of water, nutrient deficiency or disease, but if it persists over extended periods of time (multiple seasons) these causes are improbable, as they are unlikely to reoccur at the exact same location over time. As such, poor soil conditions are more likely.

When the WFAD was validated in nine irrigation schemes throughout South Africa, the anomalies identified proved to be related to salt accumulation or waterlogging in more than 75% of the cases. In most irrigation schemes, the WFAD was able to identify salt-affected areas with an accuracy of more than 70%.

Still, the process took time and specialist expertise. Initially implemented manually, a map of anomalies for a specific area was produced by processing numerous high resolution satellite images detected over a period of six month to two years. Prof van Niekerk says they wanted to create a system that gave the end-user easy access to the specialist information. "Our purpose from the start was to make this easy," he says. With Prof van Niekerk at the helm as project leader, the team then set out to develop a system that automatically analyses current and historical satellite imagery to identify anomalies, and to give end-user easy-access to the information. "We opted for building a web-based interface that you can run through a PC or a mobile," he says. This process took three years to complete, and resulted in the SAWMS.

The outcome is an extremely simple and easy-to-use tool that gives users access to technology and expertise that would otherwise be hard to come by. The user can select an area and a date, and then immediately see the relevant image that indicates the status of salt accumulation or waterlogging for that area. By selecting another date, the user can see how the affected area has changed over time. "It looks very simple, but behind every step there is a long automated chain of analysis being done," notes Prof van Niekerk.

To demonstrate its operational ability, the SAWMS was applied in several irrigation schemes and agricultural areas throughout the country.

Performance of the SAWM in different irrigation schemes

Practical application of the SAWMS showcased its strengths and limitations, while providing the project team the opportunity to work on innovative solutions to the latter.

In the Orange, Riet, Vaal and Harts basin (ORVH) area, for example, the anomaly detection technique worked well. Several fields were identified for inspection and most of the anomalies were confirmed to be salt-affected and/or waterlogged. The system also produced acceptable results in the Loskop and

Changing the background layer to Sentinel-2 (the high resolution satellite imagery)

Extremely high resolution aerial photograph background can also be selected.

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the Great Fish irrigation schemes. In the Breede River irrigation scheme the system faired reasonably well, with most fields found to be unaffected by salt accumulation and waterlogging.

However, the system initially performed poorly in the Sundays River and Gamtoos River irrigation areas, indicating the major limitation of the SAWMS. "Each field needs to have a nice accurate boundary," explains Prof van Niekerk. As each pixel within a field is compared to all the pixels in the field, inaccurate field boundaries causes all kinds of problems, as anomalies are falsely identified, he says. In some schemes the predominant crops call for large and homogeneous shaped fields, such as irrigation pivots. This is much easier to digitise than small, irregularly shaped fields with unclear boundaries.

For field boundaries, the SAWMS depends on a comprehensive data set maintained and updated by the Department of Agriculture, Land Reform and Rural Development. "We are incredibly fortunate to have this available," says Prof van Niekerk. Maintaining this data set is a huge task, as it is created manually by physically digitising field boundaries. While the information is accurate for most of the country, it can be inaccurate in areas with small and irregularly shaped fields, such as the more intensive agricultural areas of Patensie and Grabouw – the areas where the SAWMS initially performed poorly. In these cases, the results were significantly improved when project team members redigitised fields in the target area. Thus, where the department field boundaries are too generalised, a manual correction of the field vector boundaries is essential in order for the SAWMS to function effectively.

"We knew that the field boundaries were likely not going to be accurate enough in some areas," says Prof van Niekerk. "At the very beginning we identified it as something that needs more research." The project consequently included a capacity building component that resulted in students successfully designing an automated field boundary detection system with the use of multi temporal imagery. "It seems to be working well but it requires a bit of work still," notes Prof van Niekerk.

A promising prospect going forward is combining the use of automated and manual delineation of fields, even if only for irrigated areas, in order to improve the data set of field boundaries.

Helping farmers farm sustainably

With the project recently completed, the SAWMS is yet to find an official home. It has been suggested that the operational costs be funded by national government, with the agricultural department potentially acting as lead organisation giving their mandate to conserve agricultural soil and water. It is foreseen that the main users will be agronomists, soil scientists and agricultural advisors, though van Prof van Niekerk believes that famers will also benefit from it greatly, and will be able to easily use it.

The satellite images and maps that we generate will never replace feet in the field, but it directs attention to specific areas within fields where it is necessary, says Prof van Niekerk, especially since many farmers have huge farms that cannot possibly all be monitored on foot.

Haarhoff adds that the beauty of the SAWMS is that it allows them to tell farmers exactly how much money they are losing due to poor soil conservation. Harvester reports provide an account of the exact yield of every area of field as the machinery runs over it. Areas that under-perform can now be compared to the anomalies shown on the SAWMS, allowing for a calculation of the exact financial impact of a piece of land affected by salt accumulation and waterlogging. "This can play an enormous role to convince people of the impact of the problem," he says.

Furthermore, it will allow agricultural producers to see if they are farming sustainably. Monitored over the long-term, we can see if we are destroying the resource or not, says Haarhoff. This benefit reverberates much further than the resource.

Under the challenging circumstances that agriculture takes place in South Africa, destroying the resource will mean the destruction of the farm, and the farmer, says Haarhoff. "It does not make sense anymore to not make work of our problems," he says. With the help of innovative projects such as the SAWMS, researchers are helping farmers to aim this effort in exactly the right direction.

To view the report, *Salt accumulation and waterlogging monitoring system (SAWMS) development (***WRC report no. TT 782/18***)* visit, www.wrc.org.za.

WATER AND AGRICULTURE

Best management practices boost yields in smallholder irrigation schemes

With some scientifically-backed support and improved management practices, South Africa's smallholder farmers can become more successful, studies have shown. Article by Morris Fanadzo and Ernest Dube.

To meet the increasing demand for food with an increasingly scarce water supply, management of water resources must be improved. An appropriate technology is one which provides farmers an opportunity to manage their farming enterprise successfully if implemented correctly. Best management practices are methods found to be the most cost-effective and practical in increasing crop yields, farmer profits and water use efficiency. Best management practice relates to cultural management practices, such as crop selection, cultivar selection, planting dates, planting densities, tillage methods, pest management, soil fertility management and irrigation water management.

Research work funded by the Water Research Commission (**WRC Report No. TT 478/10**) to identify best management practices for smallholder farming revealed useful knowledge. One of the major findings was that a lack of basic technical skills for irrigated crop management among farmers was one of the major causes of the poor performance of the smallholder irrigation schemes. It was recommended that farmers could benefit from 'back to basics' training programmes, especially in the areas of crop and irrigation water management.

Findings indicated that farmer crop management practices compromised yields achieved in all major crops grown in two irrigation schemes. Yields achieved were a small fraction

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of the potential under irrigation. Main limiting factors were poor weed, fertiliser and water management, low plant populations, poor cultivar selection and late planting. The poor agronomic practices also suggest ineffective extension support to the smallholder farmers. This article presents some best management practices for maize and butternut crops, based on farm trials that were carried out at Zanyokwe irrigation scheme in the Eastern Cape.

Best field practices for maize production

Grain maize production is a favourite summer enterprise by smallholder irrigation farmers in summer rainfall areas across South Africa. However, smallholder farmers can obtain higher gross margins from maize when the crop is sold as green cobs as opposed to grain. A simple shift from grain to green maize production can result in a significant improvement on the incomes earned by smallholder farmers. This is because green maize is treated as a horticultural crop, meaning that it fetches a higher price per unit area compared to grain maize. For example, farmers were able to sell green maize at an average price of R2/cob, at a time when they could make only R2 500 from a tonne of grain. The advantage with green maize production is that even if the farmers fail to sell all the maize as green cobs, the remainder can still be harvested and sold as grain.

Generally, agronomic requirements for green maize production differ from those of grain maize production. Firstly, for green maize to be marketable, the cobs need to be long and large. Planting density is more critical when maize is grown for green cobs than for grain. This means that maize grown for sale as green cobs should be grown at a lower plant population than that for grain production. Small cobs are unmarketable as green maize. While ear prolificacy (ability of maize to produce more than one cob at maturity) is desirable for grain maize production, this trait is undesirable when producing maize for harvest as green cobs. This is because, with more cobs per plant, the overall size of the cobs as well as the number of kernels per cob tend to be reduced.

Transplanting can help in achieving a good plant stand which would translate into more green cobs and higher grain yields. On-farm experiments showed that transplanting resulted in a significantly higher crop stand of 96% compared to direct seeding, which achieved 78%. Transplanted maize had shortened growth duration in the field, reaching flowering stage 11 to 15 days earlier than direct-seeded maize. At low nitrogen fertilizer rates, transplants produced longer green cobs and higher grain yield than direct-seeded maize. The transplanted maize required 50 kg/ha less nitrogen for producing green mealies than the direct seeded maize. Transplanted maize will not only lower nitrogen fertilizer costs, but can also help to improve crop stands in areas where bird damage on emerging seedlings is a problem.

"Weed management is the most important limiting factor in butternut production by smallholder irrigation farmers in South Africa."

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To succeed, technologies not only have to better than those previously used, they also have to be appropriate for the level of farmers' skills and resources. Though transplanting maize seedlings offers a number of advantages as described above, one question that remained unknown was the feasibility of this strategy with regards to the labour requirement and returns realised in comparison with direct seeding. The latter practice is mechanised in most smallholder irrigation schemes and requires little labour input, yet labour was known as a constraint that compromised the management of crops in the scheme. Therefore, more studies were conducted to investigate the economics of using transplanting in comparison with direct seeding. Results from farmer-managed trials indicated that crop stand significantly increased from 48 to 97% when maize was transplanted rather than directly seeded. The net benefits were R15 005/ha for transplanted maize and R6 232/ha for direct-seeded maize. All farmers were in favour of transplanting, citing bigger cobs, early maturity and the absence of bird damage with transplanted maize, and this was supported by statistical analysis.

Interviews during focus group discussions after the conclusion of sales indicated that, regardless of establishment method, all farmers were in favour of green as opposed to grain maize production as had been the practice in the scheme. There were three widely noted benefits of green over grain maize production: (1) green maize was more profitable, (2) maize grown for green cobs had a shorter production cycle, leaving enough time to prepare for winter planting, and; (3) there was no need to invest in labour for harvesting, processing and packaging as customers purchased the green cobs from the field. When the two methods of establishment were compared, all farmers were in favour of transplanting.

Participants commented that the absence of bird damage in transplanted maize meant savings in time, labour, money and other resources as there was no need to replant or gap-fill, operations which would require additional land preparation, planting and seed. It was also cited that weed management was easier in transplanted maize because of the rapid growth of the maize. Commenting on the labour requirements for transplanting, farmers agreed that this was not a major concern as they used the same strategy in cabbage and other vegetable crops, but still realised higher profits. However, they expressed concern that that the labour intensiveness of transplanting might limit the area planted to the crop given the serious shortage of labour in the irrigation scheme, particularly in summer.

Best field practices for butternut production

Weed management is the most important limiting factor in butternut production by smallholder irrigation farmers in South Africa. Poor weed management leads to poor crop stands and total abandonment of crops to weeds, in some cases. In the Eastern Cape, the majority of farmers did not control weeds before planting and post-emergence weed control was inadequate. This resulted in average butternut yields of 6 t/ha, which is only 20 to 30% of the potential of 20 to 30 t/ha attainable under irrigation, and indicates that an opportunity existed to improve yields. The effect of weeds on the butternut crop is greatest during the period from emergence to the time before vine spreading. Post-emergence chemical weed control options for butternut farms are very limited and often ineffective since most of the registered selective herbicides control annual grasses but not the broadleaf weeds.

For butternuts, pre-plant weed control and increasing plant density from 10 000 plants/ha to 30 000 plants/ha resulted in a significant reduction in weed pressure. In fact, no marketable fruits were obtained when planting was done without prior weed control. The optimum planting density was estimated to be 25 000 plants/ha. The best nitrogen fertilizer application rate was 120 kg N/ha, which gave a yield of 26.7 t/ha. Of the three factors, lack of pre-plant weed control was the most important factor as it resulted in 100% marketable yield reduction. Pre-plant weed control to kill the first flush of weeds is, therefore, a prerequisite to successful butternut production.

Marketing of produce

Crop production should be market driven. This means that farmers should first identify target markets, and then produce in compliance with the requirements of the specific markets. Also, farmers need to have information on the profitability and demand of the different crop enterprises before deciding to produce a particular crop. For instance, under irrigation, butternut production is more profitable than grain maize production. Collective action in acquiring inputs and selling products is one way of improving the marketing of agricultural products by smallholder farmers. The adoption of the collective action strategy results in reduction in transportation costs, thereby increasing household incomes. Adoption of group marketing significantly reduced transaction costs for contractors, encouraging access to lucrative markets in the Eastern Cape.

Lack of stable markets has been singled out as significantly contributing to poor performance in smallholder irrigation schemes. The underlying causes for the market instability includes poorly organised markets, unsatisfactory marketing services provided by middlemen, informal marketing contracts, lack of pricing standards and poor state of infrastructure (e.g. roads and storage facilities) related to marketing. Results from the Eastern Cape show that strengthening of farmer organisations gave farmers the collective strength they needed to influence markets to their advantage. This intervention has started to bear fruit in that a major change in the area of marketing was observed whereby nearly all farmers in Zanyokwe are now involved in collective action marketing.

"Farmers tend to follow a fixed irrigation schedule where fixed amounts of water are applied on a fixed cycle."

Irrigation water management

Farmers need to operate sprinklers at the recommended pressure level. System pressure was the biggest factor to the poor performance of sprinkler system in the Eastern Cape. The sprinklers were operated at pressures above the recommended. This means that farmers need the guidance of the extension officers to ensure that the ideal operating pressure is used. That also means that the extension officers should have the expertise to be able to assist the farmers. There is need to ensure that

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Daniella van Leggelo-Padilla/World Bank

uniform stand pipe lengths and similar sprinklers and nozzles are used in each lateral in order to optimise the efficiency of the sprinkler irrigation system. Farmers should plan their planting activities to suit the amount of irrigation equipment they have. It is unwise to plant a large area when one has insufficient sprinklers because this will only result in yield loss due to water shortage.

One of the major problems that has been observed in many smallholder irrigation schemes in South Africa is that farmers tend to follow a fixed irrigation schedule where fixed amounts of water are applied on a fixed cycle. This usually means that more water is supplied than required in early growth phases and less than required during peak demand thereby stressing crops during critical growth phases and reducing yield. The wetting front detector is a tool that can help farmers to visualise the depth that water is moving and determine how well their last irrigation filled the profile. This information would help them to make decisions about timing and duration of the next irrigation. In general the use of water front detector by pilot farmers helped to make irrigation management tangible and realistic. It is therefore recommended as a best practice.

"The correct selection of a cultivar is of paramount importance, because the yield and quality of individual cultivars are influenced by planting times and prevailing climatic conditions."

Adoption of a cropping calendar and timely planting

Lack of adherence to a correct cropping calendar affects the quality and quantity of produce resulting in low returns. In the Eastern Cape, the adoption of the correct time of planting changed this scenario and farmers began to see improvements in quality and quantity of produce. At the inception of the project in the Eastern Cape, almost all farmers specialised in winter cabbage and summer maize. This resulted in a lot of cabbage rotting in the field as there was too much of the same product and therefore less demand. This forced some farmers to sell at very low prices such as R0.50/head so as to get rid of the

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crop. When farmers started to produce the crop in summer on the advice of the project team, they realised higher income as each head could be sold at an average R4.00 whereas in winter the maximum that can be charged per head was R2.50 at the time.

Late planting is a common experience among farmers and in the Eastern Cape, grain maize was planted until as late as mid-March. However, beside the decrease in grain yields with late planting, the market demand for green maize is highest around the Christmas and New Year holidays. This means that green maize should be planted as soon as possible after the possibility of frost is over so that the crop can mature around late December to early January. Use of seedlings was demonstrated to be a better option over direct seeding if planting is to be done as early as possible.

Research done during the implementation of the project indicated that maize grain yield increased by up to 46% when planting was done before mid-December. Therefore grain maize planting in the Eastern Cape should be done well before mid-December to avoid maize yields reductions. An exploratory on-farm trial to test the effect of planting time, fertiliser rate, plant population and variety on maize grain yield in the Eastern Cape showed that of the four factors tested, planting time, followed by nitrogen application rate were the most important factors determining grain yield. On farm-trials showed that timely planting resulted in a 2.7t/ha increase in grain yield, a 77% increase. When fertilised at farmer practice of 60kgN/ha, early planting resulted in a 26% increase in yield equating to 0.95t/ha, while the increase was 134%, equating to a 4.5t/ha increase when the maize was fertilised at 250kg/ha.

Cultivar choice

The correct selection of a cultivar is of paramount importance, because the yield and quality of individual cultivars are influenced by planting times and prevailing climatic conditions. One specific cultivar may yield well during cooler weather but perform poorly during warmer conditions, while another, of the same kind of crop, may produce the opposite result. Cultivars also differ greatly in the length of their growing season as well as fertiliser requirements. For instance, in the case of maize, long season cultivars have higher fertiliser and water requirements compared to early maturing cultivars. Plant breeders are continually producing new cultivars with different characteristics, and local seed producers are constantly introducing promising new cultivars, which they hope would supersede the established ones. Therefore farmers need to revise cultivar choices annually to ensure that the most suitable cultivars are grown. For instance, certified hybrid maize seed should be used under irrigation, and farmers should avoid use of retained seed or open-pollinated varieties. Short season cultivars should be used when planting is done after the optimal planting time while medium to long season cultivars should be used when planting is done timeously.

A situation analysis in the Eastern Cape revealed that open pollinated varieties were among the popular maize varieties grown by farmers in the scheme. Exploratory trials were then designed to demonstrate the superiority of hybrid varieties over open pollinated varieties under irrigated conditions. New hybrids yielded 50 to 65% more than the cultivars commonly grown by farmers. These results clearly indicated that low crop productivity at the scheme was partly a result of inappropriate agronomic practices. What also became apparent during farmer information days was that though the focus of the research was on dry grain maize, farmers were more interested in green maize production. The importance of selecting appropriate cultivars is more critical in green than grain maize production because of consumer preferences for green maize.

The varietal evaluation trials showed that the new hybrids could yield as high as 5 t/ha more grain yield as compared to the open pollinated varieties. This means that by simply changing the choice of cultivar, farmers could increase their yields by up to 5t/ha. It is important to note that the yield potential of the open pollinated variety traditionally grown by farmers was 4-5t/ha, meaning that even if the farmers were to attain this yield level, it would still not be profitable under irrigation. The average yield obtained for this cultivar during on-farm trials was 3.5t/ha which is 70 to 88% of the potential, meaning that farmers would obtain even lower yields. Exploratory on-farms trials demonstrated that the long season cultivars were more sensitive to reduced rates of nitrogen fertilisation than short season cultivars. For the short season cultivar, increasing nitrogen rate from 60 to 250kg/ha resulted in a 17% increase in yield, translating to 0.8t/ha while the corresponding increase was 73%, translating to 2.8t/ha for the long season cultivar.

Planting population recommendations for maize and butternuts

Planting population should be chosen to suit market requirements. Experience in the Eastern Cape showed that short season maize cultivars should be planted at higher densities of up to 90 000 plants per hectare while medium and long season cultivars could be planted at 40 000 to 60 000 plants/ha depending on planting time and rate of fertiliser used. With adequate fertilisation, the short-season cultivar yielded optimally when grown early at 90 000 plants/ha while long-season cultivar performed better at 40 000 plants/ha.

As already reiterated, to optimise on green maize production, a population of no more than 60 000 plants/ha should be used. Results of on-farm trials demonstrated that increasing plant density above farmers' practice of 40 000 plants/ha to 60 000 plants/ha resulted in more marketable green cobs and up to 30% higher grain yields. For green maize production, it is recommended that farmers should plant their maize at 60 000 plants/ha and no more than that. Butternut should be grown at a population of 15 000 to 25 000 plants/ha depending on market requirements. Where the market demands fruits of smaller size, a plant population of approximately 25 000 plants per hectare should be used to maximise on marketable yield but when the market demands bigger fruits, a lower population should be used.

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WOMEN IN SCIENCE

Celebrating the National Biodiversity Assessment's women of science

The National Biodiversity Assessment (NBA) process is not only collecting valuable information about the state of South Africa's biodiversity, it has also seen no less than five female scientists involved in the project completing their PhD studies in water-related themes. Article by Heidi van Deventer, Jeanne Nel, Lara van Niekerk, Lindie Smith-Adao and Chantal Petersen.

The NBA is a collective effort to synthesise the best available science on South Africa's biodiversity to inform policy and decision-making in a range of sectors, as well as to contribute to national development priorities. The NBA is used to inform policy in the biodiversity sector, such as the National Biodiversity Framework and the National Protected Area Expansion Strategy, as well as informing policies and strategies of a range of other sectors that rely or impact on natural resources, such as the water, agriculture and mining sectors.

The NBA process takes about five years to complete, and involves wide participation from stakeholders, scientists and biodiversity management experts throughout the country. The latest assessment is due for publication later this year. Five women have completed their PhD studies, all related to rivers and wetlands, while being involved in the NBAs of South Africa. the South African National Biodiversity Institute (SANBI) is the lead organisation, with the CSIR being a strategic partner.

These female scientists have a number of things in common: they all had research topics centred on rivers, estuaries and inland wetlands; they were involved in both the National Freshwater Priority Areas (NFEPA), NBA 2011 and NBA 2018 projects; and completed their PhD studies during the period of the NBA assessments, with support from the CSIR and the Water Research Commission (WRC). Their involvement in the NBA, PhD topics and current research interests are listed below.

Dr Jeanne Nel, Wageningen University Research

How were you involved in the NBA, which one, and what value did the NBA bring to your career?

My involvement in the NBAs started in 2004, which was the first systematic and spatial NBA done for South Africa. I lead the river

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component of this first NBA. Up until that time, the world had not seen much in the way of systematic and spatial assessment of river ecosystems, especially at country-wide scale – this was a global first.

During the first NBA, my colleague and I, Dr Dirk Roux, worked with a team of scientists from the terrestrial realm, and it got me thinking about whether systematic assessment and planning approaches that had been pioneered in the terrestrial realm could be applied to rivers. The novelty of the work in the NBA 2004 led me to undertake a PhD in this topic, and led to a set of foundational publications on systematic assessment and planning for rivers in special issues with USA and Australia scientists.

My PhD culminated in approaches, methods and data for assessing both river and wetland ecosystems and led to a nationwide initiative to identify and protect South Africa's Freshwater Ecosystem Priority Areas (FEPAs). This involved a lot of mapping and assessment of both rivers and knowledge, collating not only databases, but also mapping some of the collective knowledge that people held only in their heads. I was very fortunate during this time to be supported by a very strong and able team, including my four women colleagues in this article. The data for identifying the FEPAs fed seamlessly into the second NBA 2011, which included an assessment of both rivers and wetlands.

A highlight that stands out for me is the collaborative spirit in South Africa. We brought together over 450 experts who willingly shared their own data, knowledge and insights, and together we found new meaning and innovative solutions to support conservation of our country's river and wetland ecosystems. The collaborative networks formed during this work are as important, if not more, than the results themselves.

Where and when did you graduate as PhD candidate?

PhD Botany at the University of Cape Town, July 2009, with the title, Enhancing the conservation of freshwater biodiversity through improved freshwater conservation planning techniques.

Which papers do you consider your best output thus far?

The following two are my favourites and they both stem directly from the NBA work. The first is about the collaborative nature of putting data on a map and how it can stimulate more effective implementation; the second is the results of the first NBA and my first paper done as part of my PhD.

Nel, J.L., Roux, D.J., Driver, A., Hill, L., Maherry, A., Snaddon, K., Petersen, C., Smith-Adao, L.B., Van Deventer, H. and Reyers, B. 2016. Knowledge co-production and boundary work to promote implementation of conservation plans. Conservation Biology, 30:176-188.

Nel, J.L., Roux, D.J., Maree, G., Kleynhans, C.J., Moolman, J., Reyers, B., Rouget, M. and Cowling, R.M. 2007. Rivers in peril inside and outside protected areas: a systematic approach to conservation assessment of river ecosystems. Diversity and Distributions, 13:341–352.

What is the key message of your PhD research work?
This work showed that it is possible to plan and assess inland aquatic ecosystems with similar approaches to those used in the terrestrial realm. We thus found that river and wetland ecosystem were much more threatened than their terrestrial or marine counterparts. Because of their connected nature, rivers and wetlands require attention to both water resource and land-based protection strategies. By working together, land and water resource managers can design protection strategies to secure better ecological condition.

Future vision for your contribution to science?

To continue doing science that supports decisions and actions that achieve both social and environmental justice.

Dr Lara van Niekerk, CSIR

How were you involved in the NBA, and what value did it bring to your career?

I had the privilege to lead the NBA estuaries component in 2011 and 2018. In this, I was supported by an active and very supportive estuary research and management community across a multitude of organisations. I am deeply appreciative of the enthusiasm people showed to contribute to this body of work. As my partner often jokes "I actually did not see you and your core team stop working on the NBA between 2011 and 2019…". This is very true as we had two key projects funded by the WRC that allowed us to update our condition models and verify our pressure data in readiness for the NBA 2018. In addition, the CSIR Coastal Systems Group has also been hugely supportive of this substantial and important body of work.

The NBA 2011 generated in me a detailed visceral awareness of the overall status of South Africa's estuaries and the need to understand the ever-increasing pressures on this critical ecosystem type that makes up less than 2% of South Africa's area. The NBA 2011 also provided a clear and strategic view of the status quo and showed the way for future actions. I also had a number of researchers asking me afterwards why I don't just hand in my "bible" as a PhD…

Where and when did you graduate as PhD candidate?

PhD at the Nelson Mandela University, April 2018, with the title,

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Approaches to detecting and assessing patterns, processes and responses to change in South African estuaries.

Which papers do you consider your best output thus far?

These articles are a combination of work culminating from both the NBA 2011, NBA 2018 and my PhD work:

- Van Niekerk L, Adams JB, Bate GC, Forbes AT, Forbes NT, Huizinga P, Lamberth SJ, MacKay CF, Petersen C, Taljaard S, Weerts SP, Whitfield AK and Wooldridge TH. (2013). Country-wide assessment of estuary health: An approach for integrating pressures and ecosystem response in a data limited environment, Estuarine, Coastal and Shelf Science 130: 239-251.

- Van Niekerk L., Taljaard S, Adams JB, Lamberth SJ, Huizinga P, Turpie JK, Wooldridge TH (2019). An environmental flow determination method for integrating multiple-scale ecohydrological and complex ecosystem processes in estuaries. Science of the Total Environment 656 (15): 482-494.

- Van Niekerk, L, Adams, JB, James, NC, Lamberth, SJ, MacKay, CF Turpie, JK, Rajkaran, A., Weerts, SP and Whitfield, AK (2019). An Estuary Ecosystem Classification scheme that accounts for biogeography and a high diversity of estuary types (in prep). African Journal of Aquatic Science.

What is the key message of your PhD research work?

Freshwater inflow modification, pollution, habitat modification, exploitation of living resources, and artificial breaching are impacting on the health of South Africa's estuaries. The results showed that estuaries in the Warm Temperate region are healthier than those in the Cool Temperate and Subtropical regions, largely reflecting the country's demographics and developmental pressures. While a large number of estuaries are still in an excellent to good condition, they tend to represent very small systems in rural areas with few pressures. Larger systems, which are of higher economic and ecological importance, are in a fair to poor condition. The study also showed that although data may be a limiting factor in the assessment of change in the processes and patterns of South African estuaries; sufficient information is available to accurately determine their responses and future trajectories to Global Change pressures.

Future vision for your contribution to science?

I am very interested in exploring further the IUCN red listing of estuarine ecosystem types, understanding the future impact of climate change on our estuaries and working with students to increase my knowledge of estuarine physical processes and associated biotic responses. I also need to publish more of our South African environmental flows applied research.

Dr Heidi van Deventer, CSIR

How were you involved in the NBA, and what value did it bring to your career?

During the NBA 2011, I supported Dr Jeanne Nel, who was the lead of the freshwater component, in the typing of the wetland ecosystem types. This led to a passion, or rather obsession, to work in the field of wetlands. In the NBA 2018, I was fortunate to lead in the inland aquatic component. This allowed me to not only do the improvements on the wetlands map and typing I had been thinking of since NBA 2011, but to expand in many more ways.

I had the privilege to work with a multitude of experts across a wide range of organisations and integrate knowledge from these people into two reports: the South African Inventory of Inland Aquatic Ecosystems (SAIIAE or, in short, the Inventory Report) and the subsequent Assessment report, related to rivers and inland wetlands for the NBA 2018. The highlight for me was to receive recognition from these peers at the National Wetland Indaba 2018, for the effort put in to integrate our collective knowledge. I am deeply appreciative of the willingness people showed to work with me, and really humbled by their knowledge in their respective fields. It was a great experience!

Where and when did you graduate as PhD candidate?

PhD Geography at the University of KwaZulu-Natal, April 2016, with the title, Remote sensing of Wetland Tree Species in the iSimangaliso Wetland Park.

Which papers do you consider your best outputs thus far?

My favourite paper that has resulted from my involvement in the NBA 2011, is the one where we have modelled wetland ecosystem types:

- Van Deventer, H., Nel, Jeanne L, Mbona, N., Job, N., Ewart-Smith, J., Snaddon, K., Maherry, A. 2015. Desktop classification of inland wetlands for systematic conservation planning in data-scarce countries: mapping wetland ecosystem types, disturbance indices and threatened species associations at country-wide scale using GIS. Aquatic Conservation: Marine and Freshwater Ecosystems. DOI: 10.1002/aqc.2605.

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Two papers from my PhD has addressed more on the remote sensing of wetland ecosystem types:

- Van Deventer, H; Cho, MA; Mutanga, O; Ramoelo, A. 2015. Capability of models to predict leaf N and P across four seasons for six sub-tropical forest evergreen trees. ISPRS Journal of Photogrammetry and Remote Sensing, 101 209-220.

- Van Deventer, H.; Cho, M.A.; Mutanga, O. In review. Multi-season RapidEye imagery improves the classification of wetland communities in a subtropical coastal region.

For the NBA 2018, we have already published one paper, while another one is in review, and several others are being drafted. Here is the one we have published:

- Van Deventer, H.; Smith-Adao, L.; Petersen, C.; Mbona, N.; Skowno, A.; Nel, Jeanne L. 2018. Review of available data for a South African Inventory of Inland Aquatic Ecosystems (SAIIAE). WaterSA, 44(2):184 – 199. http://dx.doi.org/10.4314/wsa.v44i2.05.

What is the key message of your PhD research work?

My PhD research showed that the spectral reflectance of different wetland tree species can be used to distinguish these species from one another and other dryland tree species, particularly when multi-seasonal data or images are used. The first paper published new information on the variance of foliar nitrogen in these evergreen tree species of the southern hemisphere, showing that they have a significantly higher mean concentration of foliar nitrogen in the winter, compared to the other seasons. In addition, we showed that remote sensing can be used to predict foliar nitrogen across seasons, with varying accuracy.

The second paper proves that these tree species can now be separated using some of the new sensors at space-borne level. A combination of multi-seasons imagery of the RapidEye multispectral satellite, at a spatial resolution of 5 m and with a band in the red-edge region of the electromagnetic spectrum, was able to increase the accuracy of classification of the wetland tree species. Usually traditional sensors which doesn't have this red-edge band, are not able to separate tree species, especially not when they are evergreen. My PhD work therefore contributes, bit-by-bit, knowledge on how we can monitor wetlands under the threat of climate change. These threatened and range-restricted swamp and mangrove forests are usually not easily accessible, and for such cases, remote sensing can enable their monitoring more efficiently, compared to in-field visits.

Future vision for your contribution to science?

I hope to make a significant contribution in the Geographical Information Systems (GIS) and remote sensing tools and methods we can use to monitor inland wetlands.

Dr Lindie Smith-Adao, CSIR

How were you involved in the NBA, and what value did it bring to your career?

Through my involvement in the river component of the NFEPA I contributed to the NBA 2011. The assessment used river data (ecosystem types and condition) developed for the NFEPA project to determine ecosystem threat status and protection levels. This experience resulted in me currently forming part of the inland aquatic core team of the NBA 2018 (sub-lead on the rivers component of the NBA 2018). Specifically, providing leadership and technical capacity for the river sub-component. The assessment showed that South Africa's freshwater ecosystems are under increasing pressure.

The extensive collaboration across organisational boundaries required for the NFEPA project and both national assessments had a spinoff benefit in that it diversified my skills significantly. I have a background in fluvial geomorphology and freshwater biodiversity planning but got the opportunity to collaborate and work with experts across various disciplines. This resulted in multi-author and multi-stakeholder outputs. This interaction also developed my understanding of a whole catchment approach to freshwater conservation efforts.

Where and when did you graduate as PhD candidate?

PhD in Geography at Rhodes University, March 2016, with the title, Linking confinement, landforms and vegetation distribution in a semi-arid valley floor environment, Baviaanskloof, South Africa.

Which papers do you consider your best output thus far?

Smith-Adao, L.B. Nel, J.L., le Maitre, D., Maherry, A. and Swartz, E.R. 2011. A spatial assessment of freshwater ecosystems and water supply in a semi-arid environment. River Research and Applications, 27(10), 1298-1314. https://doi.org/10.1002/rra.1427.

Smith-Adao, L.B., Rowntree, K.M. and Nel, J.L. 2019. Mapping historical geomorphic and land cover changes along the Baviaanskloof River, Eastern Cape Province, South Africa (in prep), Geomorphology.

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What is the key message of your PhD research work?

This interdisciplinary investigation demonstrated a strong link between valley confinement setting, surface-groundwater interaction, cross-valley landforms, human activities and vegetation. Specifically, there are bi-directional relationships between vegetation and fluvial geomorphic process and form. Vegetation both affects and responds to hydrogeomorphic processes and their resulting landforms.

Future vision for your contribution to science?

I hope to focus on landscape degradation and rehabilitation as well as services that arise from healthy river ecosystems. I would also like to contribute to the development of refined automated desktop approaches linked to river ecosystems.

Dr Chantel Petersen, CSIR

How were you involved in the NBA, and what value did it bring to your career?

I was fortunate enough to be part of the NBA 2011 and NBA 2018 teams. The experiences gained during these projects allowed me the opportunity to integrate freshwater conservation with various disciplines which included may background in geomorphology, aquatic ecology, estuarine functioning vegetation and surface and groundwater interactions. This broadened my understanding of a whole system-based approach to freshwater issues, which achieves outcomes that are beneficial to people and ecosystems.

The experience gained from the former NBA project resulted in me currently forming part of the core team leading the river component of the NBA 2018 as well as being a part of the River Eco-Classification Committee (RECC), which guides the formulation of research for the purpose of identifying the required updates of the river ecosystem types, shortcomings and appropriate modelling methods and techniques of river types and river condition on a national scale.

Where and when did you graduate as PhD candidate?

PhD in Environmental and Water Science at the University of the Western Cape, April 2019, with the title, Effects of catchment management on physical river condition, chemistry, hydrogeomorphology and ecosystem service provision in small coastal rivers of the Western Cape.

Which papers do you consider your best outputs thus far?

Petersen, C., N. Jovanovic, M. Grenfell, P. Oberholster & P. Cheng, 2018. Responses of aquatic communities to physical and chemical parameters in agriculturally impacted coastal river systems. Hydrobiologia 813(1):157-175 doi:10.1007/s10750-018-3518-y.

What is the key message of your PhD research work?

A framework was developed to link system drivers and controllers of the drivers, within a catchment. It included their influence on the physical river template and habitat, within the context of ecosystem service provision. Moving forward further quantification of this approach will be necessary to provide the evidence base required for policy and decision makers to make informed decisions, based on a similar approach, for future investment in freshwater ecosystems and their services they provide.

Future vision for your contribution to science?

Moving forward I hope to make a contribution to the management of water resources using a catchment scale and multi-disciplinary approach to link freshwater ecosystems to goods and services.

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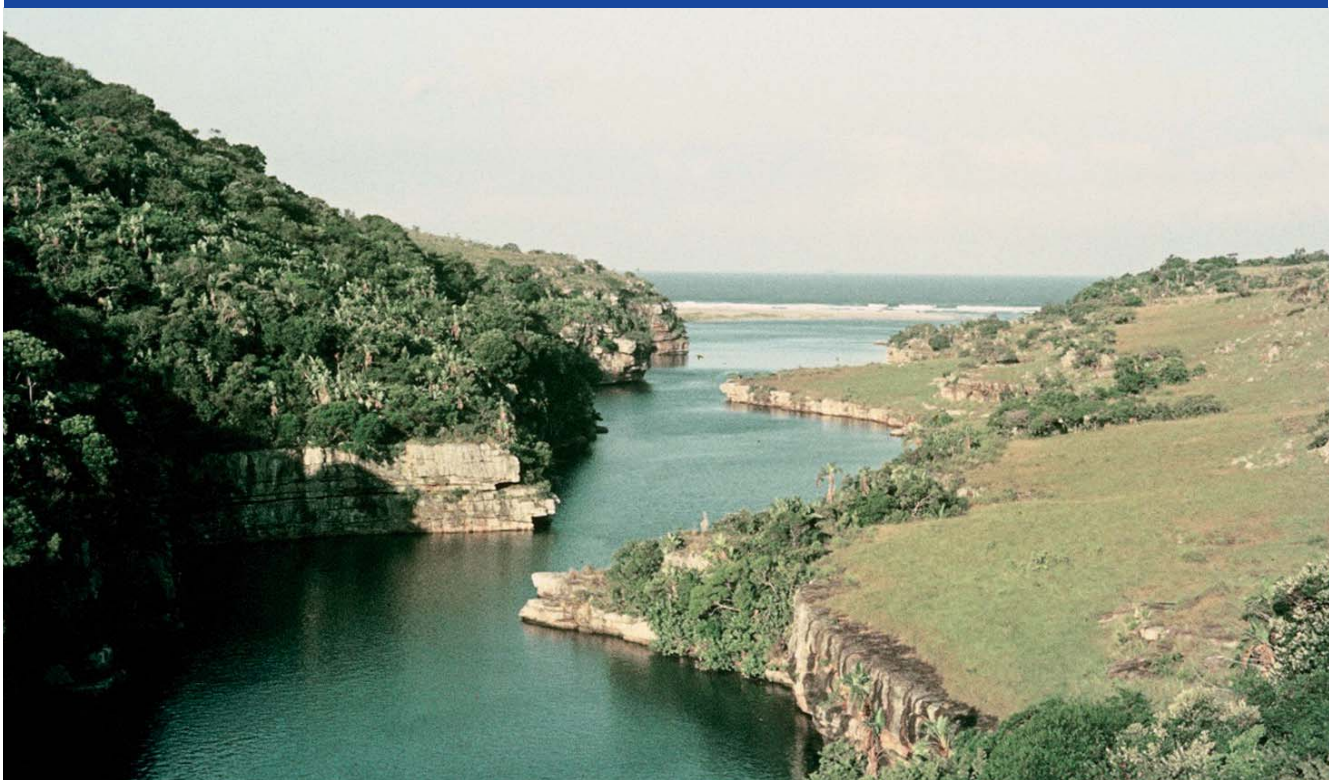
ESTUARIES

Plight of estuarine fishes in the spotlight

The aquatic life of estuaries takes central stage in a new book that explores the biology and ecology of estuarine fish species in southern Africa. Article by Jorisna Bonthuys.



Prof Alan Whitfield

The lower Msikaba estuary in the Eastern Cape.

This seminal publication by Professor Alan Whitfield draws attention to the wonder and plight of estuarine fishes in the region. There are many marine fishes that use estuaries as nursery areas and some that breed within these systems and spend most, or all, of their lifecycles within the estuarine environment.

The book, titled ***Fishes of Southern African Estuaries: From Species to Systems,*** is considered a valuable resource book for estuarine ecologists, environmental practitioners, and researchers alike.

Prof Whitfield is the Chief Scientist Emeritus and an Honorary Research Associate at the South African Institute of Aquatic Biodiversity (SAIAB) in Grahamstown. He is a leading estuarine ecologist with a particular interest in the biology and ecology of fish within these environments.

There is little about estuarine fish species that is not covered by this volume. This major work, which summarises estuarine fish research on the subcontinent, is the culmination of 40 years of dedicated research by the author and more than a century of work by fish scientists in the region.

The 500-page monograph builds on the early work of estuarine ichthyologists such as Drs Steve Blaber and John Wallace. To

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a large extent, the foundation for this new book is based on an earlier JLB Smith Institute ichthyological monograph, ***The Biology and Ecology of Fishes in Southern African Estuaries***.

"Estuaries are the meeting place between rivers and the sea," Prof Whitfield explains. These are the parts of river systems closest to the sea where salinities can fluctuate considerably. "As such, the conditions are a mixture of river water and seawater, which creates a very interesting environment for fish species that can tolerate different salinities. If you also take into consideration that fish species from both the marine and freshwater ecosystems occur in estuaries, together with some other estuarine resident species, then you have an intriguing mix that will fascinate any fish biologist."

The estuaries of southern Africa are also highly diverse, both in terms of form and functioning. They range from the clear Kosi Bay estuary entering the coral-rich subtropical Indian Ocean waters on the east coast to the turbid Orange River flowing into the cool upwelled waters of the Atlantic Ocean on the west coast. Prof Whitfield considers how this diversity in conditions affect the fishes living in these estuaries.

The book also summarises the features of the many types of estuaries and sets out the history of estuarine fish research on the subcontinent. It contains species profiles of common and interesting fishes found in these estuaries, summarises available information on each fish, and uses a guild approach to help understand the biology and ecology of the different species. The monograph also deals with environmental change and fish responses using case studies in the region. Prof Whitfield, for instance, employs the vast St Lucia system as a case study to highlight the problems caused by declining freshwater supply, mouth manipulation and floodplain development.

As climate change is likely to have a significant impact on southern African fish faunas, its effects also receive attention in this book. The relationships between fish assemblages and the degree of coastal connectivity are discussed and the reasons for fish mortalities documented, among others.

"It is my sincere hope that this synthesis will assist southern African estuarine scientists in obtaining processed baseline information from past work and facilitate their future research on our fascinating and dynamic estuarine ecosystems," Prof Whitfield states. "Also, thanks to the research of South African postgraduate students and fellow scientists, we now have a solid information base to inform legislation and assist with the making of wise management decisions for our estuaries."

Given the various forms of degradation of most southern African estuaries and throughout the world, mainly from anthropogenic causes, estuary conservation remains a vital issue. "Unless we look after these systems better than we are at present, recreational and subsistence fishery yields will continue to decline," Prof Whitfield highlights. "This applies to large estuarine systems like Lake St Lucia that are suffering from catchment and floodplain degradation, as well as freshwater deprivation arising from growing agricultural, industrial and urban demands for this precious resource."

Jill Sheppard

Prof Alan Whitfield doing research in the East Kleinemonde estuary

What, in his view, would ensure the conservation of estuarine fishes and their habitats? "We have excellent aquatic environmental and conservation legislation in South Africa. What we need most of all is the implementation of that fine legal framework by dedicated municipal, provincial and national government employees," he says.

Prof Whitfield emphasises that he has been "extremely fortunate" to have spent his entire career studying the biology and ecology of fishes in South African estuaries. "This is a privilege I certainly did not take for granted." He also says that he gets lots of satisfaction in being able to pull scientific information together and then convey it to the reader in a way that makes sense, even to the non-specialist.

One of his more interesting research results occurred early in his career when he was a Masters student working at St Lucia on the diet of predatory fishes in the lake. "When I examined the stomach contents of the thornfish (***Terapon jarbua***), I found that they were consuming mainly large fish scales," Prof Whitfield recalls. "My subsequent field and laboratory studies showed that these small fish were attacking and biting the scales off large living fish and not picking up shed scales from the bottom of the lake as I first suspected."

Does he have a favourite estuary? "My favourite system is the mysterious Msikaba estuary, which I visited only once in 1975. This magnificent estuary, which forms the southern boundary of the Mkambati Nature Reserve in the Eastern Cape, has a 'submerged waterfall' almost 35 m deep a couple of kilometres from the mouth. It also had a wonderful richness and diversity of fish species, especially mullet and kingfish."

Prof Whitfield concludes by saying that he feels "very proud and relieved" that the monograph is now published. Over the next two years, he will be helping to produce an international scientific book entitled ***Fish and Fisheries in Estuaries – A Global Perspective***.

To order ***Fishes of Southern African Estuaries: From Species to Systems***, or to download an electronic copy, visit www.saiab.ac.za.

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WATER AND SANITATION SERVICES

Water remains a moving target in South Africa

South African households' access to water services has declined between 2002 and 2018. This is according to Statistics South Africa's (Stats SA's) latest General Household Survey (GHS), which was published earlier this year. Compiled by Lani van Vuuren.

The GHS is an annual household survey conducted by Stats SA since 2002. The survey replaced the October Household Survey, which was introduced in 1993 and was terminated in 1999. The survey is an omnibus household-based instrument aimed at determining the progress of development in the country. It measures, on a regular basis, the performance of programmes as well as the quality of service delivery in a number of key service sectors in the country. Six broad areas are covered, namely education, health and social development, housing, households' access to services and facilities, food security, and agriculture. This article focuses on the water and sanitation indicators of the survey.

Water services

Despite early gains in the provision of water, provision slowed down notably after 2014. The largest decline was observed in the Free State (-4,5 percentage points) followed by Mpumalanga (-4 percentage points) and Gauteng (-1,6 percentage points). The declines, however, belie the fact that many more households were provided with water in 2018 than seventeen years earlier, Stats SA points out. It is particularly worth noting that the percentage of households with access to tap water increased by 19% in the Eastern Cape and 11,2% in KwaZulu-Natal, bringing access to 75,1% and 86,6% in these two respective provinces.

The outcomes of the GHS show that tap water inside their dwellings, off-site or on-site was most common among households in the Western Cape (98,7%), Gauteng (97,1%) and the Northern Cape (95,3%). About half (46,3%) of South African households now have access to piped water in their dwelling. A further 28,5% access water on site while 12,3% rely on communal taps and 1,9% rely on neighbours' taps. Although

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generally households' access to water has improved over the years, it is concerning that 2,7% of households still had to fetch water from rivers, streams, stagnant water pools, dams, wells and springs in 2018.

Also worrying is the declining percentage of people willing to pay for their water services. Stats SA reports that the proportion of households who reported paying for water has been declining steadily over the past decade, dropping from 67,3% in 2008 to only 40,9% in 2018.

About two-thirds (62,4%) of households rated their water services as 'good' in 2018 even though around a fifth of South African households (20,3%) reported some dysfunctional water-supply service in the same year. Households in Limpopo (48%), Mpumalanga (47,7%) and North West (37,4%) provinces reported the most interruptions.

An inverse relationship between the perceived quality of services and the number of interruptions seems to exist. The provinces with the lowest percentage of households that reported interruptions with water services, namely Western Cape (1,4%) and Gauteng (5,4%) also reported the highest satisfaction with water delivery services. Conversely, the provinces in which interruptions were more frequent were less likely to rate water service delivery as 'good'. So, for example, only 28,6% of households in Limpopo rated water service delivery as 'good'.

The GHS also explored the alternative sources of drinking water used by households that experienced water interruptions that lasted two days or longer during 2018. Nationally, 41,5% of households used water from tankers or vendors while 12,7% used water from springs, wells, dams, pools or from rivers and streams. Rainwater tanks (6,7%) and boreholes (4,7%) were also relatively common. More than a fifth of households indicated that they did not have backup plans.

Sanitation services

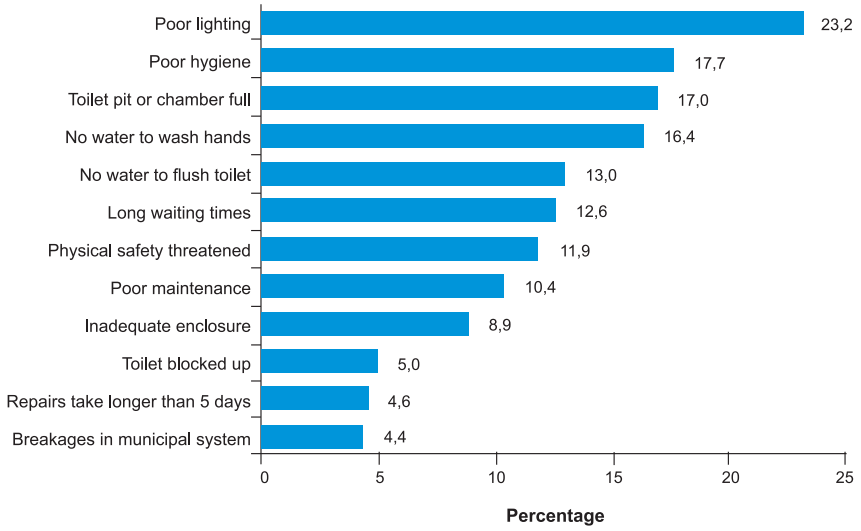
Environmental hygiene plays an essential role in the prevention of many diseases. It also impacts on the natural environment and the preservation of important natural assets, such as water resources. Proper sanitation is one of the key elements in improving environmental sanitation.

89% The percentage of households with access to safe water in 2018.

Stats SA surveyed households' access to improved sanitation facilities. This is defined as flush toilets connected to a public sewerage system or a septic tank, or a pit toilet with a ventilation pipe. Nationally, the percentage of households with access to improved sanitation increased to 83% in 2018. While the majority of households in the Western Cape (93,8%) and Gauteng (91,8%) had access to sanitation, access was most limited in Limpopo (58,9%) and Mpumalanga (68,1%). In the Eastern Cape, households' access to improved sanitation facilities increased by 54,6% between 2002 and 2018, growing from 33,4% to 88%.

Flush toilets were most common in the most urbanised provinces, namely Western Cape (89,1%) and Gauteng (88,6%). Only 26,5% of households in Limpopo had access to any type of flush toilet, the lowest of any province. In the absence of flush toilets, 70,2% of households in Limpopo used pit latrines. Approximately 188 000 households (1,1%) claimed that they were using bucket toilets that were supplied and cleaned by their local municipalities, an accusation that municipalities vehemently deny. Only 0,3% or 48 000 households primarily used ecological toilets (i.e. urine diversion or composting toilets). Given the scarcity of water in South Africa, this type of toilet is expected to become more common in future. Around 2,8% of households had no access to sanitation in 2018.

A set of questions were introduced in GHS 2013 in order to assess the quality of the sanitation facilities to which households had access to. About one fifth (23,2%) of households were concerned about poor lighting while 17,7% complained about inadequate hygiene. Although washing hands after using the toilet is vital to control infectious diseases, 16,4% of households also complained that there was no water to wash their hands after they had used the toilet. Other complaints included long waiting times, threats to their physical safety, and improper or inadequate enclosure of toilets.



Problems experienced by households that share sanitation facilities during the six months before the survey, 2018.

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Water KIDZ

What's up with the climate?

Climate change is when there is a big difference in normal climate patterns over a long amount of time. Changes in the climate have been happening for hundreds of thousands of years. Until recently these changes were due to natural conditions – for instance, because of ice ages.

Today, the climate is changing fast – something that has not happened since the end of the last ice age, 10 000 years ago. Scientists are not sure exactly how much the climate has changed, or why this is happening, but they do believe that at least some of the changes are because of things we are doing.

The Earth has warmed by around 1°C in the last century, and although that might not sound like much, it means big things for people and wildlife. Modern activities – such as plugging in devices, driving cars and cooling homes – rely on energy sources such as natural gas, oil and coal (called fossil fuels). Those energy sources release a gas called carbon dioxide (CO_2) into the atmosphere. When CO_2 and other greenhouse gases trap heat that would otherwise escape Earth's atmosphere, the planet's temperature rises. That is called 'global warming', which causes climate change.

Greenhouse gases stay in the atmosphere for a long time. Although plants and the ocean absorb carbon dioxide, they can't keep up with all the extra CO_2 that people have been releasing. So, the amount of CO_2 in the atmosphere has been increasing over time.

Why is the Earth warming up?

The Earth is surrounded by an atmosphere made up of a layer of gases. When sunlight enters the atmosphere, some of the sun's heat is trapped by the gases, while the rest escapes the atmosphere. The trapped heat keeps Earth warm enough to live on.

But during the past few centuries, the greenhouse gases we use have released CO_2 into the atmosphere. This gas traps the heat that would otherwise escape Earth's atmosphere. This increases Earth's average temperature, which changes its climate.

Climate change will have many serious and potentially damaging effects in the near future. Each of the past four decades has been warmer than the previous one. The world has experienced its five hottest years in history since 2010.

Rising global temperatures threaten human health, increase the risk of some types of extreme weather (so more floods and droughts for example), and damage ecosystems. And as the oceans warm and polar ice caps melt, sea levels are rising, endangering coastal areas. These impacts are already being felt today.

Impacts of climate change include:

- **Heat waves**: heat waves are long periods of time with above-normal temperatures. As the Earth warms, more areas will be at risk for hotter and more frequent extreme heat waves.
- **Heavy precipitation**: Heavy downpours are becoming more common in many locations.
- **Sea-level rise**: Sea-level has risen between 16 and 20 centimetres due to the melting of glaciers and ice sheets. The warming of seas and oceans is also making coastal storms more damaging.
- **Threats to habitats and animals**: As temperatures warm, many plants and animals are migrating to higher elevations or away from the equator. Some animals may have difficulty moving or adapting to new habitats.

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- **Ocean acidification**: Extra carbon dioxide is absorbed by the oceans, making them more acidic. This can make it difficult for corals and microorganisms that form shells to survive, disrupting the food supply for other sea animals.
- **Wildfires**: These are large fires that burn vast amounts of forests and brush. When they are not controlled, wildfires can destroy homes and be deadly. The number of large wildfires and the length of the wildfire season have been increasing in recent decades.
- **Drought**: Global warming will increase the risk of drought in some regions, including South Africa. Also, warmer temperatures can increase water demand and evaporation, stressing water supplies.

Car exhausts are one source of carbon dioxide.

Global warming can cause areas to experience more heat waves.

How can you make a difference?

There are plenty of ways kids can take action to fight climate change. Turn off electrical appliances and lights when you are not using them. Protect and plant trees. Encourage your family to walk or cycle to destinations (where you can) rather than taking the car. Reuse, reduce and recycle – try not to send so much waste to our landfills. Try to buy only products that can be recycled and buy from companies and manufacturers who value the environment.

Sources

- www.clean.ns.ca
- www.esa.int
- www.climaterealityproject.org
- www.c2es.org

Climate-related words

Fossil fuels – There are three main types – coal, oil and natural gas. All were formed hundreds of millions of years ago by dead trees and plants that have died, broken down, have become compacted and covered by additional materials over time. Since plants produce and store carbon dioxide during photosynthesis, this gas is released when fossil fuels are burned.
Global warming – The increase in Earth's average temperature over a long period of time.
Greenhouse gas – These are gases that absorb and trap heat in the atmosphere. The main greenhose gases are methane, carbon dioxide, nitrous oxide and water vapour.
CO_2 – Carbon dioxide is a naturally occurring gas fixed during photosynthesis into organic matter such as trees and plants. This gas is also released when fossil fuels and biomass are burned.
Anthropogenic – relating to or resulting from the influence of human beings on nature.

For the teachers

The blanket activity – How global warming actually happens

- **Materials needed:** Four to five medium-sized blankets and printed and cut out copies of each 'situation card' below.
- **Instructions:** Pick a student volunteer to play the 'Earth'. Have the student sit in a chair at the front of the classroom. Explains that the 'Earth' has just the right amount of greenhouse gases in his/her atmosphere and is sitting there comfortably. Hand out the four 'situation cards' to student volunteers in the audience.
- After each student reads his/her situation card, add a blanket to the 'Earth' (student volunteer) – each blanket represents new/additional layers of greenhouse gases. Make sure to ask the class why each situation results in more greenhouse gases being added to the Earth. Periodically check with the 'Earth' to find out how warm he/she is feeling.
- **Situation cards:** After reading each card, ask students questions such as, what is happening here? Why is it a concern? What could the person do differently?

Jane's dad went through the drive through and left the car running for five minutes while he waited for his order.	Katie got home from school and turned on every light from the hallway to the kitchen. She then went into her bedroom, shut the door and turned on her music.
Max was cold, so he cranked the heat in his bedroom, even though his window was wide open.	Carl gathered all of this week's garbage and burned it instead of sorting it and recycling.

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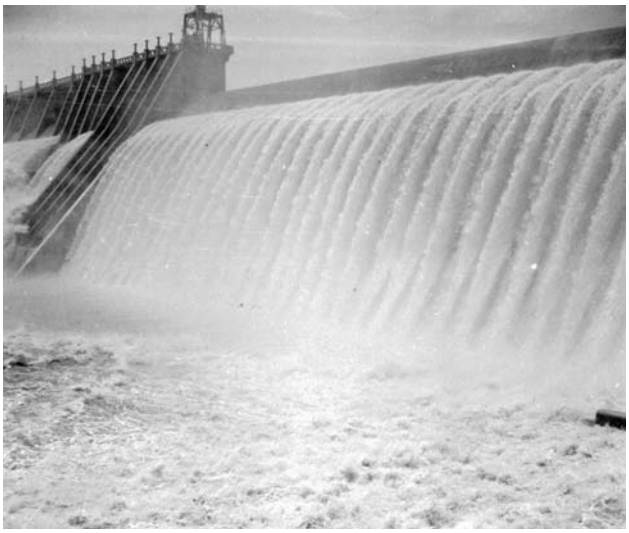
VAAL DAM – A STRATEGIC WATER RESOURCE

Located 56 km south of Johannesburg, the Vaal Dam is arguably one of South Africa's most strategic water resources. The Vaal Dam forms the central storage reservoir to the Vaal River water-supply system, which supplies water to the industrial powerhouse of the entire South Africa. The area supplied from the Vaal River System generates from than 50% of South Africa's gross geographical product (GGP), and more than 80% of the country's electricity. The dam is therefore of great importance to South Africa, and a key component of the water-supply infrastructure for Gauteng and surrounding provinces.

The site of the Vaal Dam was first identified by Government engineer, FA Hurley, in 1905, however, work only started on the dam during 1934. At the height of construction, about 1 100 men were employed on the site of the dam, and large sections were constructed by hand. Construction of the dam, a concrete gravity structure with an earthfill section on the right flank, also saw the establishment of the adjacent town, Deneysville, named after Deneys Reitz, who was the Minister of Irrigation at the time. The dam was completed in 1938 and overflowed for the first time on 13 December of that year. At that stage the dam had a full supply capacity of 994 million m^3. The dam has been raised twice, in 1961 and in 1985. Today the dam has a capacity of 2,54 billion m^3 and features 60 crest gates, each capable of releasing 115 m^3/s. The gates were severely tested during floods in February 1996 when the large flood ever recorded at the Vaal Dam site was experienced.



The origional Vaal Dam wall.

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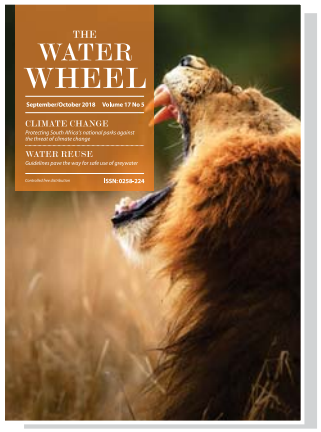
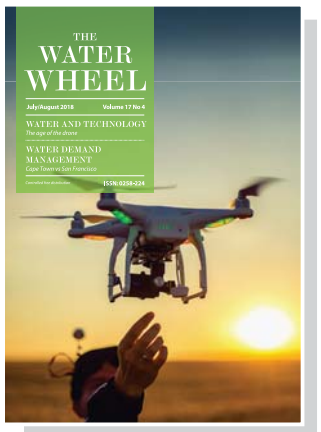
THE WATER WHEEL

SUBSCRIPTION





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What would your like to read more about in the Water Wheel?

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The Water Research Commission not only endeavours to ensure that its commissioned research remains real and relevant to the country's water scene, but that the knowledge generated from this research contributes positively to uplifting South African communities, reducing inequality and growing our economy while safeguarding our natural resources. The WRC supports sustainable development through research funding, knowledge creation and dissemination.

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.

The WRC Vision is to have highly informed water decision-making through science and technology at all levels, in all stakeholder groups, in innovative water solutions through research and development for South Africa, Africa and the world.

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