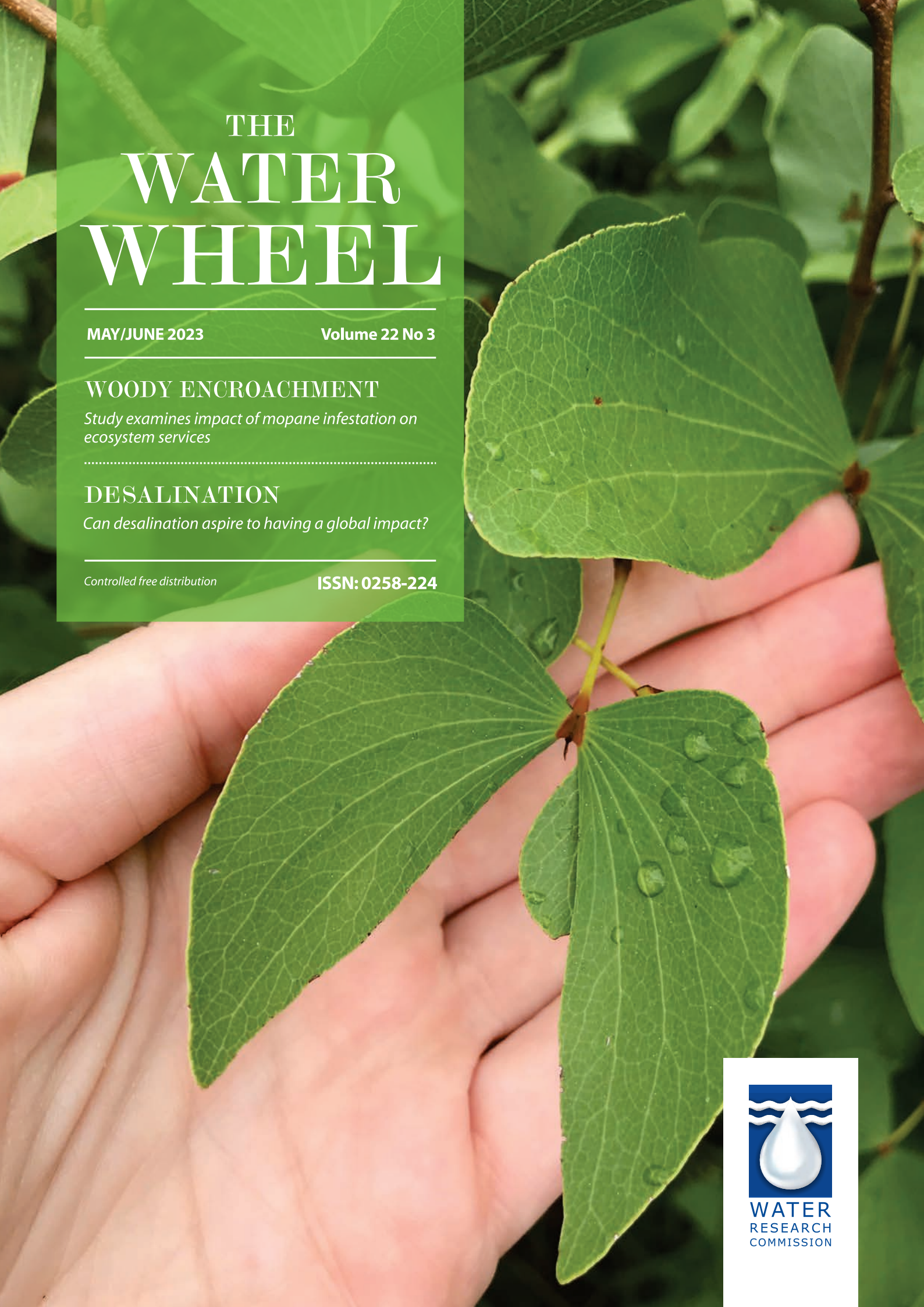

THE WATER WHEEL

MAY/JUNE 2023 Volume 22 No 3

WOODY ENCROACHMENT

Study examines impact of mopane infestation on ecosystem services

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NEWS

WRC CEO appointed to international advisory board for sanitation

Water Research Commission CEO, Dr Jennifer Molwantwa, has been appointed to the advisory board of the newly established International Water Association (IWA) Inclusive Urban Sanitation network. A task force has also been established.

The initiative is aimed at reshaping the global agenda on urban sanitation over the coming years, especially in low- and middle-income countries. It forms part of the IWA's work to promote inclusive, resilient, water-wise and sanitation-secure cities.

The advisory board and task force comprise sanitation experts, regulators, strategic partners and members from various global regions in order to secure a balanced geographical representation and address a wide variety of sanitation challenges. In addition to Dr Molwantwa on the advisory board, there are two South African experts on the task force, namely Jay Bhagwan of the WRC, and Prof Kirsty Carden of the University of Cape Town.

New hydropower policy set to boost electricity production

The Department of Water and Sanitation (DWS) has approved a policy for the utilisation of water and sanitation infrastructure and water resources for renewable energy generation.

This is in response to the global shift towards renewable energy technologies and the ongoing energy crisis.

"The policy empowers DWS to remain within its mandate while supporting the much-needed investment in renewable energy generation in the country. We have a duty as the department to ensure that the nation's water resources are protected, used, developed, conserved, managed and controlled as stipulated in the National Water Act," noted Director-General (DG), Dr Sean Phillips.

In April, the DG, together with a team from Water Use Licence Applications (WULA) met with different stakeholders and independent power producers to take them through the processes of applying for authorisation to generate electricity from existing water infrastructure. According to the policy, the DWS will support the development of hydropower as part of both social and economic development within the context of water scarcity and water infrastructure challenges without compromising sustainable protection of water resources and water and sanitation services provision.

Dr Phillips also emphasised the principles of the window for water use licence application for hydropower. "We are not going to provide any financial support to the applications during application, construction, operations and maintenance. We are not going to be involved in any of the Eskom processes or own any electricity production. The DWS will solely be responsible for water use licence applications and will ensure that the application processes are competitive, fair, transparent and underpinned by the spirit of equity allocation of water resources in line with the Act."

The types of hydropower technologies that can be applied for include impoundment; river diversion or run-of-river, pumped storage and floating or kinetic turbines (small-scale generating capacity). In addition, applications for floating solar panels can also be made.

To find out more about water use licence application, Visit: https://www.dws.gov.za/ewulaas/

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South Africa gets is 29th Ramsar site

Middelpunt Nature Reserve has become South Africa's latest designated Ramsar site.

The reserve is located along the headwaters of Lakenvleispruit, a stream in the Olifants River basin, approximately 14 km from the town of Dullstroom in Mpumalanga. The site is a permanent freshwater valley bottom forming part of the broader Lakenvlei wetland system, most of which is in the Greater Lakenvlei Protected Environment.

Middelpunt Nature Reserve is the only confirmed site in South Africa where the critically endangered white-winged flufftail (***Sarothrura ayresi***) breeds. The only other breeding sites are located in Ethiopia. South Africa is a contracting party to the Convention on the Conservation of Migratory Species of Wild Animals and the Agreement on the Conservation of African-Eurasian Migratory Waterbirds. Under both treaties, the white-winged flufftail receives the highest level of protection.

Middelpunt Nature Reserve also serves as a habitat for a number of other floral and faunal species. In addition, this nearly 10 000-year-old, peat-based wetland provides ecosystem services to the surrounding farming community through water retention, purification and flood attenuation.

Source: Birdlife South Africa

Multimillion Rand water-security project launched in Tshwane

The City of Tshwane and the Danish City of Aarhus have officially launched a three-year collaborative project to help improve the metro's capacity to manage its water resources.

"Essentially, this partnership is a window of opportunity for the [municipality] to learn best practices in water security and management from the Danish government," said Tshwane executive mayor, Cilliers Brink, in a statement.

The two cities have agreed to collaborate on water-management projects, such as reducing non-revenue water losses, conducting active leak detection, prioritising pipe replacement, focusing on own water generation and managing wastewater effectively. The Danish Ministry of Foreign Affairs has allocated R33 million to the project. This will go towards funding different study models and concepts that seek to enhance Tshwane's water security. The project will run until 2026.

"We know that we face many water challenges in Tshwane, such as in Hammanskraal and other parts of Tshwane, therefore, it is important that we work with other world-class cities and learn from them so that we can build a capital city that works for all its people," noted Brink.

Loskop water project to benefit Limpopo, Mpumalanga communities

Water and Sanitation Minister, Senzo Mchunu, says 21 villages in Mpumalanga and Limpopo are set to benefit from the Loskop Regional Bulk Water Supply Project.

The R1.67 billion project is currently underway to abstract raw water from Loskop Dam and supply water to 21 villages under Thembisile Hani Local Municipality in Mpumalanga, and to eight villages in Moutse-East under Elias Motsoaledi Local Municipality in Limpopo. Thembisile Hani municipality has been experiencing challenges with water supply due to not having access to a water source.

"The implementation of Loskop Bulk Water Supply Scheme will ensure that the municipality has a source of water and that it is reticulated to residents. It is for this reason that the department has undertaken to construct the 30 km-long pipeline that will abstract and transfer water from Loskop Dam in Limpopo and direct it to Thembisile Hani. This is coupled with the construction of a water treatment plant and reservoirs that will bring relief, and ensure that the municipality has sustainable supply to its residents," noted Mchunu.

Source: SAnews.gov.za

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NEW WRC REPORTS

[Groundwater]

Governing groundwater in city regions: Water metabolism and actor networks in the cases of Cape Town and Nelson Mandela Bay

Patterns of growing urban water demand and increasing drought risk intersect in a context of infrastructure deficits, construction delays and insufficient maintenance in many of South Africa's metropolitan municipalities. Groundwater is being turned to in times of crisis as a quick solution to supplement supplies and make up surface water deficits, both by public water service providers and private water users, including domestic, commercial and industrial users. Exploiting groundwater during crises, as an urgent and reactive measure, gives rise to poorly coordinated regulation of increasing users and usage, and fragmented management of aquifers. This undermines the sustainability with which groundwater resources are used and managed, putting both aquifers and those reliant on groundwater at risk of over-depletion and pollution. Designing interventions and innovations that ensure sustainable management of these resources requires systems-thinking, where the city is understood as a system of interdependent actors and flows of water. This study focused on the metropolitan municipalities of Cape Town and Nelson Mandela Bay (NMB) as 'learning laboratories' to co-produce a more comprehensive understanding of each urban water system. The focus was on how groundwater links with other urban water flows, what actors influence these water flows, and how things may change under various climate change and land use scenarios. The work is framed within the idea and the policy goal of cities transitioning to become water sensitive cities characterised by adaptive, multi-functional infrastructure providing access to diverse water sources, urban design that reinforces water sensitive behaviours, and equitable communities that are resilient to climate change.

WRC Report no. 3066/1/23

Web link: https://bit.ly/42XDts2

[Wastewater management]

Innovative decentralised and low-cost treatment systems for optimal urban wastewater management (IDOUM)

The reuse of treated wastewater is increasingly seen as one of the solutions to tackle the water scarcity problem. Yet, using reclaimed water for non-potable purposes and particularly to irrigate food crops, presents an exposure pathway for antibiotics and Antibiotic Resistant Bacteria and Genes (ARB&Gs) to enter the human food chain. This project aimed at: i) establishing monitoring strategies based on the data-derived prioritisation of a set of indicator contaminants and pathogens for domestic wastewater, and ii) developing energy-efficient, cost-effective, and robust treatment systems for the decentralised production of treated wastewater, mainly from domestic wastewater. In this study, this was achieved through monitoring the antibiotic resistance profiles in passive wastewater treatment using a novel algal consortia. The second component was the assessment of any remediative capacity that passive treatment has on antibiotic resistance.

WRC Report no. 2950/1/22

Web link: https://bit.ly/42Vc8Xb

[COVID-19]

Development of a framework for water quality-based COVID-19 epidemiology surveillance for non-sewered communities

As part of the efforts to stop the spread of this virus, the detection of SARS-CoV-2 in municipal sewage was successfully proven both internationally and in South Africa. Environmental surveillance of municipal sewage offers the benefit on population-level data for monitoring COVID-19. In certain cases, researchers have shown the presence of SARS-CoV-2 virus in municipal sewage before the first clinical detection in a country. Developing countries which have lower sewerage coverage are not able to access this useful tool in their pandemic response. The main aim of this project was to develop a sampling framework for COVID-19 surveillance in non-sewered communities. The sampling framework is based on field observations of non-sewered environments and include aspects such as ideal sampling points, sampling method (random vs. systematic), sample types and potential areas of virus concentration that would be later correlated to virus detection in the laboratory. This includes, for example, standing pools, greywater plumes and communal stand-pipe pools. The sampling framework will serve as standardized operating procedure for SARS-CoV-2 sampling and subsequent detection.

WRC report no. 3062/1/22

Web link: https://bit.ly/3BK7Lm0

[Estuaries]

Restoration of estuaries using a socio-ecological systems framework

The South African National Biodiversity Assessment 2019 indicated that our estuaries are under severe pollution pressure and that improvement of water quality as a key intervention would lead to significant improvement in estuary health and associated benefits that society derive from them. Innovative approaches are needed to remove wastewater inputs from estuaries to improve estuary health because both general and special standards result in high nutrient input and eutrophication. The research focused on the restoration of estuary water quality using the Swartkops Estuary as a case study. The objective of the project was to develop a socio-ecological systems framework for the restoration of estuaries. Restoration is the process of assisting the recovery of damaged, degraded, or destroyed systems. Restoration occurs along a continuum and ranges from reducing impacts to remediation, rehabilitation, and ecological restoration. The Swartkops Estuary was chosen as the study site as it is nationally important. It is one of few permanently open estuaries with large intertidal salt marshes and available nursery habitat for fish. Swartkops Estuary is also recognised internationally as an IBA (Important Bird and Biodiversity Area).

WRC report no. 3061/1/22

Web link: https://bit.ly/3BPtrxb

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[Greywater management]

Accessible greywater solutions for urban informal townships in South Africa

The URBWAT project initiated an iterative design process for greywater infrastructure, i.e. small-scale constructed subsurface flow wetlands (CWs) in an informal settlement in Johannesburg, where sanitation services are currently limited. In the project, three greywater treatment CWs were built, monitored, rebuilt and maintained in collaboration with residents in the area. Multiple pressures and (competing) goals operating in a dense settlement with little space for infrastructure meant that the physical context and the use of the CWs changed rapidly. Therefore, it became clear that building structures that were more multi-functional (thinking of water collection, washing, and channelling multiple types of water) resulted in a higher use. The results from the project can inform planning processes aiming at addressing wastewater issues in urban slums with limited availability of sanitation services.

WRC report no. 2953/1/22

Web link: https://bit.ly/3BNopkU

[Sanitation]

Development of an in-situ faecal sludge solar dryer at pilot scale

Thermal drying is an efficient treatment method for sludge treatment for volume reduction and disinfection, but it requires a high input of energy. The use of solar thermal energy for drying proposes could reduce drastically the energy consumption, leading to a significant cost reduction. Even though an important number of solar drying technologies have been deployed in the food and agriculture sectors and some applications of solar thermal drying exist for sewage sludge treatment, this option has not been enough exploited for faecal sludge treatment, with only a few cases greenhouse drying beds reported in literature. This latest project was about the development, testing and evaluation of two prototype solar thermal drying technologies for the treatment of faecal sludge, namely a greenhouse-type solar dryer and a screw conveyer, and it included a pre-feasibility study. The present project is the continuation of a previous WRC project (**K5/2582**) that demonstrated the great potential of the application of solar thermal energy for faecal sludge drying.

WRC Report no. 2897/1/22

Web link: https://bit.ly/3oeT4o5

[Hydropower]

Market analysis to determine the extent and potential of water-to-energy market in South Africa (Waste and Small/ Micro Hydro)

The concept of water and waste to energy has been around for decades. When considering that wastewater is a carrier of over 50% of waste resources that is either lost or unrecovered materials, energy or water. However, despite global reports estimating that the waste to energy market value was US$28.4 billion in 2017 and would increase to US$42.7 billion by 2025, there has been limited implementation in South Africa despite projects being identified as technically and financially viable. There is significant potential to generate energy from water and wastewater sources and references within the global market suggest that these projects can be successfully executed at scale. The study was positioned to undertake a market analysis of various water to energy applications in South Africa and understand the market size and the challenges within this market. The overarching objective was to develop a strategy that would attract investment in water to energy projects and unlock the potential within this area of the water value chain. The recommendations from the study include a roadmap that will catalyse investment for these projects and enable their successful implementation

WRC report no. 3004/1/21

Web link: https://bit.ly/3OpGBIK

[WEF nexus]

Developing a Web-based and GIS-enabled WEF nexus integrative model – Final Synthesis Report

Strategic resources such as water, energy, food, and land are under pressure from changes in climate and socioeconomic conditions and silo-based management approaches. This has led to the pursuit of integrated resource management approaches: the water-energy-food (WEF) nexus. The WEF nexus approach acknowledges the inextricable links between WEF resources to maximize and minimize their synergies and trade-offs. This short-term project was part of the WRC's goal to promote the WEF nexus research and implementation in South Africa. To bridge the gap between WEF nexus theory and practice, the global aim of this study was to develop a web-based and GIS-enabled integrative WEF nexus analytic model, iWEF. Specifically, the work reviewed state-of-the-art WEF nexus models tools and developed, tested and disseminated a web-based GIS-enabled WEF nexus analytical tool applicable at different scales. Thus, the scope of this work involved (i) reviewing existing WEF nexus tools and their characteristics, including geospatial analytic capabilities in literature, (ii) developing the web-based and GIS-enabled iWEF modelling tool, (iii) testing the iWEF model in case studies at different scales, and (iv) disseminating the iWEF model to potentially interested public users.

WRC report no. 3059/1/22

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WOODY ENCROACHMENT

Study examines impact of mopane infestation on ecosystem services

Studying the effects of woody encroachment on evapotranspiration in the semi-arid savanna region of southern Africa could provide insight into related groundwater and streamflow impacts at the landscape and biome scales. Article by Jorisna Bonthuys.

At the Mthimkhulu research site located approximately 40 km north of Phalaborwa in northeastern Limpopo, PhD student Tiffany Aldworth and scientists from the South African Environmental Observation Network (SAEON) have been exploring the effects of large-scale changes in vegetation due to mopane encroachment on freshwater resources.

Mopane (***Colophospermum mopane***) is a tree or shrub species indigenous to central and southern Africa. It is one of the main encroaching species in the southern African region, where it often grows in dense, monotypic stands with little to no grass cover.

In the northeastern region of South Africa, the density of mopane has significantly increased over the last few decades, with implications for forage production, biodiversity, water resources and tourism activities. In particular, considerable concern has been raised over the impact on water resources. The region has a semi-arid climate with low and highly variable rainfall, and droughts are common. In addition, the area's growing rural population is increasing the water supply demand.

The topic of woody encroachment, also commonly known as bush encroachment, woody thickening or thicketisation, has long been an area of scientific focus for researchers linked to the SAEON. This network encompasses seven national research nodes and performs long-term environmental observation and research.

Aldworth did her research at the Mthimkhulu Game Reserve in Limpopo, a private reserve owned by a local tribal authority. The reserve is part of the Greater Kruger National Park

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region, comprising the Kruger National Park and the private game reserves located west of the Kruger National Park. The Mthimkhulu reserve shares open borders with the northeastern side of the park.

The seasonal Klein Letaba River, a tributary of the Letaba River, is situated adjacent to the study site, which receives an average of 467 mm of rain annually. The reserve's vegetation is classified as Lowveld Mopaneveld, a semi-arid savanna characterised by a dense cover of mopane shrubs, sparsely scattered trees and a limited grass understory.

At Mthimkhulu, mopane encroachment has likely been triggered by poor land management practices over the past century, particularly overgrazing by cattle, Aldworth points out. She recently published some of her findings on the effects of mopane encroachment on evapotranspiration at the Mthimkhulu reserve in MDPI's ***Hydrology*** journal (Visit: https://www.mdpi.com/2306-5338/10/1/9).

The term ***evapotranspiration*** refers to the sum of water that is lost to the Earth's atmosphere through plant transpiration and evaporation of soil water and rainwater collected by the plant canopy. ***Transpiration*** refers to the evaporation of water from stomata (the tiny pores found in the epidermis of leaves, stems and other plant organs). This natural evaporative 'cooling system' brings down the temperature of the trees – it allows gases such as carbon dioxide, water vapour and oxygen to diffuse into and out of plants.

Aldworth says that a stable balance of grassy and woody plants in savanna ecosystems is vital in ensuring that these savannas can effectively support and regulate ecosystem services to society. These 'services' are defined as the benefits humans derive from nature, such as clean soil, food, air, and water.

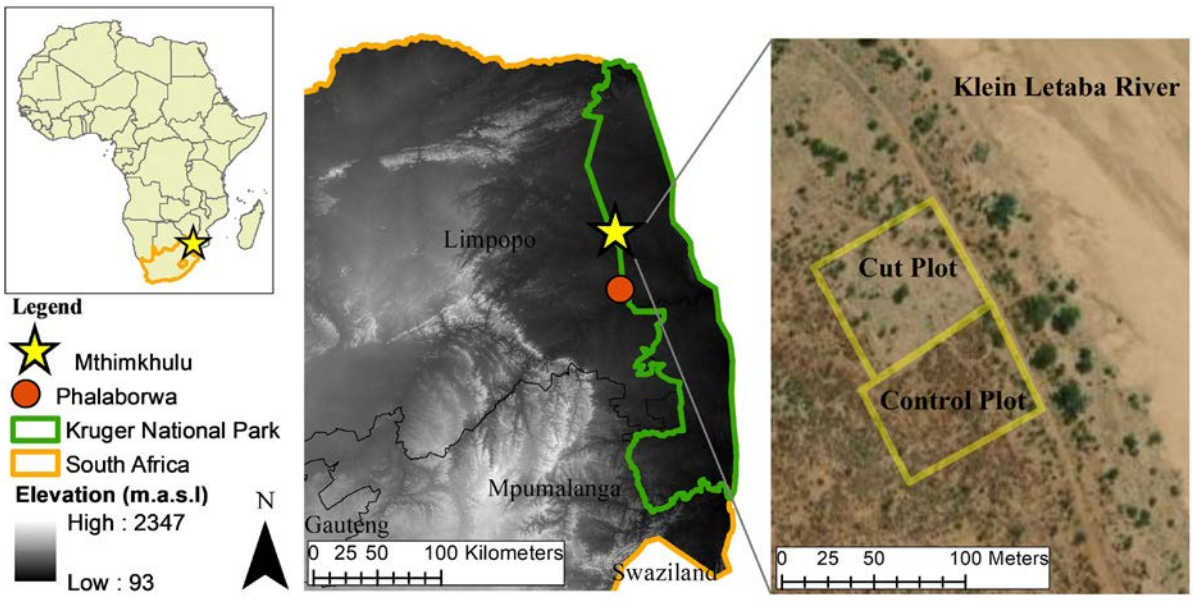
Woody encroachment alters the structure and functioning of ecosystems, she points out. This means that continued mopane encroachment could have significant implications for the supply and value of those ecosystem services delivered from them. For example, increased woody biomass can reduce streamflow, groundwater recharge, grazing capacity, and biodiversity.

There are, however, also several benefits linked to an increase in the density of mopane trees. Mopane can, for example, facilitate carbon sequestration to help mitigate climate change. In addition, it is used extensively for fuel and firewood (approximately 80% of rural households in northeastern Limpopo use wood as their primary energy source for cooking and heating), building material, and medicinal purposes. Furthermore, it is the host of the mopane worm, a highly nutritious protein source that provides food for many and sustains trade for income.

"It is, therefore, important to refine our understanding of the drivers and impacts of mopane encroachment in this area," she notes.

In 2015, the SAEON established an experimental woody plant clearing trial at the Mthimkhulu site. Experimental plots of either 60 metre x 60 metre or 120 metre x 120 metre were cleared of all mopane trees shorter than 4 metre, creating 'cut' treatments of open savanna adjacent to 'control' plots of dense savanna. No treatment has been applied to the control plots. Today, this site comprises five control plots and five neighbouring cut plots.

Researchers have been working with the local tribal authority to develop a long-term research platform in the area. Dr Tony Swemmer, the manager of the SAEON Ndlovu Node, has been instrumental in setting up this site. Aldworth has collaborated with Swemmer and other SAEON scientists to determine if woody encroachment affects the water cycle at the study site. This work forms part of a larger National Research Foundation programme that aims to model the effect of woody plant cover on evapotranspiration across South Africa.



Location of the Mthimkhulu Game Reserve and the location of the control and cut plots within the reserve.

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Tiffany Aldworth

Vegetation and research equipment at the control plot in the summer (top-left) and spring (top-right), and the cut plot in the summer (bottom-left) and spring (bottom-right).

SAEON established the Mthimkhulu site to compare ecosystem functioning and biodiversity in a protected area and communal rangeland, and determine the costs and ecological impacts of bush-clearing. The scientists involved review the extent and causes of woody encroachment, evaluate its impacts, and interpret their results to inform appropriate policy responses at this site and elsewhere in the savanna region. They also consider active management options, proactive land management tools and potential best practices to manage woody encroachment.

Understanding woody encroachment

Woody encroachment has been amongst the most significant vegetation changes in the region over the past century, as is the case for many savannas globally. In southern Africa, such woody encroachment has been particularly widespread in arid and semi-arid savannas.

Overgrazing, fire suppression, rising temperatures, altered rainfall patterns and increasing atmospheric CO_2 concentrations (due to rising fossil fuel use) are considered some of the underlying drivers of this phenomenon. One of the biggest questions in this landscape is the impact of climate change and how elevated CO_2 levels help fuel rampant encroachment, Aldworth points out.

Scientists estimate that woody plants have encroached on 10 million to 20 million hectares of South Africa's savanna and grassland landscapes.

Savannas and grasslands comprise 46% and 29% of South Africa's land surface area, respectively. Since researchers first undertook national-scale aerial photography in the 1940s, woody biomass has significantly increased within these biomes due to woody encroachment and the spread of alien invasive plants.

Investigations on the hydrological impact of invasive alien plants occurring in the higher rainfall regions of South Africa have received much attention in the past and policy direction on these species is clear. Less research has, however, been conducted on woody encroachment in the drier parts of the country. Few studies have also measured changes in evapotranspiration in response to any encroaching species in southern Africa.

This study is the first of its kind, focusing on the evapotranspiration of mopane encroachment in a semi-arid savanna in the northeastern corner of the country.

"Mopane is considered an aggressive competitor for available soil water with shallow-rooted grasses and other woody plants," Aldworth says. "Its competitive advantage [to access water] is thought to be primarily attributed to the adaptations of its roots. Although the roots of mopane are not as deep as other trees, it has a large root biomass which extends horizontally well beyond the extent of its canopy, allowing access to soil water over a large area."

Studies have also found evidence that mopane roots can utilise soil water at a matric potential lower than that of grasses and other woody plants, allowing them to extract water from very dry soils.

Unpublished data from a mopane root survey conducted by the SAEON at a site roughly 30 km south of the Mthimkhulu reserve also showed that the highest mean root concentration occurs within the first 50 centimeters of topsoil, which is very shallow for a tree species. In addition, most coarse mopane roots extended horizontally to a distance of approximately 2 metres from the tree trunks. Some roots extended as far as 16 metres away from the tree trunks.

Furthermore, scientists predict a 1.5°C to 3.5 °C temperature increase and no or little decrease in precipitation by 2100 for the Kruger National Park area. While precipitation in the area is not projected to change greatly, available soil moisture in the region is expected to decrease as a result of the large temperature increases causing greater evapotranspiration. Under future modelling scenarios, mopane populations are at the same time expected to increase in the northern Kruger National Park region.

Aldworth says that long-term environmental observation is vital to understanding some of the large-scale ecological changes underway in the region. In this regard, SAEON's efforts at the study site provide a platform for studying some of the major environmental changes being detected in the Lowveld region. Researchers are, for instance, disentangling the impacts of climate, fire and herbivores (particularly elephants) on the productivity and biodiversity of the savanna ecosystem.

Surface renewal method

In her study, Aldworth set up instrumentation to measure the evapotranspiration losses from the vegetation. Surface renewal systems were deployed on one cut plot and its neighbouring control plot.

While the surface renewal method is not a new method, an increasing number of studies conducted worldwide report its

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successful application for estimating evapotranspiration over a wide range of surfaces, including open water, wetlands, grasses and agricultural crops. This method is also being trialled for various vegetation surfaces and climate types in South Africa by some of Aldworth's SAEON colleagues working in the Grassland-Forest-Wetlands Node.

The method often yields valuable data. Surface renewal analysis is based on the coherent structure theory, which assumes that air parcels near a plant canopy are continuously replaced or 'renewed' by ambient air parcels descending from the atmosphere above. While in contact with the canopy, the air parcels are heated or cooled, due to heat exchange between the air and the canopy.

Using high-frequency air temperature measurements taken above the canopy and plotting them against time, the temperature fluctuations of these individual air parcels exhibit organised, coherent structures, which resemble ramp events.

"Knowing the dimensions of these temperature ramps allows for an estimate of the heat exchange of the air parcel with the canopy," Aldworth explains. "This information, in turn, enables us to estimate the sensible heat flux to or from the canopy."

She used electrical sensors that measure temperature called fine wire thermocouples to collect high-frequency air temperature readings. These readings were needed to estimate sensible heat flux.

Aldworth then calculated latent heat flux indirectly as the residual of the shortened surface energy balance equation, along with net radiation and soil heat flux measurements. Finally, she converted the latent heat flux data into actual evapotranspiration data.

Aldworth employed the more widely used eddy covariance method to calibrate the sensible heat flux data estimated using surface renewal. She carried out week-long eddy covariance campaigns alongside the surface renewal systems in summer and spring to obtain calibration factors for each plot. This methodology allowed Aldworth to produce continuous evapotranspiration data for nearly three years (from November 2019 to July 2022) in two adjacent savanna plots of differing woody plant densities – the first such dataset for savanna ecosystems in South Africa.

"To our knowledge, this is the first validation test of the surface renewal method over semi-arid savanna-type vegetation worldwide," she says.

Research gains

Over the three hydrological years of the study, evapotranspiration was highly seasonal. It was typically highest during the wet season when it responded to increased soil water availability, and lowest during the dry season, due to the deciduous nature of the vegetation.

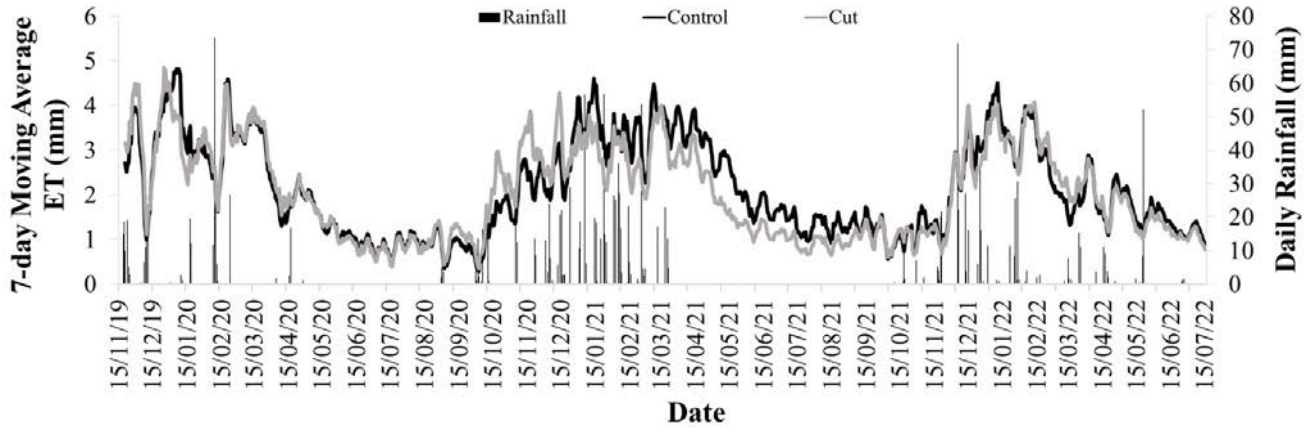
"The results suggest that grasses at the cut plot can expand their leaf area and start transpiration more rapidly than mopane trees once soil water becomes available at the beginning of the rainfall season, which fits phenology observations. However, towards the end of the wet season, the grass swards generally senesce before the mopane leaves, allowing the mopane to maintain higher evapotranspiration rates later into the growing season.

"The offset in their responses may have been a result of the mopane keeping its leaves until late into the growing season to meet a seasonal growth cycle, or the mopane's large rooting systems may have been able to access deeper soil water than the grasses as the upper soil layers dried up."

During the two drier years of the study, the removal of mopane trees had little effect on evapotranspiration at the study site. All rainfall evaporated regardless of the density of woody plants. However, for the wettest year of the study (2020-2021), removing mopane trees decreased evapotranspiration by 12%.

"These results support the hypothesis that woody encroachment

Evapotranspiration graph



Daily values of evapotranspiration over the course of three hydrological years (2019-2022) at the Mthimkhulu research site. The black line shows the evapotranspiration measured in the control plot with a high cover of mopane shrubs, and the grey line in the open, cut (grassland) plot. The daily rainfall is given on the secondary axis.

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Photo supplied

Mopane is a deciduous tree which limits its transpiration during the dry winter season by shedding its leaves. It typically retains its leaves longer into the dry season than other woody species and grasses growing in the same area. Depending on soil conditions and water availability, mopane can grow in shrub or tree form and it rarely grows taller than 5 metres high.

in semi-arid savannas can increase evapotranspiration, at least during years of above-average rainfall, and thus may reduce groundwater and soil water profile recharge," she adds.

Another significant finding of the study was that the annual evapotranspiration exceeded the annual rainfall in all three years studied at the site. For the 2019–2020 hydrological year, the driest of the three years, the annual evapotranspiration exceeded the annual rainfall at both plots by 80%.

The following year (2020–2021) was much wetter. During this year, the annual evapotranspiration at the cut plot was similar to the annual rainfall, but the evapotranspiration at the control plot exceeded the annual rainfall by 11%. For 2021–2022, a year that had a more typical average rainfall, evapotranspiration exceeded the annual rainfall at the control and cut plots by 15% and 13%, respectively.

These results suggest that rainfall may not have been the only source of water used by vegetation during dry periods.

"There is the possibility that the vegetation, particularly the larger trees, used water from deeper soil stores or groundwater that rose to within the rooting depth by hydraulic lift," Aldworth says. "The water tables are likely shallow or perched since the plots are located near the riparian area of the Klein Letaba River." Hydraulic lift is a process where plant roots facilitate the movement of deep soil water towards shallower soil layers.

In a previous study at the site, scientists used stable isotopes to determine that mopane trees make use of deeper soil water than grasses. No groundwater samples were, however, taken to verify whether groundwater was a source of water used by the vegetation.

More research on evapotranspiration and soil water processes is needed to advance scientific understanding of the relationship between vegetation structure, vegetation water consumption and water supplies in semi-arid savannas. Further isotope studies are also needed to confirm the water sources used by the vegetation.

"We need to know more about the exact mechanisms involved and the consequences of this for groundwater and streamflow at landscape scales.

"The surface renewal approach with eddy covariance calibration offers a viable method for estimating evapotranspiration in semi-arid savanna vegetation."

Aldworth is currently working on two more research papers using data collected at the Mthimkhulu site. The first paper investigates how mopane encroachment affects soil water processes and how much water is stored in the soil. The second is based on her study of the impact of woody encroachment on hydrological processes, but upscaled to a larger scale using remote sensing tools.

"Mopane encroachment may have significant hydrological implications for the semi-arid savanna region of southern Africa," she concludes. "We must upscale our in situ results to determine how the hydrology of this region is being affected and to inform appropriate management responses."

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DESALINATION

Can desalination aspire to having a global impact?

One should take a moment to reflect on how scarce freshwater really is on planet Earth; all the freshwater in lakes, dams, aquifers and rivers make up less than one percent of our planetary water. Hence the urgency with which this precious, life-sustaining resource is being managed around the world, is completely understandable. So writes Dawid Bosman of the Trans-Caledon Tunnel Authority.

But as this miniscule slice of the water pie chart comes under greater pressure from the Anthropocene, as urbanisation, population growth and climate change take its toll on our freshwater security, it surely begs the question: "What about the abundant 97% of planetary water that is saline, found in the sea and salty lakes and aquifers? Could that not be accessed?" And yes, quite simply, the technology exists, it is quite mature, and it is already being done on a vast scale in a select few markets, mainly in the Middle East.

As it stands now, desalination adds about 24 billion cubic metres per year to the global water supply and serves about 300 million people. This contribution grows at a compound annual growth rate of about 7.9%, according to Global Water Intelligence (GWI).

Projecting this growth rate forward to 2030, desalination should be adding about 3.6 billion cubic in new supply each year by the end of the decade; equivalent to 4.5 times the yield of phase one of the Lesotho Highlands Water Project in new supply, each year.

Simultaneously, the globe's freshwater supply is increasingly constrained. This is not unexpected; in 2009, the ***2030 Water Resources Group*** projected in their seminal report ***Charting Our Water Future*** that a 24% global water deficit would arise by 2030, if water productivity and augmentation continued to follow historical trends. The message was clear: Business as usual in the consumption and supply of freshwater would not be sufficient to avert the deficit. This was an urgent call on the global water sector and major water-consuming industries to

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accelerate the adoption of water-saving technologies in mining, agriculture and manufacturing. Many of these options appeared viable. There was less enthusiasm for water augmentation, due to fewer workable options and a steep marginal cost curve, culminating in seawater desalination, the most expensive option at a prohibitive $0.80 per kilolitre, and back then entirely reliant on fossil-based energy.

Today, fourteen years later, the world is not on track to resolve the anticipated deficit by 2030. If anything, the realisation has taken root that the global water challenge encompasses much more than mere supply and demand; the UN 2023 Water Conference highlighted the triple planetary crisis of climate, biodiversity and pollution. And yet, it is projected that by 2030, some 1.5 billion people would no longer be able to rely on traditional sources of freshwater, largely because of climate change and urbanisation.

Water productivity, total (constant 2015 US$ GDP per cubic meter of total freshwater withdrawal)

Food and Agriculture Organization, AQUASTAT data, and World Bank and OECD GDP estimates.
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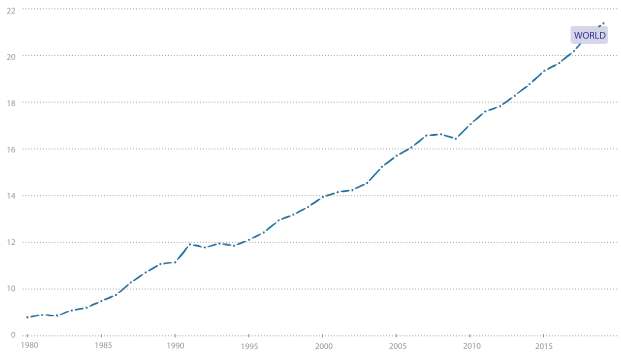

Figure 1: Global water productivity index (1980-2019). (World Bank, 2023)

Looking to the World Bank's tracking of the water productivity index, as shown in Figure 1, there has been no significant accelerated rate of improvement in the quantum of water we require per unit of economic value creation in the decade since 2009. It would seem that demand management and conservation are not progressing fast enough, and the world is not on track to close the water deficit anticipated by the 2030 Water Resources Group.

Whilst recognising that climate change, in particular, has proliferated the water-related challenges into many areas, a key question remains unanswered: How do we bring new water into the global water supply system?

The ***Future of Desalination International Conference (FDIC),*** held in Riyadh in September last year, may have provided a glimpse on at least a part of the answer. I was fortunate to be there, serving as a panellist in the finance and policy stream. The high-profile event was co-sponsored by the UK-based GWI and the Saudi Saline Water Conversion Corporation, the world's largest owner of desalination capacity, producing nearly 7 million cubic metres per day.

The aim of the conference was to explore if the global seawater desalination industry would be capable of a significant, breakout expansion, to jump from serving 300 million people to serving 1.5 billion people, amounting to a five-fold growth in a mere eight years. As the industry is now, GWI assessed, it is simply too complicated, expensive and risky to grow this rapidly. But, perhaps at FDIC we could explore how to transcend this.

It was clear at the outset that the technology domain of desalination did not present the fertile ground for dramatic growth; most technologies in seawater reverse osmosis (SWRO) are already quite mature, and the outlook for advances and innovation is limited to mostly incremental improvements in energy efficiency, recovery rate and mineral harvesting. While this may yield some cost savings, the incremental technology advances in SWRO could not unlock a market of 1.5 billion people.

Much more scope for improvement was deemed to exist in the finance and policy domain, where significant hurdles continue to impede the path to low-priced, simple and dependable desalination. A key obstacle is the general lack of well-informed and consistent government policies pertaining to the implementation and operation of desalination; this is especially so in the emerging desalination markets, beyond the Gulf nations and Middle East. And as we know, policy uncertainty tends to inhibit investment.

There are a number of strategies which most governments do not know how to craft and execute, such as the integration of desalination into an existing water resources portfolio, especially when demand for additional supply is seasonal or drought related, or how to make the trade-offs between marine impact and costs, or how to integrate desalination into a renewable energy strategy. Furthermore, there is only sparse knowledge on how to manage the financing risks, which can add to the financial outlay, and often, an absence of the necessary conditions for a successful desalination implementation, such as low non-revenue water and cost recovery tariffs. These are not easy challenges to overcome, and the organisers of FDIC felt that the conference would make a substantial start to having the conversations that would eventually provide some answers.

The conversations did not disappoint, and some powerful insights emerged.

Seawater desalination is still perceived as expensive, even though the benchmark price has dropped significantly over the past decade, and especially since around 2019, mainly as a result of the combined effect of cheap renewable energy, transparent procurement and contracting methods, and the shift towards very large-scale projects. All-inclusive prices around the $0.40/m^3 mark have frequently been seen in the mature Gulf Cooperation Council (GCC) and Middle East markets, provided that it is produced at large scale, around 500 megalitre per day, and using reverse osmosis (RO) technology powered by renewable energy.

However, if the benchmark could be lowered to $0.20/m^3, in all markets, desalination would become a viable source of water for agriculture as well. This would be a significant breakthrough, as desalted seawater then becomes a transformational force

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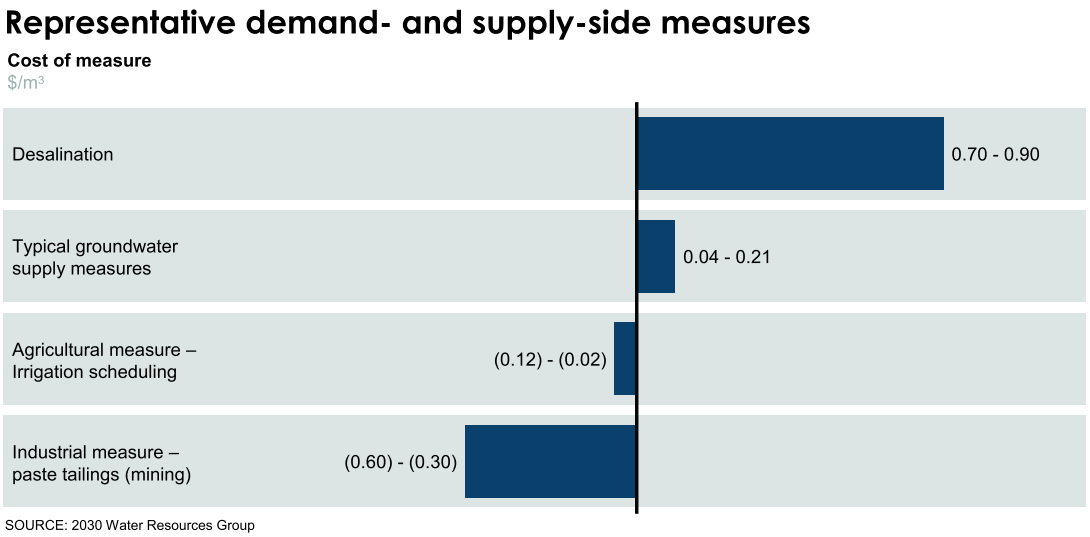

Representative demand- and supply-side measures.

in solving climate change; deserts could be greened, and vast amounts of CO_2 could be captured into the newly formed biomass. In this way, desalination could become part of the solution to climate change, instead of a contributor to the problem. But how could \$0.20/m³ desalination be achieved?

A first step would be integrating desalination with renewable energy, to bring the energy cost element down to \$0.02 per kWh. This is not unreachable, as solar photo-voltaic projects in the Middle East / North Africa region have already yielded feed-in tariffs of around \$0.01 per kWh. However, so far, desalination developers are mostly denied that pricing, and are compelled to pay a much higher fee for grid electricity, upon the reasoning that all off-takers need to pay for the grid, and solar energy does not work at night. However, demand peaks and troughs are a challenge to power grid operators, and desalination plants can run very well at night, when there is often a demand trough, so there is room for finding mutually beneficial solutions, on a case-by-case basis.

The proposed way forward is to introduce the concept of 'energy freedom' in the procurement process, whereby independent water producer (IWP) bidders can negotiate menus of peak and off-peak prices with energy suppliers, or even build their own captive power plants, if necessary. In South Africa, the easing of regulations in 2021 which previously restricted private power generation, now allows uncapped embedded power generation, and in this manner a local pathway for such solutions is already visible.

A second factor towards the goal of \$0.20/m³ is to scale up the plant capacity. One reason why the price of desalination has fallen in recent years is because of scale. Ten years ago, a 100 Ml/day plant was considered big, and the rule of thumb was that engineering, procurement and construction (EPC) costs should be around \$1,000 per each cubic metre per day capacity. Today, 1 000 Ml/day facilities are built at a price closer to \$650 per cubic metre per day capacity. The assessment from the technical stream at FDIC was that to reach \$0.20/kl desalination, the specific EPC cost needs to come down to \$450, which will require building at a scale of about 2 000 Ml/day.

When building at such a massive scale, an optimised plant configuration will be essential. What comes to mind are the innovative, easy-to-maintain vertical installation of pressure vessels of the Soreq desalination plant, the energy-flexible pressure centre design of IDE Technologies, the high recovery designs that allow reduced water handling throughout the plant, and prudence in the setting of operating specification of the plant. But even more innovation will be required; one such example may be Veolia Sidem's 'Barrel', a massive pressure vessel containing hundreds of RO elements, yielding benefits of cost, spacial efficiency, and ease of maintenance.

One caveat of massively scaling up plant capacities, is that seawater abstraction and brine dispersal will require much more attention, to minimise the impact on the marine environment. On the one hand, there are fine examples of well-designed marine works and diligent monitoring of brine dispersal during operation; the Kwinana desalination plant in Perth, Western Australia comes to mind. But it is important to feed such good practice into a prudent permitting process for new developments. An example not to follow would be the stalled development in Huntington Beach, California, where poorly advised activism and overly onerous regulation has incurred more than \$100 million in legal costs, without any soil being turned or a single drop of water produced. One solution may be to establish a credible industry certification relating specifically to the marine interface, containing clear parameters for design and permissible impacts, to introduce a standard guidance for local regulators to follow, and to simplify the environmental approval process, especially in jurisdictions where desalination is new.

In conclusion, the matter of water security is becoming increasingly complex, moving well beyond the conventional supply-demand calculus. But there is some relief in the knowledge that humanity has mastered the technology of drawing freshwater from the infinite oceans, that it can be done cleanly and cost-effectively, and is vastly scalable. If the step-change in scale could be achieved, and the sea becomes the water resource for billions of people, we may well have gained a most powerful adaptation response to climate change.

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WATER AND TECHNOLOGY

New technology to transform water quality testing in South Africa

A new technology that will take the specialised task of water quality testing from over-burdened laboratories to field testing sites countrywide is being developed at the Water and Health Research Centre (WHRC) of the University of Johannesburg (UJ) with funding from the Water Research Commission. The innovative equipment is expected to deliver near-instant results and expand the spread of water resources being monitored. The equipment includes a mobile water testing facility with supplementary drone technology and state-of-the-art digital bacterial water quality testing probes. Petro Kotzé reports.

The project could fill a serious gap in South Africa's water resources management. Monitoring and assessment of the quality of water resources are critical to determining if they are suitable for various uses, including for drinking and personal use, and the country's national monitoring programmes monitor raw surface water quality in rivers and dams for trends in, for example, chemistry, eutrophication, microbiology and ecosystems. Spot tests also need to be conducted if there are any concern, for example, when sewage treatment works fail or chemical spills occur.

However, there is currently a huge backlog in water quality testing, and results are often only available after anything from three weeks to six months. Among the many implications is the health risk to water users, who might still use contaminated water due to a lack of test results that indicate any danger.

It is a serious concern in South Africa. According to the 2022 Green Drop Report, more than a third of wastewater treatment works (334 or, 39%, out of a total of 955 systems) are classified as critical, with one of the greatest concerns being that treated effluent is not meeting the required discharge standards, particularly regarding bacteriological parameters. This can have serious consequences for the health of users and the ecosystem downstream. According to the World Health Organisation, some of the water-borne diseases that pose a high risk to South Africans include gastroenteritis, cholera, viral hepatitis, typhoid fever, bilharziasis and dysentery. Outbreaks of waterborne

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diseases have already led to the deaths and hospitalisation of hundreds of people over the past two decades and more recently due to cholera oubreaks in Hammanskraal, Pretoria. (see sidebar). More challenges, over and above the long turnaround time for test results, are the limited sites covered by the national monitoring programme, and that the data that is generated is not being stored on a central database for access by all water users.

"Our water resources are not being monitored as robustly as they should," says Yazeed van Wyk, Research Manager at the WRC. Van Wyk says the current project is one of many that form part of a framework to improve data collection and availability across South Africa, as part of the larger service that the WRC is delivering to the Department of Water and Sanitation. Another project, for example, is the development of a mobile application (app) that will allow ordinary citizens to add borehole locations and characteristics to a database for groundwater monitoring (refer to ***App for hydrocensus and groundwater monitoring – A citizen science approach***, published in The Water Wheel January/February 2023 edition, Visit: https://bit.ly/3pTTe4r).

The current study is a multi-institutional collaboration between UJ and Stellenbosch University (SUN) local startup company Drobotics and LS Telcom, each of which contributed a unique specialty to the product development.

A technology that amalgamates expertise

The seed for the project was already planted years ago, around 2004, says project leader Dr Kousar Hoorzook, currently the Programme Manager for water quality and management at UJ Process Energy Environment Technology Station (PEETS). As a post-graduate biotechnology student conducting research at UJ WHRC, she made several trips with her research group to rural Venda in Limpopo Province to collect samples to test for ***Escherichia coli*** (***E. coli***) and various other waterborne pathogens. Her Master's and Doctoral projects, supervised by Prof Tobias G. Barnard at the WHRC, focused mainly on ***E. coli,*** which is a bacterium that causes diarrhea and is found in faecal contaminated water sources.

The many sampling site visits entailed the laborious process of packing up the necessary laboratory equipment and travelling with it over long distances to their research base in the rural areas where they had to get water samples from. Often, Hoorzook remembers, this was an empty hut found in disarray, that first had to be thoroughly cleaned before they could start. The team members stayed there for weeks at a time, traveling to waterbodies or homes to gather sources to sample and analyse. They then had to return with their equipment and samples to the university's registered laboratory for further analysis. Hoorzook's experience is not uncommon. There are only a handful of registered laboratories across the country that can analyse water samples, all of them located far away from rural areas where water users are often most at risk.

The situation led to Barnard and Hoorzook coming up with the idea to build a mobile water testing laboratory, so the work that had to be undertaken back at the university's laboratory could be done on site, and the results be available within 24 hours. However, at the time the idea did not gain much traction. From 2004 to 2017, Hoorzook wrote business plans and tried to secure funding, but without luck. Then, with new people that had new ideas in the organizations, the mobile lab's potential was recognised by UJ Technology Transfer Office (TTO) and the Technology Innovation Agency (TIA). Thirteen years after they first speculated about its development, the lab, designed by Hoorzook, Barnard, Director of the WHRC at UJ and industrial designer Robin Robertson, could be built.

All photographs supplied

Project team members from University of Johannesburg Water and Health Research Centre, Drobotics, LS telecom and Stellenbosch University.

The mobile laboratory, UbuntuBlu.

The lab has high road clearance and is towed by a 4x4 vehicle. It can be parked on-site for several days at a time, and allows analysis to start immediately and continuously, without needing to travel back and forth between accommodation and a fixed laboratory in a city. It also includes a side tent for accommodation.

The mobile lab can run all basic analyses necessitated by the South African national standards for drinking water quality, including ***E. coli*** and other bacteria that cause dysentery, typhoid fever and cholera. It runs sample fridges and incubators, analysis equipment and air-conditioning on solar panels, a generator and batteries and carries its own safe water supply. It can also be customised for different types of equipment for different types of analyses.

The lab could thus be a cost-effective option to monitor not only water bodies or rural water supply, but also anything from water treatment plants, schools, clinics and hospitals. It could be used by municipalities that do not have access to accredited laboratories close by; academic institutions without laboratories, where researchers would like to start working in aspects related to water quality; and areas with waterborne disease outbreaks located far away from testing facilities. The labs could also help to create research networks to increase the available water quality data.

Now, the new project is taking the idea much, much further, to expand its reach and efficiency and potentially make an even larger impact on the country's water quality monitoring and testing.

Up, up and beyond

The mobile laboratory is now being upgraded and packaged as a unit with drone technology (from Drobotics) and digital biosensing probes (developed by SUN) through funding that Hoorzook jointly applied with Drobotics and SUN, received from the WRC while doing her Postdoctoral Fellowship at the WHRC in 2022. The specialised drone is fitted with a winch lift system and can submerge digital probes directly into the water that needs to be tested. The probes can test for bacterial and physio-chemical content in water. The data will be sent from the digital sensor probes to the drone winch to the mobile laboratory in real-time via Wi-Fi.

In total, the Integrated Mobile System comprises a UJ designed and developed mobile laboratory, UJ designed and developed water sampler, Drobotics winch/hoist, jig and real-time communications system, LS Multicopter owned and operated Matrice 600 PRO drone, SU designed and developed water bacteria testing biosensor, and off the shelf chemical and heavy metal digital test probes.

The technology can deliver water quality test results in near real-time from geo-referenced recorded test locations to the mobile laboratory to the cloud to a dashboard. The platform can carry out drone launches for water sampling operations and includes optic lenses for photogrammetry, LiDAR, thermal and hyperspectral applications for real-time surveys, security and to inspect the scope of activities. The expanded opticgammetry scope can be expanded more for the detection of physical pollutants in water through computer deep learning generated analytics interpreted hyperspectral imaging.

The technology has many benefits, van Wyk says. For one, drones can cover much larger areas of water bodies very quickly and efficiently, reducing necessary time and resources. More remote waterbodies, difficult to access by people, can also be reached. Not only is the technology more efficient than sending out people to take samples, but it promises improved accuracy and precision. The novel biosensors can provide accurate, very precise measurements of water quality parameters with very, very limited associated uncertainty, van Wyk says. "That reduces the risk of errors." By removing the human element, we are getting more reliable data," he adds. Another benefit is the turnaround time. "The results are available almost immediately." The improved efficiency will result in a massive improvement in our resilience to water quality challenges, he says.

The project is set to end in March 2024 and Hoorzook says their product is already 70% there. A provisional demonstration of the system was carried out at UJ Island at the Vaal Dam in March. The following was successfully demonstrated: the jig attached to the winch, simulating water quality test applications in operational offshore environment; real-time communications through onshore connection of the Stellenbosch communications device to an on-board computer to laptop; and, successful flight operations within an operational offshore environment to simulate the launch of digital probes for water quality testing applications of the attached winch and jig system and sampling operations to and from predetermined GPS points.

Before the development of the mobile laboratory, specialised equipment had to be transported from laboratories in town to available facilities close to testing sites – a laborious process.

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Students clean a hut they have to work from during field trips to Venda in the Limpopo Province.

A major demonstration of the full, integrated system is scheduled for July, to also test the following: conventional water quality test applications; digital water quality test applications; drone-supported water sampling operations; aerial photogrammetry applications; and real-time/near-real-time results (from the probe to the winch, the mobile lab and to the cloud).

Future solutions lie in research-backed innovation

The national backlog in water quality test results is a massive, serious issue that will not just disappear overnight, van Wyk says but we need to come up with innovative ways to solve the problem or at least, to start generating baseline information. This project is one example of how that can be done.

Over and above that, the new technology will serve as an early warning detection system. We can detect any changes in the water quality that might indicate a problem before it becomes a major issue, he says. "Early detection can allow us a quick response time to prevent further damage to the water resources and minimise the impact on human health."

The new technology includes a drone that is fitted with a winch and jig system to house chemical bacterial probes to test for certain quality-related parameters.

The importance of water quality testing to prevent death and disease

In 2000 and 2001, an unexpected cholera epidemic that broke out in KwaZulu Natal resulted in 114 000 people infected and 260 deaths. The communities at the epicentre of the epidemic experienced constant interruptions to their piped water supply and reverted to traditional water sources, which were contaminated. The primary route for the epidemic's rapid spread through northern KwaZulu-Natal to the Eastern Cape and beyond appears to have been along catchment areas (according to the South African Health Review 2016).

Since then, there have been more outbreaks of waterborne disease. The first was an outbreak of diarrhoea and typhoid in the town of Delmas in 2005. A lack of well-managed water treatment, particularly chlorination, was identified as a significant causative factor. The second outbreak, in uKhahlamba District in 2008, involved the contamination of drinking water with E. coli following the breakdown of the local wastewater treatment plant. The outbreak was reported to have led to the death of 78 infants.

In 2014, following violent protests against municipal failure to fix broken sewage pipes at Bloemhof, an E. Coli outbreak led to the widely reported infection of over 200 people and the deaths of at least three babies (some reports state the number as high as 18). The same year national media reported on the death of more than eleven infants at Biesiesvlei, close to Sannieshof, due to diarrhoea linked to contaminated water from failing sewage infrastructure. At the time of writing, investigations were continuing to determine the source of a cholera outbreak in Hammanskraal, in May, which killed at least 22 people.

Source: The South African Health Review, 2016, published by the Health Systems Trust

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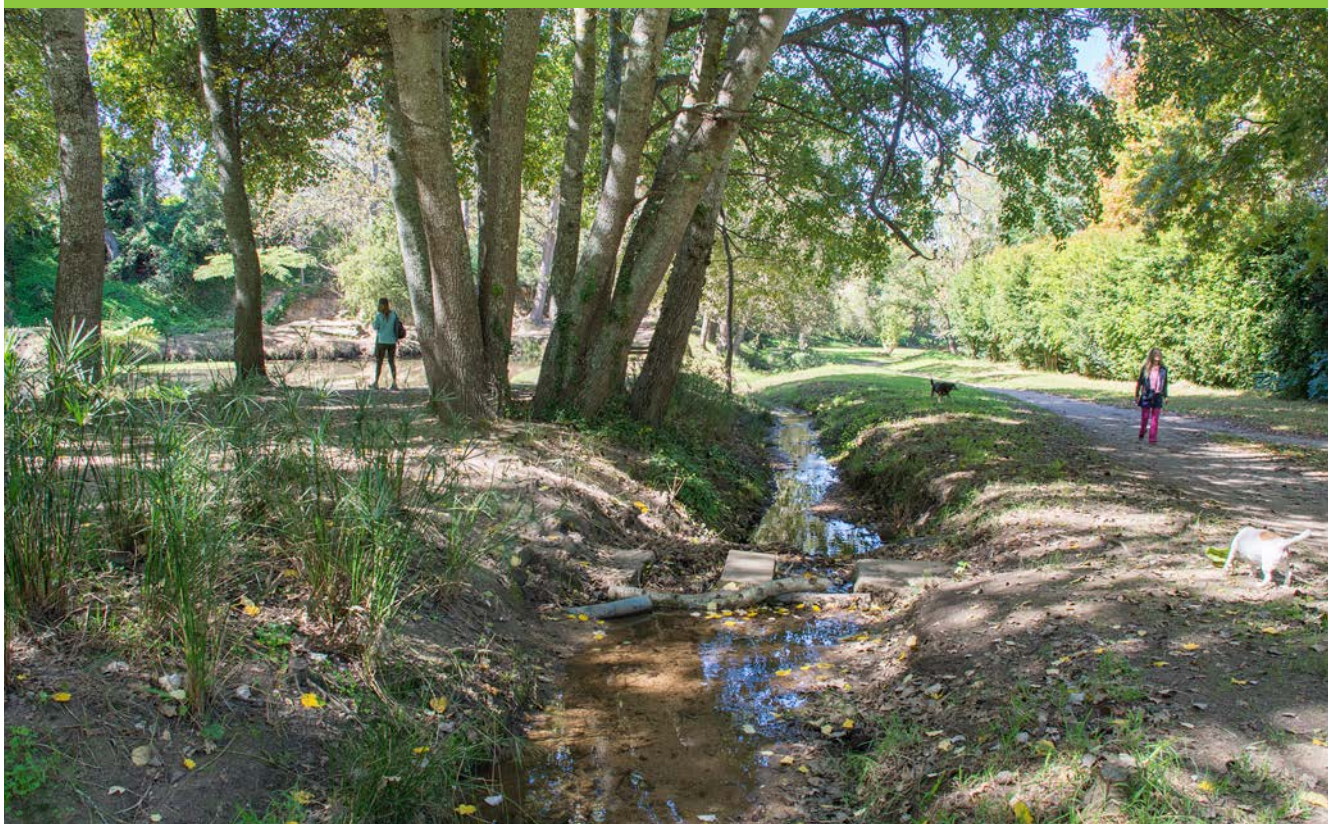
URBAN WATER MANAGEMENT

Restoring the ecological health of Cape Town's waterways – one vlei at a time

The City of Cape Town is taking great strides to improve waterway health and amenity value. Sue Matthews reports.

Sue Matthews



The year 2021 was an ***annus horribilis*** for Cape Town's three large waterbodies – Zandvlei, Zeekoevlei and Rietvlei – with all being closed to recreation for many months due to high levels of faecal contamination. The problems were variously attributed to upstream sewage spills caused by pump station failures and sewer line blockages, stormwater ingress into sewage systems during heavy rains, the theft of one manhole cover and the damage of another, and the malfunction of a screw pump at the inlet of the Cape Flats Wastewater Works (WWTW) near Zeekoevlei.

The closure of the vleis and the multitude of contributory factors focused public and political attention on sanitation issues and the environmental impact of sewage pollution. On his first day in office on 19 November 2021, Cape Town's Mayor, Geordin Hill-Lewis, visited some low-income, high-density areas that had been particularly affected by sewage spills, and asked officials to provide short-term solutions. He also commented on the need to clean up the city's waterways, which include rivers, vleis and estuaries as well as the earthen channels, concrete canals and retention ponds of the stormwater system.

Just 10 days later the City of Cape Town (CoCT) announced that its Water and Sanitation Department had produced a Sewer Spill Reduction Plan, targeting a 50% reduction in spills by 2030, and by April 2022 the more comprehensive Mayoral

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Priority Programme for Sanitation and Inland Water Quality was underway. Admittedly, many of the components were already embedded in other plans and programmes developed by the CoCT in response to the commitments made in its Water Strategy, finalised in February 2020, to improve access to safe water and sanitation and to transition to a water-sensitive city by 2040.

Nevertheless, the Mayor has put his money where his mouth is, as it were. The CoCT Budget of 2022/23 got the ball rolling, but the draft Budget for 2023/24 – tabled for comment at the end of March – ramps up spending on water and sanitation significantly. In his 'Building hope' Budget Speech, the Mayor reported that R11 million had been earmarked for more rapid-response sewer spill teams, R16 million for sewer pump station response teams, and R31 million for extra cleaning of drains and flooding prevention. But it is the infrastructure budget that will undoubtedly have the greatest impact, with expenditure set to increase sharply in the medium term to mid-2026.

"Of all the ways to spend a city's revenue, investment in water and sanitation infrastructure is arguably the most crucial," said the Mayor. "Our water and sanitation capital budget for this current financial year is R2,3 billion. By 2025 it will be R7,8 billion. That means water and sanitation's budget in 2025 will be bigger than our entire capital budget this year. This scale of investment will allow us to do the kind of critical infrastructure work that no other city in the country is doing."

He added that this will include a 330% increase in sewer pump station upgrades over the next three years, an R8,6 billion capital expenditure on WWTW upgrades, and another R1,4 billion for bulk sewer upgrades to the Milnerton, Cape Flats, Gordon's Bay and Phillipi sewer mains.

Ageing sewer pipes also need to be replaced, of course, to prevent leakages. In the decade up to mid-2022, the CoCT replaced just over 235 km of sewer pipes, with the annual target set at between 25 km and 28 km per year according to the approved budget. A year ago, the target was increased from 26 km to 50 km, but for the 2024/25 financial year this will double again to 100 km, budgeted at R300 million. The target for proactive jet-cleaning of sewer pipes has likewise been bumped up from 100 km to 200 km annually. By removing blockages caused by sand, roots, litter and illegally dumped foreign objects, jet-cleaning helps prevent sewage spills during winter, when stormwater ingress typically increases sewer flows significantly. If overflows occur, they not only cause a health hazard and added misery to residents already affected by flooding, but all too often they discharge directly into rivers and stormwater canals, severely affecting water quality downstream.

This brings us back to the vleis, but the budget addresses a lot more than sewage pollution – it accommodates a range of interventions aimed at restoring the vleis' ecological health. At Zandvlei, the estuary mouth at Muizenberg beach is bulldozed open and closed periodically, with the sometimes competing objectives of preventing flooding and erosion of waterfront properties, keeping water levels deep enough for canoeing and dinghy-sailing, maintaining salinity levels within an optimal range for estuarine plants and animals, facilitating the estuary's role as a nursery area for marine fish migrants, and flushing out excess nutrients. A study has been underway to explore rehabilitation options for the concrete outlet canal and a rubble weir at the estuary mouth, and to update the mouth management plan accordingly. The construction work, at a cost of more than R6,7 million, is scheduled in the Medium-Term Revenue & Expenditure Framework for budget year 2025/26.

The water level at Zeekoevlei, where recreational activities include waterskiing, rowing, dinghy sailing and kitesurfing, is manipulated via a weir with sluice gates. An annual 'drawdown' is conducted in autumn, when the sluice gates are opened and much of the water drains out. The lower water levels allow for reed control, litter removal and other maintenance activities, while early winter rains flush the system. After about two months, the sluice gates are closed again and the vlei soon refills. During 2022, a remediation plan for Zeekoevlei was developed, and it has been decided that the weir should be lowered to allow greater flushing. A fish ladder will be installed at the same time, and the entire project has been budgeted at R49,2 million, with the construction work set to take place in 2025/26.

At Rietvlei, the Bayside Canal will be upgraded over the next three years at a budgeted cost of R68 million. This is the main stormwater canal draining Table View and Parklands, and rapid development in those areas means that the canal's capacity needs to be increased to reduce flooding, which can affect sewer lines and pump stations. The project includes the construction of treatment ponds to improve the quality of stormwater before it enters the vlei, as well as measures to trap sediment and litter. A mechanical weed harvester will also be bought in the coming

Sue Matthews

Public engagement sessions allowed local communities to give input on draft concept designs for the Liveable Urban Waterways Programme.

Sue Matthews

This image from 2019 shows broken 'nightsoil' bags and other waste at a stormwater outlet that discharges into Milnerton Lagoon. The City of Cape Town's Water and Sanitation Directorate installed a larger litter trap in March 2022, and in November created a sandbag barrier to dam up the polluted stormwater, which is then pumped into the sewer line and conveyed to Potsdam WWTW. Litter traps are being installed in stormwater channels upstream, and a low-flow diversion of stormwater into the sewage system is being investigated.

financial year at a cost of R17 million to control pondweed in the vlei's boat-launching areas, where it creates a nuisance. Specialist consultants appointed to advise the CoCT on possible remediation options for Rietvlei have recommended that sustainable harvesting of pondweed and certain other aquatic plants will help remove nutrients, particularly phosphorus, from the system. They advised against dredging the vlei at this point, given the expense and the ecological disturbance it typically causes, because sediment build-up is largely contained within the two deep basins that were excavated in the 1970s to provide sandfill for Table Bay Harbour extensions.

The other vleis, as well as Milnerton Lagoon, will likely be dredged in the next few years, providing environmental authorisation is granted. The dredging will not only remove accumulated sediments and organic material – together with their pollutants and nutrients – but also allow greater tidal exchange in the case of Zandvlei and Milnerton Lagoon.

Like Rietvlei, which is essentially the estuarine floodplain, the lagoon is part of the Diep River estuary, but much of its freshwater input is in the form of final effluent from the Potsdam WWTW and stormwater from adjacent suburbs. The lagoon has long been plagued by water quality issues, with faecal pollution emanating from an informal settlement and from backyard dwellers disposing of 'nightsoil' in stormwater canals, pump station failures often attributed to loadshedding and misuse of the sewage system, and sometimes sub-standard sewage treatment. The CoCT has implemented a range of interventions in response, including remedial measures at Potsdam WWTW, pending the start of its R5 billion upgrade. Two contracts for the construction work are set to be signed in May 2023, and will see the works' capacity increased from 47 Ml/d to 100 Ml/d, as well as the installation of advanced membrane treatment technology to ensure the final effluent is of a high standard. Any improvements can't come soon enough for members of the Milnerton Canoe Club and residents of the Woodbridge Island security estate on the lagoon's shore, as they have borne the brunt of foul odours and health risks from contact with the polluted water for many years now.

It's not only large waterbodies that have recreational value, though, and the CoCT recognises this in its Water Strategy. Specifically, the commitment to become a water-sensitive city mentions making optimal use of urban waterways for recreational opportunities. A Liveable Urban Waterways (LUW) Programme has been developed to rehabilitate waterways using water-sensitive design approaches and nature-based solutions for multiple social and environmental benefits, with the pilot phase focusing on the Sand River catchment's tributaries, which ultimately flow into Zandvlei. A series of public engagements were held in the latter half of 2022, firstly to introduce the programme and pilot projects, then to allow interested and affected parties to participate in co-design workshops, and finally to present the concept designs.

At the initial meeting in July, LUW Programme Lead Andrew McDonald explained that projects would be limited to small

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Sue Matthews

Shop assistants from the Blue Route Mall use this grassy area alongside a drainage channel during their lunch breaks, but it will be upgraded with paths and picnic tables. A low-flow wetland with rip-rap sections will be created in the channel, and the embankment will be reshaped and revegetated.

nodes along five river reaches within the catchment, but the intention was to learn from them and then hopefully scale up to other catchments within the city. As he pointed out, the Sand catchment has a number of greenbelts that are well-used by communities, allowing people to connect with each other and the waterways.

Those greenbelts, located in leafy parts of Constantia, Tokai and Kirstenhof, already have a mix of formal gravel pathways, well-trodden tracks and dirt access roads. It's unlikely that long-time users – or the many more people who only 'discovered' the greenbelts during the work-from-home period of the COVID pandemic – would welcome too many changes, other than fixing broken bridges and remedying paths that get muddy in winter. The concept designs presented at the final engagement sessions in November reveal that project work there would primarily be in the watercourses themselves, involving reshaping of riverbanks, planting indigenous riparian species, rehabilitating wetland areas, constructing gabion- or natural stone weirs, and installing stormwater swales and sediment traps.

The other projects do some of that and more, because they're at sites offering potential for improvement in terms of creating attractive public places for the enjoyment of communities. Along the Keyser River, for example, there are two sites – one behind the Blue Route Mall and the other in an industrial area – and the concept designs include recreational nodes where shop assistants and factory workers can relax during lunch breaks. The upper Westlake River flows between a low-cost housing suburb and Pollsmoor Prison, and here the concept is to improve the walkway and pedestrian bridge granting access around an extensive reedbed to the nearby shopping centre, to provide a picnic site, lawn, playpark, biodiversity garden, outdoor classroom and sports facility, and to rehabilitate the river and wetland. At the confluence of the Sand and Langevlei canals, a wetland will be created for the treatment of stormwater before it enters Zandvlei, and litter grids and sediment traps installed, but the surrounding area will also be landscaped to increase its amenity value and encourage local residents to make use of this green open space.

In December, McDonald issued a progress update in which he noted that a multidisciplinary team of consultants had undertaken various specialist studies and produced a number of reports to provide the fundamental body of knowledge for the concept designs, which were also informed by the outcomes of the co-design workshops. He explained that the CoCT team would need to complete a number of internal processes to get the concept designs approved and budgets released.

"This will be followed by detailed design and, importantly, applications to the National and Provincial government for water use, environmental and heritage authorisation. Running in parallel to this we will procure the necessary contractors who will join our team during the construction and landscaping phase of the projects," he wrote.

"Once we have obtained authorisations and appointed the contractors, we will commence with the on-the-ground work – if all goes to schedule, we hope this will be in late 2024."

Sue Matthews

Sedimentation in the lower reaches of Zandvlei inhibits tidal exchange when the mouth is opened. The City of Cape Town has budgeted R265 million over the next three years for the dredging of vleis.

GoogleEarth

Houses have their backs to the waterway at the confluence of the Sand and Langevlei Canals, but the intention is to transform this neglected open space into an area that surrounding residents would want to visit. Sections of canal will be broken open and a wetland created to treat stormwater before it enters Zandvlei.

RESEARCH AND INNOVATION

Study busts the barriers to implementation of water innovation

Innovation may be our best hope for meeting the need for better, cheaper and greener water and sanitation. So what's slowing it down and who should be chivvied along? Matthew Hattingh reports.

When drought strikes again, guests at Cape Town's Radisson Blu won't go wanting. A borehole beneath the posh Waterfront hotel supplies an in-house desalination plant which uses a special membrane to produce about 7 000-litres of drinking water an hour.

Also in the Mother City, University of Cape Town (UCT) engineering students have come up with a 'biobrick'. It is made in part from human urine employing a method said to be similar to how nature forms seashells. Meanwhile in Howick, designers have developed the Arumloo, a toilet inspired in form and function, we are told, by the beautiful, indigenous arum lily. It combines an effective vortex with a patented trap to provide a clean flush from a miserly 2-litres or less of mains- or grey-water.

These are just a few of the many good ideas already in service or under development in South Africa. They represent beacons of hope in what might otherwise be a gloomy landscape – the country's water, sanitation and hygiene sector. Consider this: Unless things change in the sector, and sharpish, most of you reading this (in 2023) will be ***stokoud*** or worse by the time all our countrymen enjoy decent toilets, basic hygiene and a ready supply of clean water. At the current pedestrian pace of progress, South Africans can only hope to achieve universal access to these services "some time after 2050", according to United Nations agency UNICEF.

Our existing waste and water systems are increasingly decrepit. Potable water leaks away in vast quantities. Sewage gushes untreated into rivers or seeps into the groundwater. According

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to the Department of Water and Sanitation, more than half the country's 1 150 wastewater treatment works aren't up to snuff. And 44% of water treatment works are in a poor or critical condition. Meanwhile, the money and know-how needed to fix things is in short supply.

A 2018 department report reckoned at least R90-billion would have to be spent every year for the next decade to break the back of the maintenance backlog and to sort out other water and sanitation priorities. To put these figures into perspective, bear in mind the department's combined budget for 2023/24 totals about R37-billion. And these big bills are before we even consider the likely consequences and costs of dealing with climate change. Add to this, the migration of people from the countryside to cities and towns, and the reality that South Africa is a water-scarce country.

Which is why a September 2022 Water Research Commission (WRC) report warns that "more of the same… infrastructure, practices and processes" won't not cut it. Instead, it calls on us to find and put into place significantly better, cheaper and more green-friendly solutions.

Of course, this is easier said than done, and ***Understanding the policy and regulatory barriers for water and sanitation research development and innovation implementation in South Africa*** (**WRC Report No. 3031/1/22**) sets out to explain why.

It's a big topic dealing with a fragmented sector and the report takes a necessarily wide view as it draws on the results of a questionnaire-survey, interviews with innovators, and a review of hundreds of innovations. It notes that our water treatment and wastewater plants and the extensive networks linking them to our homes – and back to our rivers – have traditionally required big spending so had to be built for the long haul. Planning and financing such centralised systems does not encourage the rapid rollout of new technology, even as 'disruptive innovations' hold the promise of solutions to the development-financing difficulties facing our country.

The report included a detailed survey of the health, environmental and water laws; the laws that regulate local government; and the laws that put strictures on how municipalities may raise finance and how they may spend that money. We are reminded these laws are frequently not in concert. And the authors explained how even policies expressly intended to spur innovation can end up reigning it in.

"National acts and legislation have the tendency to encourage bureaucracy to minimise risk. Bureaucratic government structures aim for precision, reliability and efficiency, therefore pressing for officials to be methodical, prudent and disciplined to attain conformity. Innovation is often the opposite of conformity," the report observed.

Ashraf Hendricks / Groundup

Drilling emergency boreholes in Cape Town in 2018. Emergency situations, such as Cape Town's recent 'Day Zero' scare, can make government authorities more open to implementing research, development and innovation but it is not the ideal way to spark progress.

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The authors quoted Nico Steytler, a local government law expert, who believes a plethora of policy and legislation could be suffocating or overregulating municipalities. "The long-windedness and minute detail contained in a number of pieces of legislation leave little room for innovation, experimentation, local responsiveness and discretion," he writes. What's more, "The 'one-size-fits-all' approach, which underlies all local government legislation, means the same set of rules regarding institutional structures, administrative and financial duties and processes apply, irrespective of the resources (human, financial, etc) available within the municipality."

None of which is to suggest the report's authors – Melanie Wilkinson, Louiza Duncker and Thandokazi Kolisi, of consultancy Sustento Development Services – favoured the wholesale scrapping of regulations and policies. Rather, they recommend review, revision and reform. And they would like to see the sector cultivate a bigger appetite for risk. "There is no innovation without failure," as they observe.

In a telephone interview from her East London home-office, Wilkinson told ***The Water Wheel*** that a government-backed review should extend to strategy. It should look at how the government, working within the existing frameworks, might better support those things that make innovation possible. And by innovation, Wilkinson had more in mind than "widgets" – toilets that flush frugally, for example. While such things must be pursued, innovation was equally about finding better systems and processes, including innovative environmental policies and financing models, she said.

Crucially it was also about marketing and other tools to take us beyond research and development to "deployment/diffusion, localisation and socialisation". Which is to say, the demanding and often overlooked business of getting innovations to users and finding ways to make them appealing, or at least more acceptable.

It was assumed that designers and developers should be taking their innovations to market. "However, experience has shown that very different skill sets are required for each stage in the water, sanitation and hygiene innovation value chain."

We will return to the value chain concept and notions of a 'circular economy' later, but first, let's consider a few things that can make innovations a tough sell. The 'yuck factor' was one of the reasons the market may be unwilling or not ready to adopt disruptive innovations "which require capture, treatment, recycling and reuse of wastewater, faecal sludge, faeces or urine". National standards, including those of the South African Bureau of Standards (SABS), were another bugbear.

The report noted that national water and sanitation norms and standards, while recognising the importance of water conservation, recycling and environmental practices, insisted on reliable and repeatable services. This led to a "reluctance to try new and relatively untried ideas". Similarly, the national building regulations and codes, as published by SABS, promoted unity – but "innovation and unity do not necessarily go together".

But if the existing, stultifying standards were giving some innovators a headache, then the total absence of standards for a lot of new or newish technology was the stuff of migraines for others, denying them market access. "It's one of the biggest challenges," said Wilkinson, "we need to adapt to South African conditions," she said, mentioning that in the hygiene sector standards for menstrual products were adopted only a few years ago. "One of the requirements is if a product is given to the community it needs to be SABS approved."

The report noted that health and safety regulations sometimes conflicted with water, sanitation and hygiene goals. And it quoted from the international literature, which listed "concerns about public health and possible risks associated with adopting new technologies with limited records" as among the primary barriers to innovation in the water sector.

Another barrier was "unrealistically low water pricing rates". In percentage terms, South Africans were the least likely of all Southern and East African urban consumers to have water meters, the report said, quoting a 2019 UNICEF paper. Although those South Africans who do have meters pay higher tariffs than their counterparts in all but one of the countries surveyed, this remained insufficient to recover the cost of the service.

"Poor pricing, poor billing, and poor payment by consumers together with the increasing cost for the operation and maintenance…have led to financial instability in South Africa's water, sanitation and hygiene value chains," the authors said. This instability made it harder for water service providers and authorities to adopt innovations.

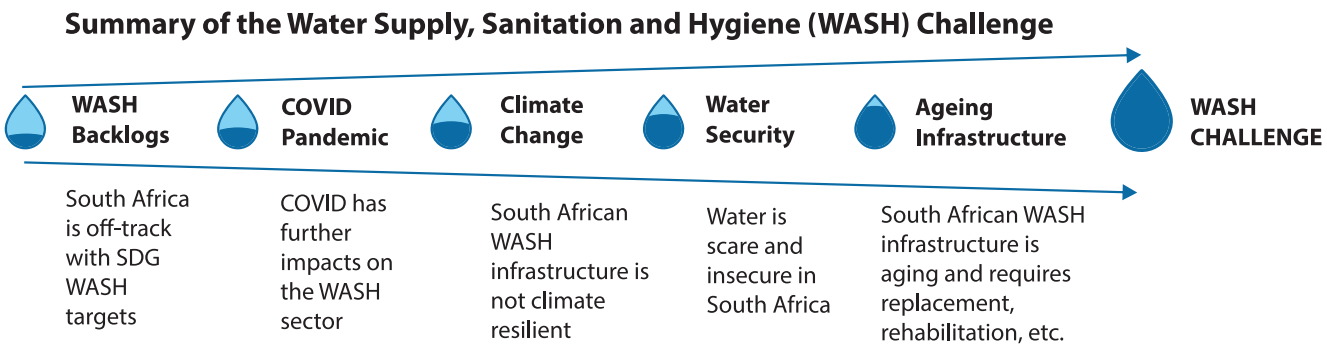

Figure 1. Why innovation is important – the WASH challenge.

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"The long-windedness and minute detail contained in a number of pieces of legislation leave little room for innovation, experimentation, local responsiveness and discretion."

Let's return to the value chain, we touched on earlier. The authors use the concept, which has its origins in management science, to describe the succession of activities that take water and waste, from one 'pillar' to the next on its journey to and from consumers. A value chain links a water source to the conveyance pillar, which might be in the form of a bulk network and include piping, pumps and storage. Thereafter the water reaches the treatment pillar, followed by the distribution pillar and then on to the end-user pillar – households and industry. Wastewater distribution is next, followed by treatment and disposal, and ideally, reuse.

Reuse, recycling, replenishing resources and keeping waste to a minimum, the authors said, were vital if we were to achieve economic growth while protecting the natural environment and ensuring the wellbeing of future generations. Water and waste value chains needn't be 'linear' – taking water from source to disposal. Innovation could reforge the chains to form part of a 'circular economy', wherein "the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised".

The authors tallied 314 innovations along the different water, waste and hygiene value chains they surveyed. But while they found an abundance of innovation, it was neither balanced, nor coordinated. A "crowding" of innovation was observed at some points and pillars. There were a "significant number of water saving/reduction innovations… such as low-flow taps and shower heads and the innovations in low-flush sanitation". But serious gaps in innovation were identified at other points, particularly at the intermediate pillars, including conveyance, water treatment, distribution to the user, distribution from the user and wastewater treatment.

More innovations were needed in green pumping and piping systems; real-time leak detection and monitoring; low-energy and natural chemical use in wastewater treatment; and recycling of treated faecal sludge from municipal facilities. There were also many unrealised opportunities for innovation in materials.

All in all, it's a daunting to-do list. But happily, Wilkinson sees hope. She pointed to rapid changes in hygiene practice and near universal introduction of hand sanitiser sparked by the Covid-19 pandemic. She cited too the big, rapid water-saving strides made in Cape Town as "Day Zero" loomed during the 2017/18 drought.

She was excited by the range of innovations her team encountered and the new technologies emerging. These included "closed loop" and "off-grid" solutions like the all-in-one water treatment plants pressed into service in the wake of last year's KwaZulu-Natal floods. "Next generation innovations could fundamentally change the manner in which basic water services are provided in the country in that in-situ treatment, reuse and recycling innovations could shift the role of local government in provision of water services and impact on their regulatory role and financial status," the report noted.

In a sense, technology may rewrite the ground rules, even as rules, regulations and policy directed technology. Among its recommendations, the report called on the government to support a review of policies and regulations. It wanted more support for innovation; better monitoring of innovations; the deployment of new and existing financing tools; and a more zealous enforcement of tariffs.

The country's procurement policies would need a thorough wash and clean too.

As Steytler, the law expert, said in the report: "There is a balance to be struck between letting the flowers of local initiative and innovation bloom, and preventing the weeds of mismanagement, incompetence and corruption from taking over the flower beds."

We need more arum lilies.
To download the final report, Visit: https://bit.ly/3oJ7WuO

HYDROLOGY AND CLIMATE CHANGE

Researchers focus on hydrological models to understand potential climate risks and vulnerability

Using a systematic approach to improve hydrological modelling of anthropogenic and climate change impacts in at-risk catchments has improved our understanding of climate risks and vulnerabilities in our region. The Water Wheel highlights some of the latest research in this field and how related findings can help inform water management and adaptation responses. Article by Jorisna Bonthuys.

Over the last decade, the severe impacts of droughts have highlighted the vulnerability of water sources in South Africa. Globally, Mediterranean regions such as the Western Cape are considered to be some of the most vulnerable areas to the impacts of climate change, especially in terms of experiencing longer and more severe droughts.

"In future, climate change will have a huge impact on our water resources and how we manage those available resources," says Dr Andrew Watson from Stellenbosch University's School for Climate Studies. He specialises in hydrological and groundwater modelling. Watson and others have been exploring how to improve the hydrological modelling of human impacts on the landscape and climate change impacts in at-risk catchments.

In recent years, there has been significant investment in generating more precise climate projections to provide hydrological model users with future climate scenarios that can be used at local scales. However, hydrological models must also be stress tested under current and recent conditions to ensure their simulations are credible and correctly parameterised.

The researchers have, therefore, focused on this aspect with the rainfall-runoff model JAMS/J2000. This model has been used in Southern Africa through research collaborations between Germany and South Africa. "Over the last seven

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years, our systematic approach provided valuable insights into data requirements, simulated hydrological process variability, factors impacting model uncertainty, and methods to improve hydrological process simulation and model robustness," Watson says.

The researchers considered many factors, including those that impact model uncertainty and performance and influence hydrological process changes. They have also been developing stable isotope-enabled modelling tools which use this novel signal in catchment waters to reveal important changes in hydrological processes.

Solving big problems

Efforts are underway in the School for Climate Studies to build hydrological expertise that can inform appropriate adaptation responses to sustain the ecological goods and benefits from local catchments. Through the Stellenbosch University Water Institute, recent studies have, for instance, explored how irrigated agricultural catchments were affected in the Western Cape by the recent multi-year drought (2015-2018). The researchers use this event to understand how hydrological models can help understand previously opaque groundwater depletion and recharge changes.

Often data scarcity hinders how and where available hydrological models can be employed, undermining the credibility of modelling results, especially in sub-Saharan Africa. "In our recent work, we have been trying to solve two big problems," Watson says. "Firstly, can we get models operating credibly or all our catchments along the western part of southern Africa, and from these, learn about past and future shifts in hydrological processes?

"Secondly, we want to diagnose and reduce model-based uncertainty and error. For example, is uncertainty and error due to the catchment size we are trying to model, due to the influence of upstream dams, or perhaps due to irrigation usage? Being able to account for these and other potentially important factors, such as climate variability, will enhance the value of results."

Watson and others considered whether or not hydrological models have been able to provide insights into the role of climate variability, like 'dry' and 'wet' years, during recent droughts. He says that deliberate monitoring, combined with novel approaches and tools, is vital to reduce uncertainties in hydrological projections.

The role of rainfall-runoff data

The scientists analysed the impact of rainfall as measured at multiple rainfall stations on simulated streamflow and its components in the Berg River catchment. They published their first findings in the ***Journal of Hydrology.*** The results highlighted the importance of good overall data coverage for improved low-and high-flow simulations and identifying critical locations responsible for peak runoff generation processes in these areas.

The availability of rainfall stations in the headwaters of this water-stressed catchment has been critical for simulating peak streamflow, Watson points out. In addition, it has highlighted the need for more high-elevation stations for more accurate flood prediction. In contrast, low-lying stations were more important for simulating low-flow conditions.

The findings also emphasise the need for collaboration between local weather bureaus and farmers, now the most prolific collectors of rainfall data, to improve the model's predictive power (e.g. flood and drought forecasting). Watson foresees that this information will become increasingly important to help identify ecohydrological changes and to develop climate adaptation strategies, particularly in arid and semi-arid regions.

Soil-moisture and drought

The researchers have also considered how this hydrological model could help detect droughts and employed the soil-moisture deficit index (SMDI) to evaluate indicators of agricultural drought. They focused on how this index can indicate seasonal change that would be relevant for planners and even for informing early warning responses. The researchers did this by zooming in on the most significant droughts of the last three decades, trying to determine how this event affected such indicators in the Berg River catchment.

By combining SMDI with the J2000 model, they could detect crucial drought onset triggers and tipping points regarding water use behaviour their findings show. "Like the climatologists, we found that pre-wet season [rainfall] shortfalls in March, April and May are the most dangerous and usually result in much longer dry conditions," Watson says. "But when we experience drought, we get reduced model performance.

"We have also seen an increasing trend in the drier summer months of December, January and February. A drought in March, April and May is also very significant because this impacts the runoff generation in the wet season quite substantially."

In 2015 and 2017, headwater areas were affected for the first time over the 35-year simulation, apparently due to the drought-induced decline of groundwater in this catchment. This showed the importance of detecting headwater drought as an indicator of water stress and drought severity, Watson points out. He says these and other findings provide a reference scale for recent droughts in Mediterranean climates, such as ongoing dry conditions in central Chile and California. "As climate change takes hold in many Mediterranean areas, the early identification of more severe forms of drought is crucial in forming effective strategies to manage centralised water supply systems."

The results also underline how the use of groundwater can exacerbate drought effects. "Future droughts will likely be characterised by headwater stress in this catchment, requiring widespread groundwater use to curb agricultural losses. This can reduce agricultural profit margins, increase competition, and drive conflict over water use allocation."

These issues have already surfaced in the drier margins of the Western Cape (such as the Verlorenvlei region). The researchers warned against the overuse of groundwater during droughts. "Even though significant aquifers are present, any over-use by the agricultural industry of groundwater poses a long-term threat to water security and adds additional stresses to the

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Mediterranean regions such as the Western Cape are considered to be some of the most vulnerable areas to the impacts of climate change.

natural ecosystem," the report states.

Using groundwater during dry periods could fuel the progression of meteorological and agricultural droughts to more severe long-term forms (hydrological and groundwater droughts). "While groundwater provides a cost-effective solution to bridge the gap between dry and wet periods, its resilience in the Western Cape still requires further investigation, particularly if it will be used to meet the agricultural and domestic requirements during droughts," the article states.

A multi-catchment approach

In addition, the scientists have used a multi-catchment analysis to determine what causes hydrological modelling uncertainty in different kind of catchments. They used this approach for the Verlorenvlei, Berg, Eerste, Breede and Bot River catchments.

These five adjacent catchments are important from an ecological and water provision point of view and support key agricultural sectors. In addition, reservoirs in the Berg and Breede catchment account for 58% of the total surface water supply for the City of Cape Town, including big dams like the Theewaterskloof Dam.

In 2022, the researchers involved published their findings on hydrological variability in the journal ***Sustainability.*** Watson says a multi-catchment approach [to modelling] can help determine factors which impact model uncertainty in the province. "It helps us understand variability across catchments in terms of hydrological processes and how that impacts water management."

The large catchments had an overall surface runoff, interflow and baseflow contribution of 44%, 19% and 37% respectively, and lower overall uncertainty in terms of this model. Surface runoff was determined as the most significant for hydrological flow, with 44% of the total, followed by baseflow, with 37%.

"A key point in our modelling was that groundwater significantly contributed to water resilience during the recent multi-year drought. This becomes very relevant, seeing that Western Cape is going to use augmented groundwater as one of its main drought relief strategies. Should we be doing that? Groundwater is seen as a huge baseload contributor to the bulk water supply. Yet groundwater and the ecological reserve are important to maintain, especially during dry seasons. This topic is also important given how much effluent wastewater treatment works supply to our major river systems."

As severe agricultural droughts threaten water resources and supplies in this province and elsewhere, new scientific tools and decision support systems are needed to create a more robust water supply system. Hydrological and groundwater drought onsets are easier to detect and identify with detailed hydroclimatic monitoring infrastructure such as weirs and groundwater level monitoring.

This means that only after a meteorological drought has passed can its effects be understood and the onset of different drought forms identified. Similarly, water use behavioural changes and groundwater abstraction can mask a hydrological and groundwater drought. Watson says more research about abrupt increases in water use (over days and months) and slow recharge (sometimes over years) is needed. Researchers also need to understand the increased groundwater consumption and be able to quantify these amounts if future hydrological model predictions are to be of management value.

Climate extremes and modelling

The Western Cape has been subject to more frequent meteorological droughts in recent years. During the multi-year drought, its overall reservoir levels dropped to 17%. In addition, signs of hydrological change, including abrupt changes to groundwater levels, were detected. Rainfall–runoff modelling was, however, unable to represent these conditions. This prompted researchers working on hydrological models and their uses to examine the driving forces that reduce model performance during dry years.

In 2022, Watson and his co-authors published findings in ***Frontiers*** on how climate extremes influence conceptual rainfall-runoff model performance and uncertainty, using the Berg River catchment as a focus area. They assessed model-related performance and uncertainty under extreme climate conditions, referred to as 'wet' and 'dry' periods assess agricultural droughts between 1984 and 2018.

The researchers employed soil moisture deficit index (SMDI) values to assess the severity, duration and scale of the recent multi-year drought compared to the other dry periods within the 35 years simulated. Watson says the JAMS/J2000 model provides a good simulation for periods where the yearly long-term mean precipitation shortfall was less than 28%. Above this threshold, and where autumn rainfall was reduced by 50%, the researchers recommend using a set of 'dry' parameters to improve model performance.

Applications of drought-related indices suggest that rainfall in March, April and May has been the main period of meteorological shortfalls during recent droughts in the province, with reductions of between 50% and 70%. 'Dry' modelling parameters also better account for changes in streamflow and reduced peak flows, which occur in drier winter years. However, the availability of climate data was still a potential factor.

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Although long-term simulations are needed for climate change predictions, the researchers recommend switching between 'dry' and long-term simulations for future model applications. "The results show planners should consider 'wet' and 'dry' periods and not only calibrate their rainfall-runoff models under relatively common normal conditions," Watson says. "This is needed to avoid maladaptive responses to climate change."

Isotope-enabled hydrology

Efforts are underway to determine if validating simulated hydrological processes with isotopes could provide a better hydrological model (making it more robust to climate variability). "Isotopes are exceptionally good at telling us what processes water has undergone as well as where and how our water is moving in a catchment," Watson says. "Whether streamflow is dominated by surface runoff or not, the water that is stored in the soil or from our aquifers can be tracked with isotopes.

"In recent studies, we used end-member-mixing analysis to confirm and validate some of the hydrological processes our model is telling us about in our catchments." This approach helps identify and quantify the dominant runoff-producing water sources.

Watson's current focus is on developing isotope-enabled models and exploring the application of these and other hydrological models in the region. "We identified a more robust model parameter set, and with the available data, it should be better suited to simulate change."

Using isotopes enables researchers to track water through an entire column of soil into an aquifer and water movement through different river systems. "We analyse the isotope composition of hydrogen and oxygen of rainfall, groundwater and river water (δ^2H and $\delta^{18}O$)," he says. "These isotopes tell us what processes the water has been subject to [such as the evaporation rate], and the mixing proportions tell us something about the main source of the water [groundwater, surface runoff, soil-water]."

Watson was also involved in a larger study where scientists dated water in the different Western Cape aquifer systems and identified which aquifers are actively recharged. He believes using isotopes to validate simulations can help reduce model uncertainties and improve the application of modelling tools.

"We are developing a new novel hydrological model," he says. "It will be one of the first which does not require extensive programming skills to run and be relevant for different processes and climate types." This work is done in conjunction with the International Atomic Energy Agency (IAEA), which would like to transfer the approach to countries working on similar problems using isotope techniques.

"The model is at the forefront of understanding hydrological processes in our catchments, how we see evaporation happening, observe changes in soil moisture, and track the different forms of flow coming into our rivers such as interflow, surface runoff and baseflow. We can, for instance, track headwater processes this way. If our headwaters are contributing more or less water than before, we can use isotopes to ensure that the models are simulating this more robustly."

This work is part of two Europe Union Horizon projects, the EU funding programme for research and innovation, and focuses on managed aquifer recharge. "The information generated can help policymakers and people involved in disaster risk management help ensure that our water infrastructure and planning are ready for the changes coming our way."

One of these projects will fund the development of a detailed isotope-enabled model through collaborations with scientists in Germany, Costa Rica, and at the IAEA. "Together, we want to address a major gap in previous models which are difficult to use and often quite site-specific," Watson says. "From our investigations and studies elsewhere, the JAMS/J2000 model can be used for different catchments and environments."

Other investigations are underway related to water, climate, and biodiversity. Watson is, for example, modelling climate risks related to hydrology and biodiversity at UNESCO's world heritage sites in Southern Africa. "We are driving hydrological models with different climate forcings, stochastic weather generators (statistical models that generate possible weather variables) with the University of Cincinnati and Deltares, and making globally available projections.

"After seven years of research, stress testing this hydrological model is as important as the climate inputs, and we are ensuring that the appropriate level of effort is placed in developing robust models," he concludes.

Ashraf Hendricks / Groundup

A dry Berg River Dam during the drought of 2017. Results of a hydrological study in the Berg River catchment highlighted the importance of good overall data coverage for improved low-and high-flow simulations and identifying critical locations responsible for peak runoff generation processes in these areas.

OPINION

Isotope hydrology: An indispensable tool in the hydrogeologist's toolbox

Water Research Commission Research Manager, Yazeed van Wyk, elaborates on the importance of isotope hydrology as part of water resource management.

Every year on 22 March World Water Day is celebrated around the world. This day is designated by the United Nations to focus on the of freshwater and its sustainable management, and provides an opportunity to raise awareness about the global water crises and the need to conserve and protect this vital resource.

According to the United Nations, more than 2 billion people lack access to safe drinking water, and by 2050, up to 5.7 billion people could be living in areas with water scarcity. In Sub-Saharan Africa, for example, an estimated 40% of the population lacks access to basic water services, and more than 300 million people do not have access to improved sanitation facilities. Based on this we are seriously off-track to meet Sustainable Development Goal (SDG) 6: water and sanitation for all by 2030. The use of isotope hydrology is a powerful tool that can help meet Sustainable Development Goal (SDG) 6, which aims to ensure the availability and sustainable management of water and sanitation for all. With this in mind, isotope hydrology is an important approach to achieve this goal. Isotope hydrology is a field of study that uses the natural variations in stable and radioactive isotopes of water to study the movement and behaviour of water in the environment. It can be used to study a variety of hydrological processes, including groundwater recharge, water quality, groundwater/surface interaction, evaporation, and precipitation. It can also be used to understand the behaviour of contaminants and pollutants in the environment, such as the movement of radioactive isotopes or the distribution of contaminants in a river and groundwater systems. Isotope hydrology is thus particularly useful for understanding the water cycle in regions where traditional hydrological methods may be limited.

This information can be used to better understand water resources and develop more effective strategies for managing them. In South Africa and the Southern African Development Community (SADC) region, the use of isotope hydrology is vital in managing and conserving water resources.

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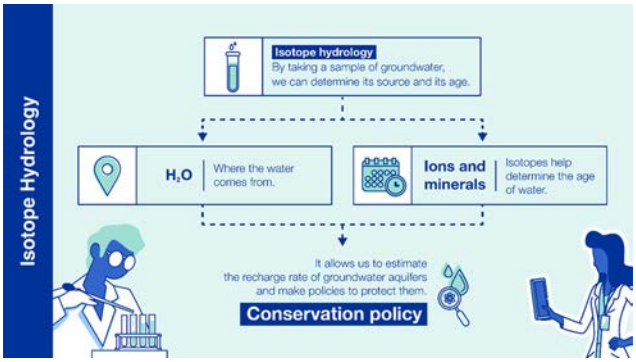
However, the region faces a significant shortage of skilled professionals in isotope hydrology. This shortage has resulted in inadequate monitoring and management of groundwater and surface water resources, which poses a significant threat to the South Africa's socio-economic development. In the late 1970's to early 2000's South Africa had a vibrant and actively engaged community of isotope hydrology practitioners. This has changed dramatically over the years with most researchers having either retired or moved abroad, which has resulted in a "stagnation" of new research ideas. South Africa has also fallen behind other African counterparts in the North (Egypt, Tunisia, and Morocco) in terms of having well equipped Regional Designated Centres (RDCs). These International Atomic Energy Agency funded RDC's are instrumental in building the necessary capacity of member states in a range of areas related to isotope hydrology, nuclear technology, including nuclear safety and security, radiation protection, and nuclear energy. They also provide training and educational programs, as well as access to specialized equipment and expertise.

To address this shortage, there is a need for the development of isotope hydrology skills in South Africa and the rest of the SADC community. This can be achieved through the implementation of training programmes, capacity building initiatives, and research partnerships. Training programmes in isotope hydrology can offer theoretical and practical knowledge to individuals interested in pursuing careers in the field. These programmes can also provide opportunities for current professionals to upgrade their skills and knowledge, ensuring that they are up-to-date with the latest developments and technologies in the field.

Capacity building initiatives, such as mentorship programmes and exchange programmes that has been a hallmark of past practices, can again provide opportunities for individuals to work with experienced professionals and learn from their expertise. These initiatives can also provide opportunities for knowledge-sharing between countries in the SADC region, promoting collaboration and building regional networks. Research partnerships between academic institutions, research organizations, and industry can also promote the development of isotope hydrology skills in the region. These partnerships can provide opportunities for students and professionals to work on research projects, promoting innovation and new technologies in the field.

The development of isotope hydrology skills in South Africa and the SADC region has significant benefits. Effective management and conservation of water resources are critical for the region's socio-economic development, and isotope hydrology plays a vital role in achieving these goals. Moreover, the development of isotope hydrology skills can promote the growth of local industries and job creation. With a skilled workforce, the region can develop new technologies and innovations that can be used to address local water resource management challenges and contribute to the global water resource management field.

The Water Research Commission (WRC) through its groundwater hydrology portfolio has been rebuilding the isotope capacity in South Africa in partnership with the IAEA, Universities, DMRE and the Department of Water and Sanitation. Through the "RAF7021 Enhancing, Planning, Management and Sustainable Utilization of Water Resources (AFRA)"program, where the WRC is the National project counterpart. In addition, the WRC has funded key isotope hydrology projects focusing on the use of stable , carbon , nitrogen, and sulphur isotopes. However, the quality and state of analytical laboratories for analysing these isotopes are in a poor state and suffer from major backlogs as a result of a lack of funding, equipment, and staffing issues. If invested in by local government structures and catchment management agencies, these tools can be used to enhance environmental monitoring of water resources, by discriminating between different forms of anthropogenic stress and potentially identifying critical sources of water resource quality degradation, which then can be targeted for stricter enforcement of water resource protection measures.



A. Vargas/IAEA

Overall, isotope hydrology is an important tool for understanding the movement of water and other substances in the environment and can provide valuable insights into hydrological processes and water resource management. It is by no means the only tool and should be used in combination with other techniques to improve water security. These include remote sensing, hydrogeological models, geochemical modeling, and water quality analysis.

In conclusion, South Africa has a rich history of nuclear research and development, and it has played an important role in global efforts to promote isotope hydrology research. However, in recent years, its participation in the IAEA has been limited, and there has been a lack of investment in developing isotope hydrology capacity. To revitalize South Africa's role in the IAEA and ensure that the country can fully benefit from isotope research initiatives, it is crucial to add additional GNIP stations in key areas and establish a local regional designated centre that can provide training and support to isotope hydrology professionals in the region. This will not only enhance South Africa's capacity to contribute to global research efforts but also strengthen regional cooperation and enhance economic development. With the right investment and support from the government, industry, and international partners, South Africa can once again become a leading player in the isotope hydrology space and help drive efforts towards sustainable water resource management.

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Washing your hands

WATER RESEARCH COMMISSION

Step 1

1

Wet hands
under running water.

Step 2

2

Add soap
to aid cleaning and to kill germs.

Step 3

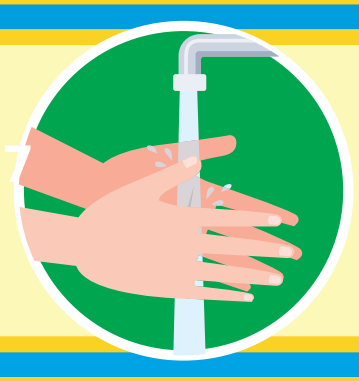
3

Rub well
for at least 15 seconds.

Remeber
Rub the front and back of your hands well and between your fingers

Step 4

4



Rinse well
under warm running water.

Step 5

5

Dry hands
with clean paper towels.

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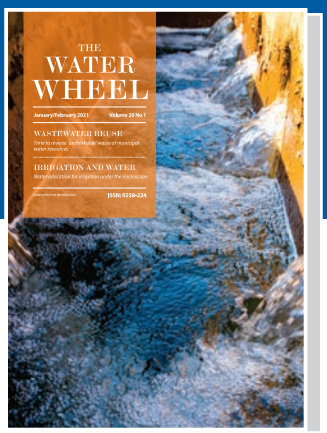
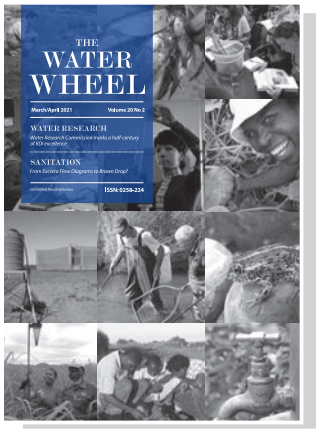
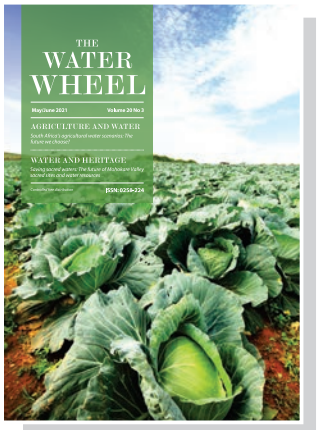
THE WATER WHEEL

SUBSCRIPTION







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

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The Water Wheel

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DEEPLY ROOTED IN SOUTH AFRICA WATER SOCIETY

www.wrc.org.za

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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THE POWER OF KNOWLEDGE TO THE PEOPLE