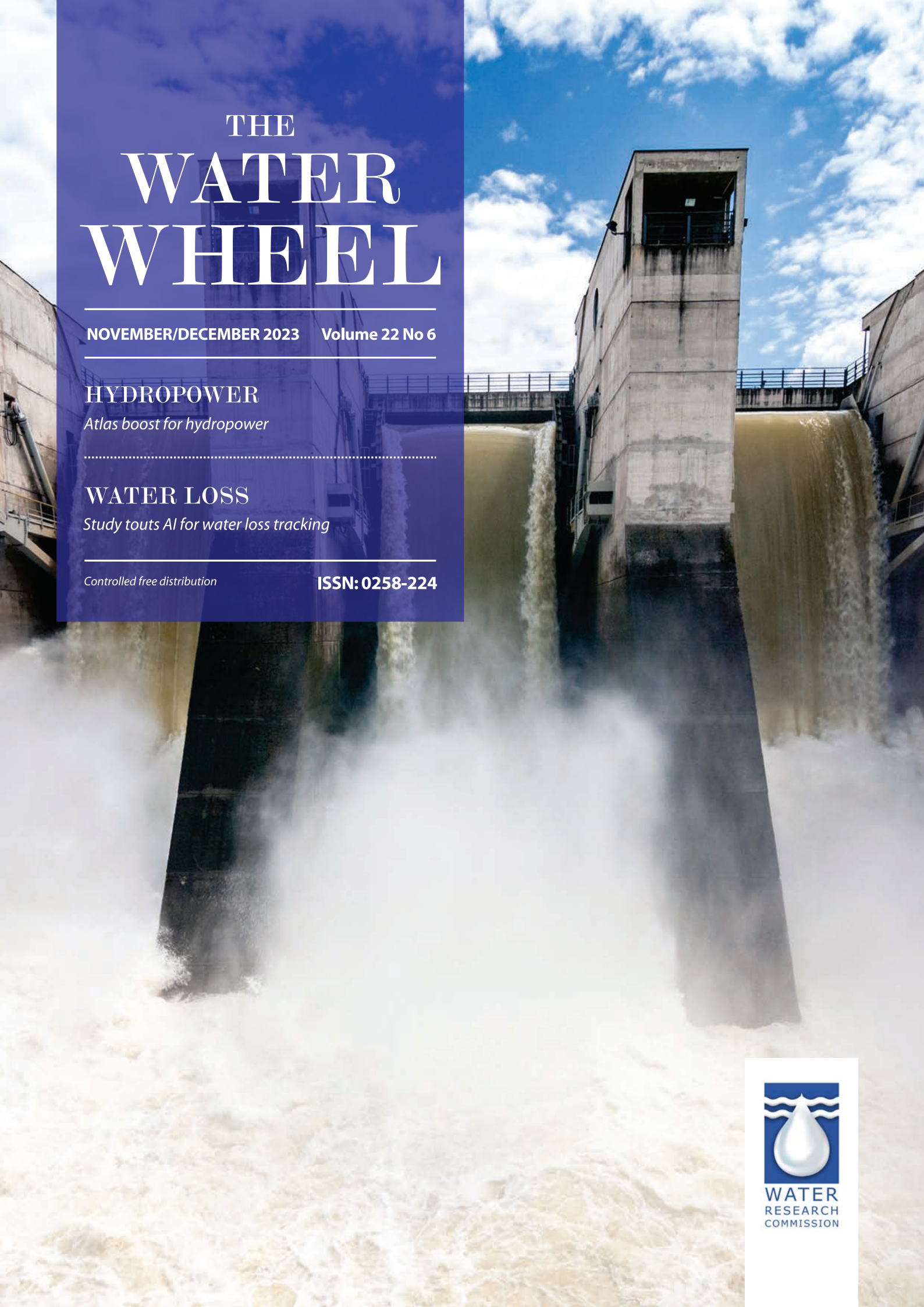

THE WATER WHEEL

NOVEMBER/DECEMBER 2023 Volume 22 No 6

HYDROPOWER

Atlas boost for hydropower

WATER LOSS

Study touts AI for water loss tracking

Controlled free distribution

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WATER RESEARCH COMMISSION

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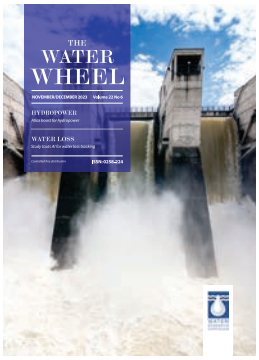

The Water Research Commission (WRC) has funded the development of South Africa's first hydropower atlas. See article on page 12.

NEWS

SA welcomes adoption of new global framework on chemicals

Minister of Forestry, Fisheries and the Environment, Barbara Creecy, welcomed the new Global Framework on Chemicals, a major outcome of the recent 5th Session of the International Conference on Chemical Management, held in Bonn, Germany, in September.

The framework is aimed at benefiting stakeholders in developing countries on the implementation of priority targets to manage chemicals and waste. It provides a vision for a planet free of harm from chemicals and waste, and is operationalised through concrete targets and guidelines for key sectors across the entire lifecycle of chemicals that aim to improve the sound management of chemicals and waste.

The framework calls for, by 2035, a phase out of highly hazardous pesticides in agriculture where the risks have not been managed and safer alternatives are available, and further seeks to strengthen links between the new instrument and climate, biodiversity, human rights and health agendas. It will be financed from contributions from all stakeholders, including the private sector. A dedicated trust fund will be set up and managed by the United Nations Environment Programme

Scientists should play prominent role in water – Deputy Minister

Deputy minister of water and sanitation, David Mahlobo, has urged policymakers to put science at the centre of policy formulations to make informed decisions that will propel the country to greater heights, thus improving the lives of people for the better.

He was speaking at the opening of the 50th Congress of the International Association of Hydrogeologists, which took place in Cape Town from 19 to 22 September.

According to Mahlobo, a country that does not invest in science will perish and South Africa needs to improve on this aspect. "Scientists and engineers need to make their mark and [impact] direct future policy positions of the water sector, particularly the use of groundwater as an alternative measure that will ensure universal access. We need you to guide us and take us to task to come up with policies that will get us into finding lasting and sustainable solutions to the water challenges around the globe," he said.

Mahlobo acknowledged current challenges with regards to assurance of water supply around the country. "Because we have not invested in operations and maintenance, we are experiencing a lot of water losses in our systems, between 30 and 45%. The other challenge is the lack of investment in our infrastructure that matches the population growth and migration from other countries as well as people moving from rural to urban areas."

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South African water specialist announced as next IWA President

South African water expert, Prof Hamanth Kasan has been elected as the next president of the International Water Association.

Prof Kasan was chosen by the IWA Governing Assembly during its meeting on 16 September in Bordeaux, France. He will take office at the end of IWA's World Water Congress & Exhibition taking place in Toronto, Canada, on 11-15 August 2024, when he will succeed the current President, Tom Mollenkopf.

"I am really pleased to have been elected to serve as the next president of IWA. Having been a part of [the organisation] for a great many years, I know well the power and potential of our association as a member-led organisation." Noted Prof Kasan. "I look forward to taking up the role, working with all governing members, board, strategic council, management and staff for us to ensure further development, growth and impact of IWA."

Among his wider professional activities, Prof Kasan has had a 22-year career at Rand Water, where he was a General Manager. He is Honorary Research Professor at the Institute for Water and Wastewater Technology, Durban University of Technology, and a Senior Fellow of the Water Institute of Southern Africa. Prof Kasan has a PhD in microbiology, water and environmental engineering.

IWA President Tom Mollenkopf welcomed the President-elect saying: "It is a great pleasure to welcome Prof Kasan back to the Board of the International Water Association as President-elect, following his election by our global Governing Assembly. Hamanth is well known to the IWA membership, having been active in the water sector internationally and across the African region."

Empowering communities through the law

The Endangered Wildlife Trust (EWT) has launched a new website providing important information in a user-friendly format on the laws that govern land, air, water and species (LAWS) in South Africa.

The new website, www.laws.ewt.org.za, was developed to help non-legal minds decode the complex legal and governance framework relating to the environment in South Africa.

According to the organisation, this complex legal framework is often confusing for the public to navigate. "Access to meaningful information on the environmental legal and governance frameworks in South Africa is key to citizens ensuring that their rights are upheld, and that they are not contributing to illegal activities, and to ensure good governance by promoting transparency around environmental laws and governance."

The website provides access to and summary notes of current legislation, regulations, policy, judgements, and international environmental law. All information on the EWT LAWS website is available in five of the country's official languages: English, Afrikaans, isiZulu, isiXhosa, and Sesotho. It is anticipated that as the website expands, the organisation will include live and recorded webinars and expand the texts to other official languages.

The website was made possible through the support of the Lewis Foundation, the British High Commission and the Embassy of Finland.

WRC Executive Manager comes out tops in director assessment

Water Research Commission Executive Manager for Water Utilisation in Agriculture, Prof Sylvester Mpandeli, recently achieved a top score of 85% in an evaluation undertaken by the Institute of Directors South Africa (IODSA).

Prof Mpandeli was evaluated as a Board Member of the South African Weather Service (SAWS). He is also Chair of the Special Project Committee, which deals with the core business of SAWS.

The evaluation was based on five categories, namely ethical characteristics (covering issues such as integrity, competence and responsibility); personal and social competencies (self-awareness, self-management, social awareness); fiduciary roles and responsibilities (legal obligations, monitoring and evaluation issues); technical competencies (corporate governance and evaluating technical expertise); and contributions at meetings (looking at positive influence, board dynamics and chemistry).

The evaluation was undertaken both by IODSA and fellow Board members. "The results confirm the high level of competency of WRC's senior managers," the organisation said in a statement.

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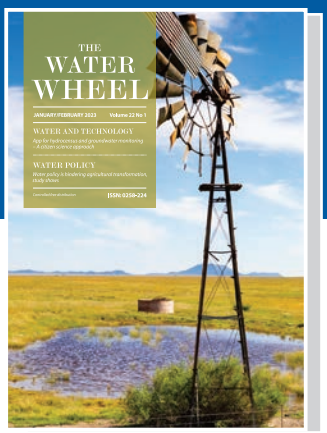

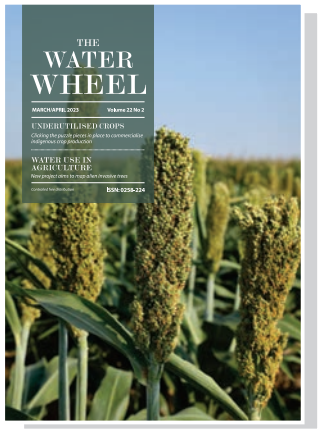

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Water restrictions lifted on parts of Algoa water supply system

The Department of Water and Sanitation has lifted the water restrictions on the Kouga / Loerie sub-system and Groendal sub-system due to improved storage levels in the dams.

Announcing the lifting of water restrictions for some sub-systems within the Algoa Water Supply System in the Eastern Cape in early October, the department said the recent rainfall had brought significant relief from the protracted drought experienced in the Algoa region, with a significant recovery in dam levels experienced. A prime example has been the Kouga Dam, which is spilling for the first time since 2015.

"This catchment is of strategic importance to the western parts of Nelson Mandela Bay Metro, Kouga Local Municipality as well as the agricultural sector in the Gamtoos valley," the department said. At the time of writing, the system's recovery showed that the accumulated storage had reached 70%, with Kouga Dam at 101.42%, Churchill Dam at 100.93%, Groendal Dam at 101%, and Impofu Dam at 24.37%. It was anticipated that the Impofu Dam's levels would also increase due to spilling from the Churchill Dam.

The relaxation of water use was set to contribute to the economic recovery in the domestic, agricultural and industrial sectors in the region, the department noted.

Source: SA news

WATER DIARY

Wetlands
23-26 October
The National Wetlands Indaba will take place at the ATKV Buffelspoort, North West Province with the theme 'It's time for wetland restoration'. The indaba is an annual event intended to provide a platform for a cross-disciplinary gathering of practitioners involved with the conservation and sustainable utilisation of South Africa's wetland resources.
Visit: https://nwi26.org/

Sustainable development
25-27 October
The 24th WaterNet/WARFSA/GWP-SA Symposium will be held in Zanzibar, the United Republic of Tanzania at the Hotel Verde – Azum Resort under the theme 'Accelerating change: Fostering innovation and integration for sustainable resources management for sustainable development in East and Southern Africa.
Visit: https://www.waternetonline.org/annual-symposium/current-theme

Irrigation and drainage
18 November
The 25th International Congress on Irrigation & Drainage will take place in Vizag, Andhra Pradesh, India.
Visit: https://icid25congress.in/

Young water professionals
8-10 November
The 7th Water Institute of Southern Africa (WISA) Young Water Professionals (YWP) conference will take place in Stellenbosch. The conference will provide opportunities for YWPs to learn, build skills and expand their network through oral presentations, poster sessions, workshops and networking opportunities. YWPs will leave with a broad overview of water sector developments and a clear idea of where the water landscape is heading.
Visit: https://wisa.org.za/event/7th-wisa-ywp-conference/

Large dams
15-17 November
The annual conference of the South African National Committee on Large Dams will be held in Gauteng. The conference will offer dam and water resources engineers as well as all contributing to the dam engineering industry importance international, regional and local linkages, networking and exchange of knowledge and experience opportunities. The theme of the conference is 'Dams-a critical resource in present time'.
Visit: https://sancold.org.za/

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GLOBAL

World seeing an upsurge of cholera – WHO

Comprehensive cholera statistics for 2022, published by the World Health Organization in September, shed light on the scale and extent of the ongoing cholera upsurge.

While data for cholera remain inadequate, cases reported to WHO in 2022 were more than double those of 2021. Fourty-four countries reported cases, a 25% increase from the 35 countries that reported cases in 2021.

Not only were there more outbreaks, but the outbreaks were larger. Seven countries – Afghanistan, Cameroon, Democratic Republic of Congo, Malawi, Nigeria, Somalia, Syrian Arab Republic – have each reported over 10 000 suspected and confirmed cases. The larger the outbreak, the harder it typically is to control.

Cholera is an acute intestinal infection that spreads through food and water contaminated with faeces containing the bacterium Vibrio cholerae. It is closely linked to the lack of adequate safe water and sanitation, due to underdevelopment, poverty and conflict. Climate change too is playing a role in this upsurge as extreme climate events such as floods, droughts and cyclones trigger new outbreaks and worsen existing ones.

Current data for 2023 suggest that this global upsurge is continuing. Twenty-four countries are currently reporting active outbreaks, with some countries in the midst of acute crises.

Source: WHO

Free online courses focus on sustainable urban planning

UrbanShift, the Global Environment Facility-funded partnership led by the United Nations Environment Programme (UNEP) and supported by C40 cities, World Resources Institute and ICLEI (Local Governments for Sustainability), has launched a new digital platform to enhance knowledge and understanding around integrated, sustainable urban development.

Developing country cities are projected to triple in size in the next decade, making integrated urban development necessary for both people and planet. As such, UrbanShift City Academy, an online learning platform, was designed to train urban practitioners to rethink existing urban systems and develop integrated processes that contribute to building climate-resilient, nature-positive cities.

"Understanding sustainable urban design is crucial for addressing urban challenges," noted Geordie Colville, Chief of the Energy and Climate Branch at UNEP. "The [academy] equips learners to envision cities as socio-ecosystems, blending built and natural environments with the local economy."

The academy is built around eight free online courses covering topics ranging from climate action planning to sustainable neighbourhood design to circular economy strategies. The courses are available in six languages, including English.

Visit: https://academy.shiftcities.org/

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Rivers contain hidden sinks and sources of microplastics

Significant quantities of microplastic particles are being trapped in riverbed sediments or carried through the air along major river systems, a new study has shown.

The research, conducted along the length of the Ganges River in South Asia, found on average about 41 microplastic particles per square metre per day settled from the atmosphere. In addition, analysis by scientists found 57 particles per kilogram on average in sediment from the riverbed as well as one particle in every 20 litres of water.

The research, published in ***Science of the Total Environment***, represents the first combined analysis of microplastics in water, sediment and air around a major river system. The research was conducted using samples collected by an international team of experts as part of the National Geographic Society's Sea to Source: Ganges Expedition.

Lead author, Dr Imogen Napper, a Research Fellow at the University of Plymouth and National Geographic Explorer, said: "We have known for some time that rivers are key pathways for the transfer of microplastics to marine environments. However, there has always been uncertainty about the sheer amounts being transported, and whether they represent long-term sinks. This study goes some way to unravelling that mystery, and revealing the true scale of microplastic contamination that our river systems can represent."

In addition to highlighting the overall abundance of particles, scientists found fibres to be the most common type, representing up to 99% of the microplastics discovered in some of the samples analysed. Within this, rayon (synthetically altered cellulose) was the dominant polymer – representing up to 82% of the fibres found in some samples – ahead of acrylic and polyester, and blue was the most common colour.

The sediment samples often contained denser microplastic particles than those found in water and air, and higher population densities correlated with increased microplastic abundance for air and water samples.

• To access the original article, Visit: https://pubmed.ncbi.nlm.nih.gov/37647965/

New urban water safety course available

The World Health Organisation has announced the launch of a new self-paced course on the OpenWHO learning platform titled 'Water safety planning for urban water supply systems – an introduction'.

The course emphasises the significance of drinking water safety in urban settings. It outlines the principles and steps crucial for ensuring a reliable and safe water supply chain. In four modules, participants will learn the fundamental principles of water safety planning, its practical steps and key terms related to urban water supply. The content presents real-world practices that lead to successful water safety planning, particularly highlighting resilience against climate challenges.

Designed by the WHO Regional Office for South-East Asia, the course is a valuable resource for professionals in water supply, health sectors and government officials. A Certificate of Achievement is available to all participants who successfully complete the course.

To find out more, Visit: https://openwho.org/courses/water-safety-planning

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NEW WRC REPORTS

The South African hydropower atlas

Hydropower, which utilises the flow of water from existing water infrastructure and rivers to generate electricity, is considered a good renewable energy source and an alternative to fossil fuels. South Africa is acknowledged to be not particularly endowed with the best hydropower conditions as it might be elsewhere in Africa and the rest of the world. However, large quantities of raw and potable water are conveyed daily under either pressurised or gravity conditions over large distances and elevations. An initial WRC scoping study highlighted the potential hydropower generation at the inlets to storage reservoirs. In South Africa there are 284 municipalities, several water supply utilities and mines, all owning and operating gravity water supply distribution systems which could be considered for small-, mini-, micro- and pico scale hydropower installations. Most of these water supply/distribution systems could be equipped with turbines or pumps as turbines, supplementing and reducing the requirements for pressure control valves. The hydro energy may be used on-site and supplied to the national electricity grid or feeding an isolated electricity demand cluster. There are also numerous storage dams in South Africa which release environmental releases or releases water for irrigation purposes which could be retrofitted with turbines to harness the available flow and pressure. The research project's aim was to enhance the uptake of micro-hydro technology, making local stakeholders (private sector, financial sector, government entities, etc.) aware of the opportunities that this technology brings, and the efforts required to get this technology successfully implemented in South Africa. The project provides general information regarding the assessment of hydropower potentials and provides the information required regarding the feasibility of such projects.

WRC report no. TT 916/23
Web link: https://bit.ly/3PVMVH3
Link to atlas: https://bit.ly/3cmuiJu

Scoping study to explore hydro potential in the nearby vicinity of Baakens River and the lake

The electrification of urban areas in South Africa, including many informal settlements, reached its culmination during recent years. However, the electrification of rural areas still has a long way to go before most of the rural communities could be provided with reliable and sustainable electricity supply. The national electricity grid, managed by the parastatal ESKOM, has been experiencing problems caused by various reasons, particularly since 2008. The research project's aim was to enhance the uptake of micro-hydro technology, making local stakeholders (private sector, financial sector, government entities, etc.) aware of the opportunities that this technology brings and the efforts required to get this technology successfully implemented in South Africa. A municipal hydropower development tool was developed to assist municipalities with the identification and development of hydropower sites in their area. The tool was developed based on the pre-feasibility phase of the hydropower development process. As a case study, the sites within the Nelson Mandela Bay Municipality were identified based on a pre-feasibility analysis.

WRC report no. 3087/1/23
Web link: https://bit.ly/3rVMBA6

Towards liveable neighbourhoods by redesigning using water sensitive design

It is known that water sensitive design (WSD) can regenerate urban catchments to bring multiple benefits, such as enhancing ecological health, securing water resources, increasing recreational opportunities, enhancing ecological and human health, reducing of urban heat island, mitigating floods and offering a range of economic benefits. But how can WSD spatially be integrated in an existing city setting given prevailing constraints? Located in Cape Town, the purpose of this study was to generate spatial WSD proposals that are responsive to the social inequity and informality challenges of a Global South city context. The empirical context of this study was Hangberg, a low income and informalising neighbourhood located at the edge of a biodiversity conservation area on the slopes of the Sentinel Mountain.

WRC report no. 2801/1/23
Web link: https://bit.ly/3FiYmDB

Hybrid water supply systems and conjunctive use in the context of water sensitive settlements: A case study of Sekhukhune District Municipality, Limpopo Province

As water demands approach the total renewable freshwater availability, each drop of freshwater gets increasingly valuable, hence the need for efficiency and intensity in its management. Given that demand will continue to increase, there is a need for innovative supply and demand management to achieve economic, environmental and social sustainability. To meet the demand gaps, there is need to develop robust tools to deliver on the alternative, but suitable sources of water sustainably. This can be achieved through a mix of centralised and decentralised water supply systems as well as a mix of conventional and alternative water sources to meet water demand loads sustainably. The mix is referred to as hybrid water supply systems and is situation-dependant, hence it varies from one settlement to another. The tenets of the hybrid water supply and management systems are anchored in the principles that define the water sensitive urban design (WSUD) and sustainable drainage systems (SuDS). This study aimed to develop a set of critical frameworks for hybrid water supply systems that are generic in nature but utilise information for Sekhukhune District Municipality and literature as the basis/functional units of the study. The frameworks developed include the following: a generalised domestic rainwater harvesting potential and rainwater harvesting systems selection framework; framework of water energy nexus analysis for a rainwater harvesting system; global warming potential analysis framework; and a framework for developing stormwater harvesting systems and monitoring. A mathematical model for conjunctive use of surface water and groundwater in the municipality was also developed and tested.

WRC report no. 2534/1/23
Web link: https://bit.ly/46xAMzc

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Understanding bound water content and water binding strength in faecal sludge from on-site sanitation technologies and human faeces

Dehydration allows for the reduction of the volume and mass of faecal waste considerably and can cause the deactivation of pathogens. There is a need to improve the actual dehydration methods (dewatering and drying) and develop innovative technologies that are adapted to the faecal material and socioeconomic context. The aim of this project was to characterise the moisture boundness in faecal sludge, i.e. how moisture can be found in the sludge structure matrix and its interactions with the solid material. The understanding of moisture boundness will be greatly beneficial to improve the dewatering and thermal drying processes. The investigation was led by the Water, Sanitation and Hygiene Research and Development Centre, University of KwaZulu-Natal. The first part of the project consisted of the analysis of the results from previous investigations that give an indication of the moisture boundness in faecal materials and the compilation of the extracted information to formulate the first explanations of moisture boundness in the faecal materials. The second part of the project is generated a new set of data through experiments to obtain a more detailed and insightful representation of moisture boundness based on a multi-dimensional study. This work was done by conducting experiments following different approaches to characterise moisture boundness, including the determination of the sorption isotherms and the hydraulic properties. For this study, faecal sludge from different on-site sanitation facilities within the eThekwini municipality (Durban metropolis, South Africa) was used.

WRC report no. 3086/1/23
Web link: https://bit.ly/3rULPTW

Development of a South African national input database to run the SWAT model in a GIS

An important requirement for hydrological modelling is spatial input datasets, including topographic data, land use-cover interactions, soil properties, and climate conditions. The combination of models and remote sensing techniques within a geographic information system (GIS) framework is commonly utilised to assess hydrological processes such as streamflow, water erosion, sediment yield dynamics and nutrient inputs/outputs. A major limitation to model application in South Africa, however, is the lack of standardised geo-spatial and open-source datasets developed for South African vegetation and soil types. This study collated multiple geo-spatial datasets at a national scale and interpreted/formatted the data for use as baseline input to run the Soil and Water Assessment Tool (SWAT) in any catchment in South Africa. ArcSWAT is a graphical user interface for SWAT and ArcGIS software extension, streamlining access to key databases and facilitating the preparation of input datasets.

WRC report no. 3053/1/22
Web link: https://bit.ly/3QjcYJt

Development of a regionalised approach to estimate areal reduction factors and catchment response time parameters for improved design flood estimation in South Africa

Event-based deterministic design flood estimation methods are the most commonly used by practitioners in ungauged catchments. In the application of these event-based deterministic methods, it is acknowledged that both the spatial and temporal distribution of runoff, as well as the critical duration of rainfall, are influenced by the catchment response time. Typically, all complex, heterogeneous catchment processes are lumped into a single process to enable the estimation of the expected output (design flood) from causative input (average areal design rainfall and catchment response time). Design point rainfall estimates are only applicable to a limited area and for larger areas, the average areal design rainfall depth is likely to be less than the maximum design point rainfall depths. Areal Reduction Factors (ARFs) are used to describe this relationship between point and areal rainfall, i.e. design point rainfall depths are converted to an average areal design rainfall depth for a catchment-specific critical storm duration (response time) and catchment area. The overall objective of this project is to develop a regionalised approach to estimate ARFs and at-site catchment response time parameters for improved design flood estimation in South Africa

WRC report no. 2924/1/23
Web link: https://bit.ly/3QktzN5

Integrating ARD prevention and mine waste minimisation: soil fabrication from coal waste

Rehabilitation post mining requires revegetation of lands and potentially of waste dumps. Both require availability of fertile soils, typically excavated and transported from surrounding areas, with associated cost and environmental impact. Stockpiled soils may contribute to the soils available for revegetation but are typically no longer fertile and not in sufficient amount to comply with the requirements of the environmental management and rehabilitation programme. In this study, the research team focused on the potential for technosols, fabricated from fine coal waste and organic amendments, with or without bioaugmentation, to be constructed and applied as a soil substitute. This work was motivated threefold: by the need for increasing quantities of high quality, regenerative fertile soils for mine rehabilitation; by the desire to reduce excavation of natural soils and its associated environmental impact; and by the potential to re-purpose low-risk mine wastes, to both reduce the need for excavation of virgin materials and to reduce the waste disposal burden.

WRC report no. 2844/1/23
Web link: https://bit.ly/46CQdWL

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HYDROPOWER

Atlas boost for hydropower

There's great scope for generating electricity at thousands of dams and water infrastructure sites across the country. A new web-based mapping tool helps point the way. Matthew Hattingh reports.

If you're one of the many South Africans who sometimes turns on a tap only to be greeted by groaning noises and hollow coughs, and who much more frequently flicks a light switch, only to confront darkness, there's a chance you may have found yourself asking: Is there some kind of a link between water supply outages and loadshedding? The answer, as it turns out, is: Kinda.

While the two crises have a different genesis, their creation stories have a number of things in common – and we are not necessarily talking about snafus and ***verneukery.*** Something called the water-energy nexus appears to be at play. It's an oft-cited principle that describes the proportional relationship between water supply and energy demand. It tells us that every step of the water and wastewater treatment cycle consumes energy. And almost every power source demands water for its production.

This being the case, "technologies that can couple water and energy supply, especially in areas with high population densities" should be explored. And this is even more true of countries where water is scarce and likely to become more so as climate change hits home. We are quoting from ***The South African Hydropower Atlas***, a recently published Water Research Commission (WRC) publication (***WRC Report No. TT 916/23***) which details the development of the eponymous atlas, intended to serve as a database, planning and research tool.

The report's authors and developers of the atlas, civil engineers Marco van Dijk and Anja Bekker and geographers Christel Hansen and Noluthando Mahamba, of the University of Pretoria, noted that atlases had already been compiled for other forms of renewable energy in South Africa. It was time hydropower caught up and promoted its cause.

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Meanwhile, a ***Scoping Study to Explore Hydro Potential in the Nearby Vicinity of Baakens River and the Lake (WRC Report No. 3087/1/23)***, also published earlier this year, has put the atlas to the test, using it to identify sites for further study in the Nelson Mandela Bay Municipality and its surrounds. This second report, the work of Van Dijk and Bekker, describes a preliminary feasibility study in the Eastern Cape metro. It explained how this provided a shortlist and also led to the development of a spreadsheet-based assessment tool, which the authors hope will prove useful to other municipalities.

With the shortlist to hand, the researchers spent a week in the field, firming up their preliminary findings. However, at this point they ran into a "major challenge" accessing information. We will return to this later.

Apart from assessing the technical feasibility of the different sites, establishing whether these made rand-and-cents sense was "crucial", so the second report crunched the numbers using familiar financial indicators and techniques. According to the literature, civil works typically account for 40% of the cost of a hydropower project; electromechanical equipment, a similar figure; with the balance going to construction, design fees and management. Yearly operations and maintenance costs range between 0.25% and 4% of the cost of each of a project's main components.

But before we go into more detail, some perspective. Long before rolling blackouts first roiled the country, towards the end of the Mbeki era, and long before the Elektrisiteitsvoorsieningskommissie (Eskom) was established in 1923, electricity was generated by municipalities and private companies. In the early days there was no national grid and hydro often supplied the juice.

The gold mines of Pilgrim's Rest, for example, were powered by two 6 kW hydro-turbines as early as 1892, complemented by a 45 kW turbine in 1894 for the town's first electrical railway. Cape Town and Pretoria once relied on small-scale hydro, while smaller towns started local distribution of electricity through isolated grids powered by hydro stations. "However, with the expansion of the national grid and the cheap, coal-generated power it supplied, large numbers of [hydro] systems were decommissioned."

Back to the present and it seems we may be coming full circle. South Africa's coal-generated power is now neither especially cheap nor particularly plentiful. While hydropower, a proven technology – globally it's the source of 16.5% of electricity and growing – could be on the brink of a local renaissance. Which is not to say it ever left these shores; rather it ceased to be a mainstay of power production.

Figures vary, but South Africa's installed hydropower capacity is reckoned to be nearly 3 500 MW. It's a modest figure relative to the country's 54 177 to 64 500 MW of total generation capacity, most of which is coal-fired. Pumped storage schemes, notably Ingula in KwaZulu-Natal (capacity: 1332 MW), Drakensberg in KwaZulu-Natal and the Free State (1 000 MW), and Palmiet and Steenbras, both in the Western Cape (400 MW and 180 MW), produce the majority of South Africa's hydropower.

These schemes consist of lower and upper dams, with a combined power station-pumping plant between the two. Off peak, when demand for electricity drops, reversible pump-turbines draw electricity from the national grid to pump water from the lower to the upper dam. On peak, water is released, generating electricity.

Hydropower has many benefits, as the reports remind us. It's clean, renewable, and comes with low operating and maintenance costs. And particularly in the case of pumped storage schemes, can respond rapidly to changes in demand. But such schemes can mean big capital outlays. Ingula, for example, was completed in 2017 as costs spiralled to R42.58-billion (in today's money). Big dams are even pricier to build and in water-scarce South Africa offer mostly modest power generation capacity. Indeed, only the Gariep and Vanderkloof dams, with 360 MW and 240 MW respectively, come to the national grid party.

Dams also disrupt river-flow, harming natural systems and habitats, including the plants and animals that depend on them. However, many of these concerns fall away in the case of South Africa's numerous storage dams and other gravity-fed water infrastructure. At these sites the environmental damage has already been done and the construction costs long ago sunk.

We are talking here of dams that release water for environmental or irrigation purposes and which "could be retrofitted with turbines to harness the available flow and pressure".

What do we mean by "other infrastructure"? The atlas provides a lengthy list, including, pumped-storage (which we touched on earlier), inter-basin transfer schemes, irrigation, weirs and run-of-river schemes. There are also water and wastewater treatment and distribution systems which are operated by 257 municipalities, several water supply utilities, the Department of Water and Sanitation, mines and even Eskom.

All of this infrastructure, vast networks of pipes, canals and conduits, "could be equipped with turbines or pumps-as-turbines, with the added benefit of supplementing or reducing the need for pressure control valves", the reports observe. The atlas identifies many thousands of megawatts of potential hydropower waiting to be unlocked from a few thousand sites. But in truth, unless done on a large scale, these installations

Marco Van Dijk

The 96 kW hydropower plant at the Vaal Central Water Board's (formerly Bloem Water) Brandkop reservoir in Bloemfontein. The plant was installed in 2015 and powers the utilities' head office.

Marco Van Dijk

Water exiting the sleeve valve at the Spioenkop Dam outlet, near Winterton in KwaZulu-Natal. There is an opportunity to install a hydropower plant at the dam – and at many other such sites across the country.

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will make at best a modest contribution to staving off loading-shedding.

Most of the sites fall in the pico, micro and mini ranges – up to 20 kW, up to 100 kW, and up to 1 MW, respectively. Such outputs are dwarfed by Eskom's bomb squad, the newish coal-fired Medupi and Kusile power stations, which have, at least on paper, generating capacities of 4 800 MW and 4 764 MW respectively. Then again, size isn't everything, as fans of rugby's Cheslin Kolbe and Faf de Klerk will tell you. And like the pint-sized Bok backs, small-scale plants are versatile and box above their weight in other ways.

The reports noted rural electrification had been "in the doldrums" because of Eskom's troubles, but small-scale hydro schemes offer a means to jumpstart the rural rollout. It's also a good way to get power to isolated places, dispensing with long, costly transmission lines. What's more, hydropower can help meet the on-site energy needs of waterworks and other "own use" municipal facilities. It can be fed into the grid too (although this comes with plenty of red tape).

Back to the atlas and what went into it. Criteria were developed to narrow down the number of sites for inclusion. For this, the authors drew on Department of Water and Sanitation data, including flow volumes for rivers, canals and conduits. Other data came from: the Surface Water Resources of South Africa studies; the South African National Committee on Large Dams; the department's Green and Blue Drop reports; and municipal water service development plans.

Evaluation frameworks were developed for different forms of hydropower, each with its own parameters, decision flowcharts and tailored formulas for calculating power output. By way of an example, and because the authors believe its inclusion in the atlas represented a first in hydropower research, let's look at the frameworks for wastewater treatment works.

To start with, sufficient data must be available in the Green Drop reports, the annual audit of the country's wastewater plants. If so, the question is: Is the design capacity of the site under consideration indicated? If not, certain assumptions are made. Either way, the plant's likely discharge is calculated. This is then fed into a formula which uses the height difference between a plant and its outlet (or an estimate of this) to calculate the likely power output. Other variables in the equation include the hydraulic efficiency of the intended turbine.

If the calculated output is less than 5 kW the available potential is considered too small and the site excluded from the atlas. So, what does the atlas look like and how do you use it?

It is hosted on the web using ArcGIS Online, proprietary software which the authors felt trumped the open-source alternative in providing a secure and reliable platform. A graphical user interface, with icons, buttons and menus lets users visualise data, zoom in and out or pan across maps or navigate to a particular place or set of coordinates. Multiple users can simultaneously create and share maps, scenes and layers, and add to, analyse and extract data. They can also bookmark, print and share maps.

Layers can be turned on and off, letting users view different combinations of elements in any part of the country. For example, users can view existing hydro schemes (colour-coded

WRC archives

The Kwamadiba micro-hydropower plant, situated northeast of Mthatha in the Eastern Cape, is an example of small-scale hydropower providing much needed electricity to rural communities.

according to capacity), as well as rivers, weirs, treatment works, road networks, municipal and provincial boundaries, and more.

Time to put things to the test. Van Dijk told the ***Water Wheel*** his team was invited to Gqeberha (previously Port Elizabeth) by the Mandela Bay Development Agency, which felt the Baakens River might have power potential. It was later decided to widen the net and look at water and wastewater treatment plants too. Using the atlas, the researchers identified and shortlisted 12 sites for visiting: Six wastewater and one water treatment works; three weirs; one run-of-river site, on the Swartkops River; and the Groendal Dam (outside the municipality).

The next phase of the project should have involved gathering comprehensive information at the 12 sites, but the project hit headwinds. Van Dijk said they had been unable to access most of the sites. He explained that the team had been keen to verify elevations so power outputs could be more accurately calculated. The silver lining to this was that it spurred the team to develop their spreadsheet-based municipal assessment tool, which helped them to produce summary feasibility reports.

The authors recommended that the municipality develop a hydro plant at the Groendal site as a demonstration exercise and that other feasible sites be developed in the next phase. The authors calculated the cost of the Groendal development as R1.57-million and that it would pay for itself in six-and-a-half years. "Clean, renewable electricity would be generated at less than 70 c/kWh."

Van Dijk acknowledged a lack of support from some municipalities and long delays in getting projects to the tender stage was "super frustrating". But he was buoyed by the Department of Water and Sanitation's commitment to opening its facilities to hydropower proposals and water-use applications.

The technology was proven, he said. "It's just the application in a different way; smaller… It's a game-changer."

To view the South African Hydropower Atlas visit: https://bit.ly/3o5qhl3
To view the report, *The South African Hydropower Atlas* (**WRC Report No. TT 916/23), visit:** https://bit.ly/3PVMVH3
To view the report, S*coping Study to Explore Hydro Potential in the Nearby Vicinity of Baakens River and the Lake* (**WRC Report No. 3087/1/23)**, visit: https://bit.ly/3rVMBA6

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IRRIGATION

Curbing major water losses from farm irrigation schemes

A Water Research Commission (WRC) report is paving the way for a new 'Irri-Drop' monitoring scheme to reduce water leaks and losses from large irrigation schemes. Tony Carnie reports.

Lani van Vuuren

Farming consumes the lion's share of South Africa's increasingly scarce water resources, making it imperative that every drop is used more carefully. Government research studies suggest that irrigated agriculture consumes a whopping 62% of national water demand every year – yet farming is also the least water efficient sector, with reported wastage of up to 45% in some irrigation schemes.

Adding to these challenges, studies point to a national water deficit of 17% by the end of this decade at a time when government is also striving to increase irrigated land by more than 50%. These are some of the reasons why the Department of Water and Sanitation requested the WRC to help develop a new framework for reporting water use efficiency in agriculture.

This framework, dubbed the Irri-Drop Report, aims to generate more information on the extent of agricultural water losses at irrigation schemes across the country. In a new report published by the WRC, local water and agriculture experts note that the framework borrows cues from existing schemes such as the Green-Drop, Blue-Drop and, more recently, the No-Drop reports, for rating water use efficiencies in wastewater and municipal water management.

The proposed Irri-Drop framework aims to provide a tool for assessing irrigation schemes in terms of water conveyance efficiency and the readiness of this sector to deal with water losses in a transparent manner. The project, titled ***The state of irrigation water losses and measures to improve water use***

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*efficiency on selected irrigation schemes (***WRC report no. 2970/1/23**), was based on studies and data analysis from the Vaalharts and Loskop irrigation schemes (the two biggest irrigation schemes in South Africa).

It was compiled by researchers from the Agricultural Research Council; the University of Venda; the Department of Agriculture, Land Reform and Rural Development and the Gauteng-based software solutions company NB Systems.

The Vaalharts scheme, on the boundary of North West and Northern Cape provinces, is made up of a 1 176 km network of canals and storm drains covering an area of more than 29 000 hectares. The first canals date back to 1934, with most water fed to crops using centre-pivot irrigation systems. Some traditional methods, such as overhead sprinklers and flooding, are still in use, but on a very limited scale and are being replaced by micro-sprayer and drip systems. Vaalharts farmers produce a wide variety of crops including lucerne, groundnuts, pecan nuts, potatoes, cotton, olives, citrus, apricots, grapes, peaches, watermelons, grains, and vegetables.

Loskop, the second biggest public irrigation scheme, is fed by Loskop Dam at the boundary of Limpopo and Mpumalanga provinces. The reservoir irrigates an area of nearly 19 000 hectares via a 495-km long network of concrete-lined canals.

Dr Macdex Mutema, a senior researcher at the Agricultural Research Council and lead author of the the study, notes that upgrading irrigation infrastructure can be very costly. Therefore, it is important to redirect funding to projects that can yield the best water saving benefits (such as information management systems which have shown potential to improve sustainability and to modernise irrigation systems).

Mutema says one of the key findings of the study was that global water losses at Vaalharts were around 20% per year (19.4% and 18.7% for the 2019/20 and 2020/21 water years, respectively) whereas water losses from the Loskop scheme were around 25% (25.2% and 25.1% for the same water years).

The authors note that the lower percentage losses at Vaalharts still constitute much greater volumetric losses (81.9 and 67.6 Mm^3 for 2019/20 and 2020/21, respectively) compared to Loskop (34.7 and 35.6 Mm^3 for 2019/20 and 2020/21, respectively) because it is a much bigger irrigation scheme with greater annual water consumption.

But Mutema emphasises that these losses apply only to the irrigation canal distribution scheme – not to losses on farms or farm reservoirs served by the schemes. He notes that there is often an assumption that most of the losses occur within irrigation schemes, whereas losses at farm level are also significant – potentially exceeding 20%.

"A very important recommendation is to extend the Irri-Drop Report concept to at least cover on-farm water delivery networks in addition to the current focus on water conveyance networks between the main reservoirs and farm gates," the report states.

"There is an urgent need to address this information gap for better accounting of water deliveries to farmers. Nevertheless, establishment of more gauging stations at strategic positions of the canal networks is still important because the best and less financially stressing way to minimise water losses from canal networks is to identify problem areas and take remedial actions, which is only possible with a dense network of gauging stations."

Overall, the report concludes that it is still feasible to develop an incentive-based programme (similar to the No Drop Report) for use by the Department of Water and Sanitation as a tool to encourage higher water conveyance efficiency in irrigation schemes. It notes that both Vaalharts and Loskop are equipped with flumes (engineered concrete structures to measure the flow of water in open channels). However, many flumes were now largely obsolete or did not have gauging staves and there was a need to replace them with new, less-labour intensive technology to reduce drudgery and associated human errors.

A better alternative was to use electronic data loggers, which are more accurate and have the further advantage of allowing data to be downloaded from a remote location. But this technology was currently too expensive to install at every offtake point on the canal networks including the farm gates.

One of the most urgent recommendations was therefore to identify appropriate gauging stations on the main canal, secondary, tertiary and community canals and to equip these gauging stations with accurate measurement devices. The researchers emphasise that like any other computer-based programmes, the quality of the reports published on online platforms will depend on the quality of input data.

"Therefore, it is important to have a good working data collection system and competent personnel to handle the data collected." Another key finding from the project was confirmation that evaporation water loss from canals is negligible in comparison with the other losses.

"The last very important finding is that good technical design of canals needs to be supported by equally good management and maintenance plans for better water conveyance performance."

Several measures for improving the efficiency of canals have been put forward, including improvements in operations and maintenance of the infrastructure. This should include proper maintenance plans and sealing the gaps between the concrete slabs which make up the canal walls and beds in order to reduce leakage.

Mutema notes that most of the big irrigation schemes have shutdowns twice a year for maintenance and sediment clearance. During this period, some farmers have to depend on their own reservoirs as a temporary water supply. While maintenance shutdowns could last for one to two weeks, longer shutdowns could create problems for farmers, especially in areas furthest downstream.

However, if joint cracks and holes were not repaired timeously, the damage became worse over time and magnified the volume of water losses. Mutema also saw evidence of damage to concrete canal structures by rodents burrowing through

Nico Benade

Maintenance workers repair a damaged section of canal at the Loskop irrigation scheme.

weak or cracked sections. "We are talking of holes 40 – 50 mm in diameter dug by rodents, as well as cracks that had not been repaired for four years.

"We also saw scenarios where there is a significant increase of households moving closer to the canals to access water for livestock or domestic use."

There was further evidence of farmers whose crops appeared to be thriving, even in areas where nearby canals were dry. So, the suspicion was that these farmers were accessing borehole water (or surface water from drainage canals). However, the volumes of water lost in this way had not been quantified.

Mutema and his colleagues note that maintenance and repair work of water infrastructure in irrigations schemes is sometimes hampered by a lack of clarity over ownership and responsibility between water users and irrigation authorities. In addition, some farmers lacked the skills and resources to maintain and repair canals. Hence, they depended on the authorities.

In addition to a lack of skills and resources, farmers often lacked the collective ability or willingness to perform the tasks needed, partly because maintenance requires closing the canals for repairs, which interrupts production and subsequently farmers' livelihoods.

"This is one reason why farmers are generally reluctant to support rehabilitation works in the absence of subsidies," the report says.

Prof Sylvester Mpandeli, the WRC Executive Manager for Water Utilisation in Agriculture says: "The bottom line is that we need to reduce water consumption in farming due to human population growth and climate change. So, it's very important that our farmers use less water to provide more food. We should also be embracing the Fourth Industrial Revolution to monitor water use."

On the crucial issue of who should be held responsible for canal maintenance, Mpandeli says: "Our farmers need to understand that government does not have money to maintain these canals.

"Many irrigation farmers are also generating foreign exchange from exports, and they need to get together to decide how they are going to maintain the canals rather than waiting for the government to assist them. We still have a long way to go in learning from other countries in this respect," says Mpandeli,

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Image supplied

A section of broken wall on one of the canals at the Loskop irrigation scheme. Enormous volumes of water can go to waste if irrigation canals are not maintained properly.

who is also Vice President of the International Commission on Irrigation and Drainage (ICID).

Mutema notes that while large irrigation systems such as Loskop and Vaal-Hartz have well established management and maintenance schemes, the percentage water losses are likely to be higher in smaller irrigation schemes (possibly exceeding 40%).

Mpandeli adds that there are plans by the WRC to launch follow-up projects next year to fill in some of the information gaps and to quantify irrigation water losses more accurately at a provincial and catchment level.

Lani van Vuuren

Loskop Dam in Mpumalanga irrigates an area of nearly 19 000 hectares via a 495-km long network of concrete-lined canals.

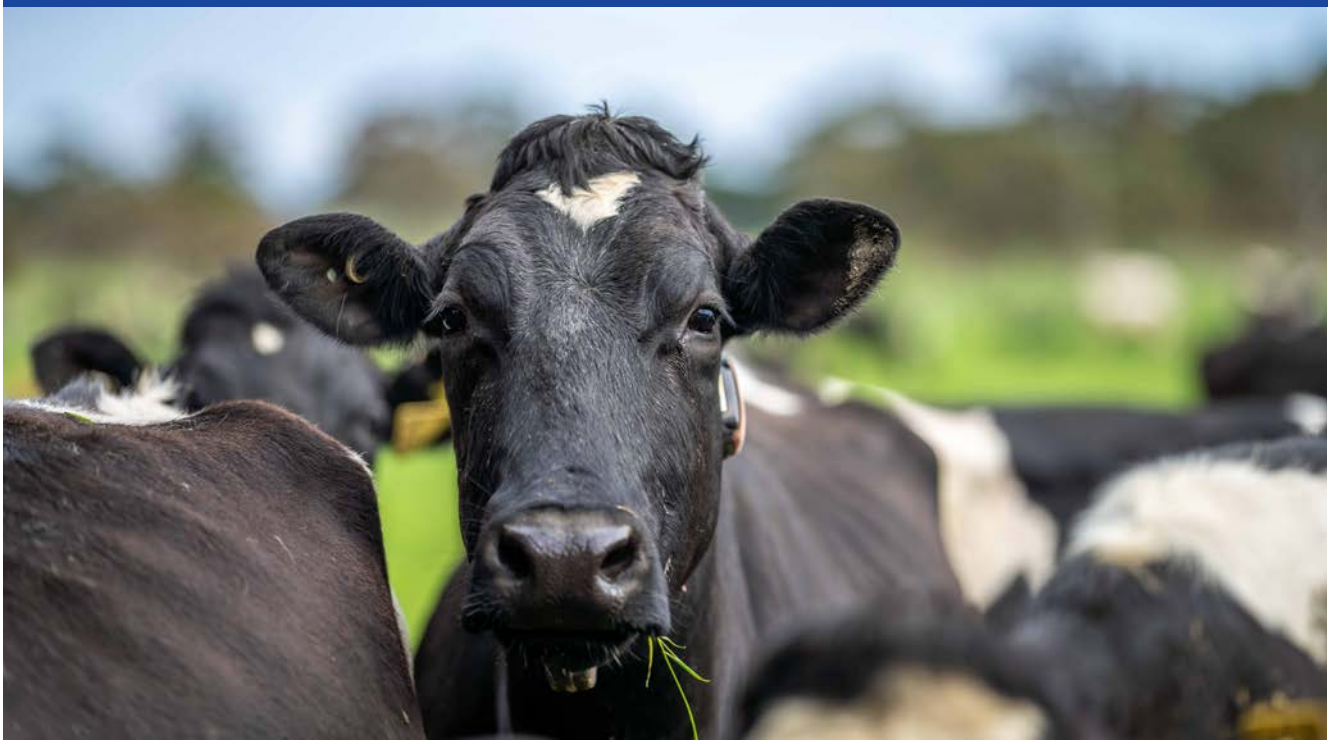
Lani van Vuuren

One of the canals on the Vaalharts irrigation scheme, the biggest government irrigation scheme in the country.

WATER AND AGRICULTURE

How much water does a milk cow need? Study looks to save water in dairy industry

A study of water use on dairy farms in the Eastern Cape found numerous ways to improve their water use efficiency, with astounding financial benefits to the farmers who participated. Article by Petro Kotzé.



Milk production is the fourth largest agricultural sector in South Africa. In 2019/20, about 3.427 million tons of milk were produced, mostly on farms distributed around our coastal areas where mild temperatures and good rainfall provide quality pastures.

The bulk of water on dairy farms is used for irrigation, as pastures for livestock feed need supplementary water when there is not enough rain. Of the estimated 160 litres of water used to produce a litre of milk, around 135 litres are for irrigation (the rest are for the animals themselves and to wash facilities and equipment). Consideringn the total amount of milk produced, the sector uses a substantial amount of water each year – well over 3 billion litres (according to the mentioned total tons produced in 2019/20), roughly what 20 million people use daily. A study by Trace and Save and the WWF-SA analysed water use efficiency and irrigation efficiency on pasture-based dairy farms in South Africa. Though the results varied between farms, in general, they found that large amounts of water are potentially being wasted every year due to irrigation system inefficiencies. The study also proved the large financial benefits of improvements and that, with the necessary motivation and knowledge, some can already be implemented by farmers, as many that participated in the study have done upon seeing the results.

The project was led by soil scientist Lorraine Phadu, a sustainability researcher for Trace and Save. "We approached

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this study from a holistic perspective," she says of their approach. This included aspects below and above ground, she adds, such as soil health, irrigation which are the pivots themselves and the climate that they function in.

An overview of the farms that participated

For ten months in 2021, from March to December, Phadu collected data on the water use and efficiency of 15 centre pivot irrigation systems on six dairy farms in Tsitsikamma and Outeniqua in the Southern Cape. The area is not only known for dairy farms but also for its ecological significance. The water management areas include dense clusters of freshwater ecosystem priority areas for rivers, wetlands and threatened and critically endangered fish sanctuaries and support areas.

The farms that participated in the study rely on a mix of irrigation and drylands for grazing, Phadu explains. This includes a variety of species such as lucerne, ryegrass, chicory, Kikuyu, white and red clover. The water for irrigation is mostly collected in dams and weirs, and then pumped to the pivots using electricity, but the availability of water, and the irrigation systems vary substantially across the farms. Some farms were found to have very effective irrigation systems in place, while others relied on rainfall and irregularly irrigate with varying amounts of water. The condition of irrigation systems also varied, with some of the irrigation systems found to be in good condition, used at capacity and fitted with mechanisms like ring feeds and variable speed drives to decrease electricity use, while others were found to be poorly designed, badly maintained, old and used more electricity than required.

The farmers' approach to irrigation varied widely too, based on a combination of technology, experience, knowledge and even, Phadu says, gut feeling. About half of the farmers use soil moisture probes and irrigate according to soil moisture content, either based on their own interpretation of the data or that of consultants. Other farmers irrigate according to the availability of water, depending on rainfall and dam levels, regardless of soil moisture. Some farmers have very little water available and schedule their irrigation so the water can last throughout the entire season. There are also farmers who irrigate according to their experience, anticipating certain pasture growth rates for a season. Lastly, there are farmers who irrigate conservatively, using as little water as possible, to lower their risk of running out in periods of low rainfall. "Some of these farmers were taught by their fathers or their grandfathers, and what they are applying is according to that generational knowledge," Phadu notes.

For the purpose of the study, pivots were fitted with water meters and data loggers to measure the amount of water entering the pivot. Every week, the farmers measured the pastures' growth rate and calculated tonnes of dry matter. The farmers also recorded the daily amount of milk produced by each cow.

How efficient was the irrigation?

The researchers found that, on average, more than 507 000 litres of water is potentially wasted per hectare every year due to irrigation system inefficiencies. The most efficient systems wasted only 84 210 ℓ/ha while less efficient systems wasted as much as 1 113 079 ℓ/ha. If every farm fixed all inefficiencies in its irrigation systems, as per the most efficient system (96,3%) in this case study, potentially 423 204,68 litres of water could be saved per hectare, every year, per farm.

Phadu explains that the systems' efficiency is driven largely by wind speed, the distance of the sprinkler head from the ground, and the droplet size. When the wind speed is high, and small droplets are irrigated from a sprinkler head far from the ground, a lot of water is lost. "Even if you have an efficient system but you have chosen a windy and hot day, you're losing a lot of water," Phadu says, mentioning that the team's data showed that as much as 40% of the water on a windy and hot day can be lost before it hits the pasture.

The research team went a step further. Had all the water (including the 507 414 ℓ/ha water lost) that flowed through the water meters reached the pasture, an extra 1.6 tonnes of dry matter could be grown, instead of buying it in. The cost of bought in roughage to compensate for the shortage amounted to R4 598/ha, which is R1 149 500 per year on a 250 ha farm. This still excludes the additional financial, logistical and environmental input required to buy in roughage grown elsewhere.

Phadu explains that they really wanted to drive home the financial benefits of savvy water use.

The wasted water was still pumped to the pivot, and this amounted to 15 769,30 kg CO_2/ha and approximately R483,95/ha/year in Eskom electricity bills. All and all, if the values are extrapolated, the cost of an inefficient pivot covering an area of

Photo supplied

The soil that the pasture is grown in is an integral element of efficient water use in farming operations.

Photo supplied

A 'catch can test' in action, to test the irrigation efficiency of pivots. Water droplets are captured to calculate efficiency measures (calibration, system and scheduling).

30 ha will be approximately R57 419,10/year for pumping water that did not reach the pasture. According to the final report, "This is considerably more than the most efficient pivot in this study, for which the cost would be R14 515,50/year for pumping water that did not reach the pasture."

You have to look at the weather, the time of the day when you are irrigating and your system efficiency, Phadu reiterates. Another integral element is the soil health. "You have to know the capacity of your soil to hold water, because as you are irrigating you want that water to be held in the soil and be provided to the pastures as per need." In the study area, soils with more abundant fungi and carbon or overall healthy soils, retained water better, and resulted in better pasture water-use efficiency.

The findings indicated that, for efficient irrigation, farmers need accurate weather and environmental data, a good understanding of their systems and to work to build soil carbons that will improve soil structure and a good water holding capacity. In essence, the research found that the overall water used for irrigation would decrease if farmers applied higher quantities of water per irrigation event, but irrigate less often.

Why the change is not easy

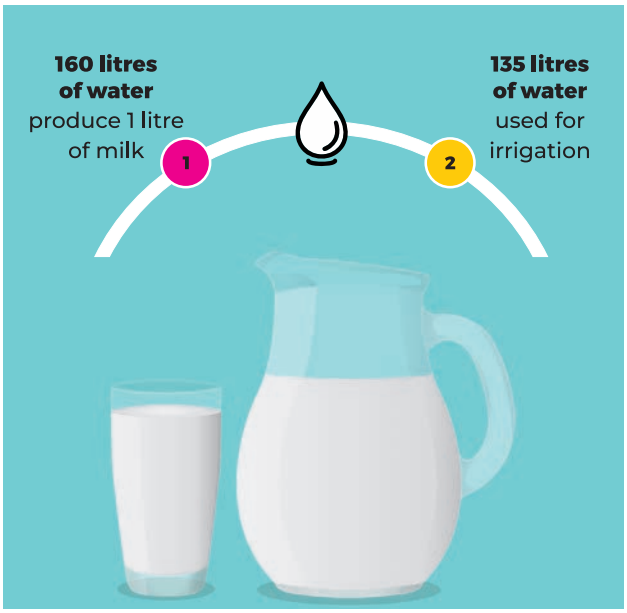
There are serious challenges to implementing the study suggestions. First is the "major financial costs for the implementation and upkeep of infrastructure, both to improve irrigation system efficiency and monitor water use." According to the final report, the costs of the water meters ranged between R8 000 and R10 000 each and the installation, the data logger and any adjustments needed on the pipework were on average R25 000 to R40 000. Weather stations cost R8 598 each.

Photo supplied

The bulk of water on dairy farms is used for irrigation, as pastures for livestock feed need supplementary water when there is not enough rain.

A second challenge is the lack of maintenance and follow-up support from irrigation equipment service providers. "It was heartbreaking to know that the farmers paid hundreds of thousands of Rands for a pivot, but then had to wait four or five months to get leaks fixed," Phadu says. Many became despondent to even try new suggestions, she says.

An important point that was raised was that current water allocation regulations do not account for costs incurred by farmers if less water is used for irrigation. Consequently, there is little incentive for farmers to use less water than what is allocated to them. "If they don't use the water, they still have to pay the full amount," Phadu says. "Like any other business, profitability and production is the main thing. As such, once a farmer gets water [and has to pay for it], they want to turn it into pasture, to turn into milk, especially because pasture is the cheapest source of food for the cows."



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More challenges included the time and effort necessary to change and/or adopt new methods and a lack of information to motivate the need for change or upgrades. According to the report, "Most farmers were not aware that their systems were not as efficient as they had been told, or farmers often stick to traditional methods of irrigation scheduling and are satisfied with their results."

Most of the farmers didn't know that it is possible for them to improve their own systems and management, Phadu says. Since they participated in the study, a number have addressed some of the highlighted issues and implemented better practices. For example, one farm has installed 12 water meters and serviced all his pivots, another fixed and replaced pumps. A number installed low-energy precision irrigation (LEPA) systems and fixed leaks in their pivot systems.

What can be done, and what should be done

The main thing for efficient water use, Phadu says is that you need to start measuring your water use accurately. Like a farmer said to me, she remembers, "You can't manage what you don't measure."

Water meters are integral, she adds. "You need to know how much water exactly is getting through to your pastures." Then, you need to know how much moisture is in your soil, and how much water your pasture needs. "Finally, you need a weather station to tell you the evapotranspiration, which is the crop water requirement. You need to maintain and service your systems as much as possible."

Phadu points out that the effort and initial financial costs are more than worth it. "If you're improving your irrigation efficiency, you're also improving your pasture water use efficiency. At the end of the day, this results in less water to produce first, more pastures and then, milk, at a lower cost."

Over and above that, the benefits extend to the ecosystem that the farmers rely on, improving the natural environment's capacity to support them, their broader community, and the future generations of farmers that will one day replace them.

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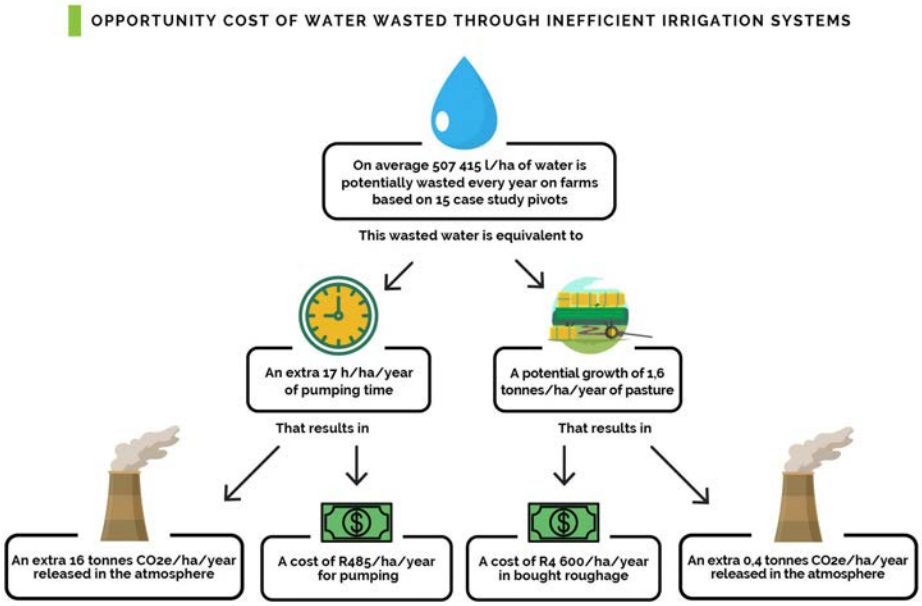

This flow diagram taken from the final report, describes the potential opportunity costs extrapolated from the average amount of water wasted due to inefficient application of irrigation in this study. System efficiencies measured during one irrigation event were used to estimate the amount of water wasted over the period of measured water use.

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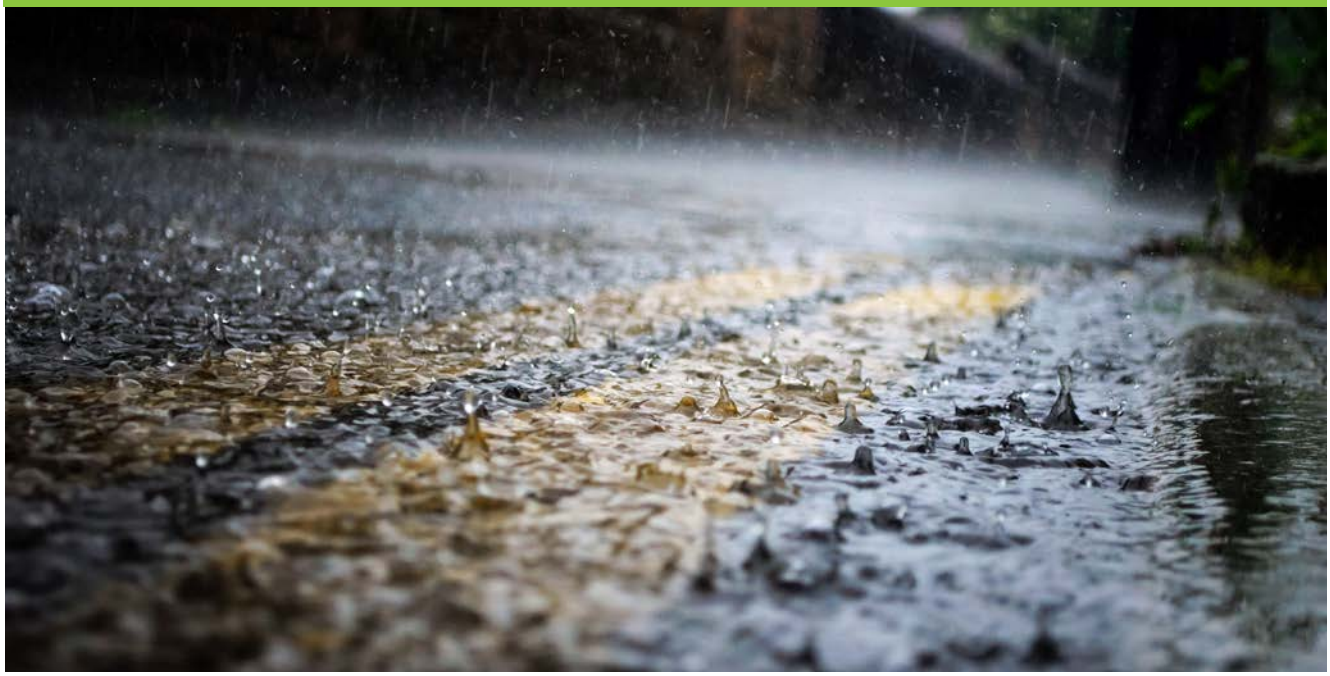
CITIZEN SCIENCE

Citizen science: Community-based early warning tools improve weather and climate risk awareness and resilience

Current experiences of weather and future projections of climate change and variability indicate the need for building adaptive capacity of governments, private sector and communities to prepare and respond accordingly. The impact of extreme weather is felt mostly at the community level and can vary a lot within a very short distance, therefore severe weather warnings need to be timely. So writes Michael Mengistu and Miriam Murambadoro.



Reflecting on the recent floods in Durban and Cape Town, Bonani Madikizela, research manager at the Water Research Commission (WRC), highlights that "Citizen science and early warning bottom-up approaches have been overlooked not only in South Africa but globally, as everyone has assumed a top-down approach would work to save lives during extreme weather events."

To overcome this oversight, the WRC is funding a three-year project on citizen science in support of weather and climate risk awareness for five vulnerable communities in South Africa. Currently in phase two, the project will run until March 2026. The project aims to develop a monitoring network for early detection of weather- and climate-related disasters to adapt and mitigate the impacts on livelihoods as well as build community resilience. The project team is led by Dr Michael Mengistu from the South African Weather Service (SAWS), along with scientists from SAWS and collaborators from the University of KwaZulu-Natal (UKZN), the University of Cape Town (UCT), and the United Nations Educational, Scientific and Cultural Organization (UNESCO).

The project aims to perform an intercomparison field study of low-cost citizen weather stations (CWSs) against standard professional weather stations to quantify bias and errors associated with CWSs; engage communities to assess risk knowledge and response capability based on indigenous knowledge systems (IKS); develop training materials for stakeholder outreach activities to build the capacity of citizen scientists and community knowledge of highly technical

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concepts and information on weather, climate, and early warning; co-design disaster early warning monitoring tools and networks; test or simulate the proposed disaster warning tools developed to improve community-based early warning systems and the community's response procedures.

The role of citizen science in weather and climate risk awareness

Weather and climate-related extreme events such as heatwaves, storms, floods, droughts, and wildfires are a threat to economic stability, natural systems, and human health, well-being, and safety. Marginalised communities at the rural and peri-urban levels are the most vulnerable to high-impact weather events. Communities in South Africa have had varied experiences with climate change-related extreme weather events, including the recent floods in KwaZulu-Natal and droughts in the Eastern Cape that have highlighted the social vulnerability of these communities. There is therefore a need to enhance policy and decision-making as well as community disaster risk reduction initiatives for both slow and rapid onset hazards. Other stakeholders such as private sector and civil society need to support citizen scientists as they learn about weather and climate change in their communities and develop an appropriate early warning system.

Scientific weather data and knowledge are crucial for monitoring and providing early warning services and systems, particularly in the most climate-vulnerable communities. The interaction between science, society, and technology is critical for weather, climate, and environmental monitoring, disaster risk reduction and management, and policy and decision-making thereof. Early warning system (EWS) aspects of risk prediction, monitoring and issuing of warnings have traditionally been conceived and produced in the traditional way of producing knowledge with hydromet services and disaster management authorities disseminating these to users (top-down), with limited input from users who are direct observers that live in the space in which the impacts of extreme weather are felt. The linear process, however, usually fails to align user needs with what science has to offer to stimulate shared learning and build the users' capacity to respond.

Through citizen science, communities can contribute to managing and reducing extreme weather risks that affect them by supporting bottom-up and top-down knowledge transfer and learning approaches. Citizen science is the practice of public participation and collaboration in scientific research to increase scientific knowledge. The citizen science approach allows the public to be more proactive and will assist in building resilience to extreme weather events through bottom-up and top-down knowledge sharing and learning.

Citizens also bring different knowledge types, including value-based information, such as that concerning people's perceptions, belief systems and cultures that influence how they perceive and respond to risks. Indigenous and local peoples' in-situ knowledge practices also have the potential to make significant contributions towards the citizen science approach for early warning knowledge and weather and climate risk awareness.

Citizen scientists could contribute to the early warning value chain by providing local data through observations and verification of forecasts. Therefore, weather data collected by citizen scientists can improve SAWS' local weather forecasts, and enable communities to respond more efficiently to extreme weather events. Through this citizen science project, SAWS will connect with the public and build capacity for communities' responses to impact-based forecasting. SAWS will provide support to citizen scientists by offering training on weather data collection, analysis, interpretation, quality control, and archiving. Additionally, citizen science has the potential to help improve the accessibility and sharing of warnings as well as provide disaster management officials, decision-makers, and scientists with ground-truth data to verify and disseminate warnings.

Co-designing and co-production of early warning tools

This study is being implemented in five study areas in KwaZulu-Natal, Limpopo, Gauteng, the Eastern Cape, and the Western Cape provinces in collaboration with communities, volunteers (citizen scientists), government departments and civil society organisations to co-design disaster early warning monitoring tools and networks that will improve community-based early warning systems and the community's response procedures. The enrolment of citizen scientists from the study sites is being undertaken using citizen science engagement, which comprises four phases.

The first phase, which has been completed, was the initiation/crowdsourcing phase where workshops were held with participants to co-create an early warning shared vision for their respective communities, share the objectives of the study and identify volunteers. The second phase of the citizen science process (underway at the time of writing) is the development phase, whereby community engagement workshops are held to assess their knowledge of climate risks in their respective communities (community risk assessment), drivers of vulnerability, early warning, and current adaptation or response mechanisms (assets and capabilities) available, which includes the knowledge from local IKS.

The third phase is the live phase where citizen scientists will be trained on how to collect, interpret, and disseminate weather information from their simple automated weather stations. Participatory community engagement tools will be used to co-design and co-develop early warning tools for each community,

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The project team training Viva Foundation School learners in Mamelodi (Gauteng Province) on weather and climate monitoring during phase 1 of the citizen science project.

Photo supplied

The project team and citizen scientists at Viva Connect School in Cullinan, Gauteng, demonstrating how the citizen weather station (CWS) works.

including how best to disseminate impact-based warnings from SAWS. The fourth phase of the citizen science approach will be the reporting phase, whereby the activities and lessons drawn from the study sites will be compiled into a report and other community preferred communication platforms, including social media. Citizen scientists will also receive certification to commend them for their role and competence in citizen science.

In addition, the citizen scientists will be trained to monitor the stations and will continue with this role with support from relevant local government departments and other stakeholders upon completion of the project to ensure the sustainability of the early warning system. The project will also include a component of building interest among the youth and schoolchildren in meteorology, hydrology, and environmental science so that more students enrol in these fields of study at universities to meet the critical skills gap in South Africa. Future work should include incorporating these lessons learned into an education curriculum statement so that every school in South Africa has access to information on weather extremes, preparedness and resilience within the global change context.

Intercomparison of low-cost citizen weather stations

The study will also include an intercomparison field study of low-cost citizen weather stations (CWSs) against standard professional weather stations. This intercomparison analysis is necessary to identify instrument performances (validation and quality control/assurance), biases, and dependencies. Different models of popular low-cost automatic weather stations (AWS), locally made weather monitoring tools, and standard SAWS AWS will be used in the intercomparison study. The sensor intercomparison study will be conducted in collaboration with a team from the universities of KwaZulu-Natal and Cape Town.

Please contact Dr Michael G. Mengistu [michael.mengistu@weathersa.co.za] or Dr Miriam Murambadoro [Miriam.murambadoro@weathersa.co.za] for more information on the project.

Photo supplied

Local weather information collected from CWS stations will also benefit small-scale farmers. Here the project team is engaging small-scale sugarcane farmers in Swayimane (KwaZulu-Natal Province).

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WATER LOSS

Study touts artificial intelligence for water loss tracking

Cloud-based artificial intelligence technology is the way to go for leakage management, according to a position paper from the Water Research Commission (WRC) position paper. Article by Sue Matthews.

Although artificial intelligence (AI) has been an integral part of our everyday lives for some years now – influencing what we see on social media, streaming platforms, online shopping and internet searches, for example – perhaps nothing has brought home its practical applications as much as ChatGPT, launched in November 2022. Now the vast potential of AI is being more widely recognised, so it should come as no surprise that the technology has a role to play in reducing non-revenue water (NRW).

Typically defined as the water provided by utilities – such as municipalities, water boards and other water service providers – but 'lost' before reaching the customer, NRW includes both real (physical) losses and apparent (commercial) losses. In other words, real losses are due to leakages from water distribution pipes and their connections, while apparent losses represent water for which no revenue is received because of illegal water consumption, deliberate non-payment and inaccurate metering.

Honing in on leakages specifically, a market analysis identifying trends and developments in leakage management technology was recently undertaken as part of a WRC project. The findings are outlined in a position paper titled 'Next generation water loss tracking, compliance, management, and performance solutions', written by the project team of Alisha Syal, Elizabeth Court and Jo Burgess of Isle Utilities, together with the WRC's Executive Manager for Water Use and Waste Management, Jay Bhagwan.

The focus on leakages was warranted, because about 40% of water 'produced' in South Africa is lost in this way, compared

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to about 6.5% representing other forms of NRW losses. The 2022/23 No Drop Watch Report, released in early June, revealed that the Infrastructure Leakage Index for the 2021/22 municipal financial year had peaked at 6.4 in 2022, following signs of improvement in 2017 and 2018. The increase in leakage-related water losses was attributed to the COVID-19 pandemic, which resulted in operations and maintenance budget cuts and a lack of capacity in municipalities to undertake repairs, due to ill health and deaths. However, the report was based on data submitted by only 42 of the 144 municipalities that are water services authorities (WSAs), and then extrapolated to those that did not submit any information. A more accurate picture should emerge once the full No Drop Report covering the 2022 audits is published.

In their position paper, the project team point out that minimising leakages is not just about reducing water wastage and ensuring municipalities don't lose their product before it can be billed to a customer (any leaks on a customer's property will obviously be for their own account). The water-energy nexus means that more efficient water distribution will save electricity too, because pumping water through the distribution network consumes massive amounts of energy. Indeed, the authors report that the City of Toronto saved US$1 million in energy costs annually through optimal pump scheduling alone. Of course, treating raw water to a potable standard that is ready to be distributed also uses electricity and requires chemicals, human resources and ongoing maintenance – and that's just the operating costs.

Apart from reasons related to financial sustainability, reducing leakages will increase customer satisfaction and improve public opinion of a municipality's competence and enviro-social responsibility, because people generally don't take kindly to water supply disruptions, low water pressure, and precious water spewing from broken pipes.

The project team note that water loss tracking and management consists of four fundamental pillars: pressure management, active leak detection, asset condition monitoring, and smart analytics. Cloud-based smart analytics platforms allow all four to be integrated, and there is growing competition within this rapidly evolving field between large and small technology providers. The large players include established companies such as Royal HaskoningDHV and Xylem, which have extensive experience in producing or implementing a range of smart technologies. The smaller companies include FIDO Tech, a UK-based start-up that has extended its reach internationally.

The company was approached by Thames Water, which serves some 10 million customers in London and surrounds, to help target leakage in a defined area. The FIDO AI algorithm analysed more than 35 000 sound files collected by acoustic loggers over the previous four months in just 2.5 hours, returning a report that Thames Water compared with its own leakage repair records and dig data. An analysis was then conducted on the entire logger estate of 27 000 devices so that Thames Water could decide whether to replace or maintain its existing loggers. Daily reports allowed Thames Water to identify 33 points of interest for follow-up, 11 of which led to the discovery of misaligned loggers and 20 correctly confirmed as leaks or not leaks (including four customer side leaks), representing an accuracy of over 92%. In its 2022/23

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The latest available figures suggest that around 40% of municipal water is lost to leaks.

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financial year, Thames Water fixed more than 66 800 leaks and has committed to replacing 112 km of the leakiest water mains pipes across London. This should ensure a daily saving of 27.8 million litres of water, equivalent to 11 Olympic-sized swimming pools every day!

The FIDO solution was just one of 35 identified by the project team through a technology scan, and all but two had cloud-based capabilities. "Cloud-based systems enable multiple users to access a GIS system at one time, whilst further enabling operators to download and publish maps to the internet," they note. "Furthermore, operators can now leverage cloud-based AI and analytics to analyse spatial data without having to install additional on-premises software or hardware."

The benefits of GIS mapping are clear – a cluster of leaks, even if repaired, may indicate that a pipe needs to be replaced. But cloud-based AI enables real-time monitoring of pipes, pumps and reservoirs, and when coupled with predictive analytics can provide early warning signs of potential failures, enabling proactive action to prevent system disruptions and optimise maintenance schedules. Cloud-based platforms can also be integrated with customer communication systems to send out notifications of when leak repairs or pipe replacements will be carried out, while AI-powered chatbots or virtual assistants can respond to customer queries and provide information and suggestions.

There are also opportunities to integrate customer billing systems – data that has previously only been used for billing can also be used to identify leakages. This is already possible with the smart meters that are being rolled out in many South African municipalities. Apart from allowing more accurate billing and remote reading, the smart meters detect excessive usage and water leakages, and instantly send an alert to the customer via email and SMS.

But getting municipalities to take the extra step of integrating the meters into a cloud-based platform with smart analytics capable of aggregating and visualising data from various loggers, sensors and other sources may be a bridge too far.

"Water utilities are generally conservative when it comes to investing in new software, often preferring the stability of legacy solutions rather than embracing new digital platforms," they note, adding that utilities may also remain resistant to paying the monthly OpEx fees associated with cloud-based systems. There are concerns about data security and cybersecurity, as well as uncertainty in less-developed markets as to whether GIS software offers a clear return on investment. Uptake of GIS may be particularly limited in municipalities where little information is available on an ageing network of underground and inaccessible pipes, never properly mapped.

Furthermore, field technicians and control room staff tend to be reactive, typically only responding to leaks and alarms, so a change in mindset will be needed for them to adopt a more proactive, predictive approach that allows them to detect events before they cause significant incidents. "However groundbreaking or cutting-edge a technology is, its full potential can absolutely not be realised without behavioural change and

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Water leaks are not always as spectacular as this burst water main, however, they present a real problem for South Africa's water service providers.

the correct attitudes to use the system and achieve the most effective results," note the project team. There may also be a skills gap within the organisation, requiring specialised expertise to implement cloud-based platforms and AI technologies.

Of course, AI and machine learning tools are only as good as the data available to them, so the project team make a number of recommendations to prepare utilities for the way forward. For example, centralising existing datasets and adopting common data standards across the organisation will be crucial to providing better data accessibility, and data literacy should be prioritised in training and recruitment. But sharing and integrating data should be seen as just one component of interdepartmental collaboration – staff will also need to be able to communicate better across departments if the silo mentality is to be overcome.

Addressing concerns over data security and cybersecurity, the project team suggest implementing a central hub to be managed by a neutral science council, such as the WRC's Research Observatory, or housed by the soon-to-be Water Infrastructure Agency. They point out that the South African government has been working to finalise the National Data and Cloud Policy, which will provide guidelines and recommendations for the adoption and utilisation of cloud services in both the public and private sectors. Regardless, water utilities need to strengthen their capacity to determine gaps in security technologies and improve their risk-management approaches.

"Defending critical infrastructure is a cat-and-mouse game, forcing water utilities to stay on guard, innovate constantly, and implement new technologies," they state. And to ensure utilities take their responsibility to address leakages and other water losses seriously, whether or not they embrace the latest technologies, they conclude the position paper with a strong standpoint: "Stricter regulation is required whereby NRW targets are set and penalties issued if they are not met."

WATER RESOURCE MANAGEMENT

Dead Sea: Death march or turnaround strategy?

Throughout history, the Dead Sea basin has served as a source of refuge and inspiration for followers of Judaism, Christianity and Islam, writes Handré Brand. Today, the religious significance of the Dead Sea is being overshadowed by its rapid disappearance. Institutional, social, gender and economic issues related to water management options for the Dead Sea basin are thus far more complex than what is currently envisioned by engineers and policymakers. These issues need to be addressed adequately to achieve equitable and sustainable water management (Lipchin 2006).

The Jordan River drainage area forms a unique and delicate freshwater ecosystem. It stretches from the Lebanon Highlands and Hermon Mountain ranges to the Dead Sea over a distance of 223 km in a north-south direction. The height of the water level of the Dead Sea is (at the time of writing) indicated as 437 m below sea level. This is consequently the lowest-lying landmark on Earth (Sevil and Gutiérrez 2023). The salt concentration of the water is about 340 grams per liter.

Today, the Dead Sea area is experiencing serious environmental problems, such as a decrease in the water level, increases in the salinity of the water, and the emergence of sinkholes on the shore. It is crucial to investigate the causal factors of the phenomena and put together effective action plans to conserve and efficiently maintain the Dead Sea and the Jordan River Rift Valley as natural assets.

The relatively rapid decline over the past few decades in the water supply from the Jordan River to the Dead Sea and the accompanying sinkhole crisis may be indirectly linked, according to Popperl (2018), to two important historical disputes over the Dead Sea Valley's economic resources. First, as early as 1920, the British Mandate governments of Palestine and Jordan granted prospecting rights to Jewish industrialist, Moshe Novomeysky, to mine potash and other minerals in the Dead Sea area. In 1952, the Israeli government took over Novomeyski's interests, centralised the industry, and established the Dead Sea Works Ltd. This industry pumps salt water on a large scale from the north to evaporation coils in the south in order to extract minerals.

The second issue concerns Israel and Jordan's ongoing competition to obtain water rights from the Jordan River. This dispute has resulted in several million cubic meters of water

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being diverted annually from the Sea of Galilee to the Israeli National Water Canal System, below the Deganya Dam.

Professional water management is crucial to ensuring that the available and precious water resource is distributed equitably among the interested riparian countries (especially Israel, Jordan, and the Palestinian Territories as well as Lebanon and Syria to a lesser extent), while still maintaining the ecological balance of the Dead Sea ecosystem. The Jordan River, the main source of water for the Dead Sea's supply, is experiencing a significant decrease in water flow, ***inter alia***, related to human activities such as regional population growth, agricultural development, and domestic use.

Therefore, it is essential to compile innovative water management action plans in order to avoid further disagreement and conflict. Should the drastic deterioration of the Jordanian system continue, it will have serious geopolitical implications for all interested parties and the risk of reaping the (dangerous) fruits will become an unpleasant reality.

According to Nissenbaum (1993), the economic significance of the Dead Sea region can be seen above all in its historical role in relation to tourism, industrial development, and agriculture. The Dead Sea area yields agricultural products such as salt, potash, and bromide, as well as sugarcane, dates, and balsam. Asphalt deposits have been used for waterproofing purposes and other religious rituals such as mummification from time immemorial. The water of the Dead Sea possesses therapeutic and medicinal properties, and this hyper-salty water source (water with salinity higher than sea water) is particularly popular among tourists.

However, declining water levels and environmental degradation pose a threat to all sectors. Therefore, studying the potential future of the Dead Sea can provide valuable insights into promoting sustainable economic development and securing individuals and groups that rely on the region's resources. In this regard, physical geographer Ibrahim Oroud (2023) tested a hypothetical energy balancing model based on a monthly time interval of 800 years. The aim of the study was to predict the future (simulated) height of the water level, total water area, and water temperature of the Dead Sea under different scenarios such as varying freshwater inflows and a wide spectrum of atmospheric variables.

Projections suggest that the Dead Sea is developing toward a reduced hypersaline hot lake (dwarfed hypersaline hot lake). The period necessary for the Dead Sea to reach a quasi-stable equilibrium spans hundreds of years. However, simulation and forecasting data such as the above should always be treated as approximate information, due to the complexity of the systems involved, the long integration period involved, and uncertainties caused by variations in the local climatological variables.

The Dead Sea region contains a wealth of geological and archaeological artifacts, providing valuable insights into Earth's development history and ancient civilizations. It is at the same time an artifact of tectonic activity. Further research by climate professionals and the environmental and geosciences are determinants in understanding past climatic conditions, changes in the landscape, and human history, thereby fostering an understanding of the environment's history and its significance for the future.

The Dead Sea area is constantly exposed to global heating and climate changes such as modified rainfall patterns and rising temperatures. The surface temperature of the Dead Sea area rises by about 0.6°C per decade (Kishcha 2018). Climate changes should necessarily have a further impact on the saltwater lake and surrounding karst topography just as is the case with comparable regions such as the Great Salt Lake in Utah.

The purpose of this article is to discuss some points of view regarding the falling water level of the Dead Sea and to raise the question of whether a reversal to limit this escalating natural disaster is a feasible possibility.

Sinkhole development

According to Sevil and Gutiérrez (2023), the development of sinkholes is geomorphic in nature. Briefly put, it is a process by which the Earth's surface is altered by physical and chemical factors. Sinkholes are responsible for increasing economic losses worldwide. The presence of sinkholes in the highly dynamic salt rock (karst) of the Dead Sea is a striking example of the way in which human behavior increases the risk of sinkhole development.

Since 1980, the coastal area of the Dead Sea has been characterised by the emergence of thousands of sinkholes because the level of salt water is constantly decreasing. The relatively rapid development of sinkholes in the Dead Sea area presents an extraordinary opportunity to study their evolution. The evolution of the morphometry and distribution of sinkholes provides essential information on which risk assessments for future trends are based.

Sevil and Gutiérrez (2023) conducted multi-temporal cartographic analyses in a specific sector on the west shore of the Dead Sea. The database allows for aerial and satellite footage, high-resolution three-dimensional photogrammetric models, and fieldwork. The sinkholes mapped by these researchers indicate singular, small, relatively shallow, and semicircular sinkholes located within larger sinkhole basins. From 2005 to 2021, 702 new sinkholes appeared in the area in which the surveys were made. An average subsidence rate of 45 cm/year was calculated for the karst area where sinkholes occur.

There are currently over 5 000 mapped sinkholes in the Dead Sea Area (Yizhaq, Ish-Shalom, Raz, and Ashkenazy 2017). These sinkholes are observed mainly along the edge of a salt layer deposited during the Plio-(youngest) Pleistocene epoch. The bigger Lake Lisan (precursor to the Dead Sea which stretched 70 000 to 15 000 years BC to the Sea of Galilee) retreated during this epoch, thus forming the present smaller Dead Sea (Frumkin, Ezersky, Al-Zoubi, Akkawi, and Abueladas 2011).

There exist two (and often conflicting) schools of thought about the causes of the emergence of sinkholes in the Dead Sea area (Ezersky and Frumkin 2013). One point of view is that the sinkholes are structurally controlled and are limited to tectonic fault lines, based on observations and data obtained through seismic surveys. According to this, the sinkholes are therefore basically fault-line-induced.

The second explanation model emphasises that sinkholes arise as a result of the solution of subsurface salt layers due to the displacement of hypersaline (hypersaline) groundwater

by brackish/unsaturated groundwater with lower salinity (Frumkin ea 2011). This amounts to aggressive (or unsaturated) groundwater draining from adjacent and underlying Judea aquifer (see the sketch below) into the lower-lying Dead Sea and in this way promoting sinkhole formation.

In conjunction with this, sinkhole formation is indirectly promoted by the sharp decline in the Dead Sea's water level (with a drop of 34 m over the past 50 years and more recently increased at a rate of more than a meter per year).

Finally, regarding the effective monitoring of sinkhole formation in the Dead Sea Region, Ezersky et al (2014) recommends the following mode of operation: "Only a careful ground monitoring policy, year after year, coupled with geophysical measurements could allow the setting up of a predictive model concerning the propagation of hazards".

Evaporation

Shafir and Alpert (2011) conducted a pan-evaporation study in the vicinity of Sodom off the coast of the southern Dead Sea. Natural evaporation is an essential meteorological parameter especially when it comes to the industrial sector in the Dead Sea area.

The results of the study suggest that pan evaporation has increased by 20% to 25% over recent years. The causes are attributed to changing global and local climatic conditions. Global changes refer to the effect of global heating, as a result of which the frequencies of some synoptic systems in the region have been modified. The local causes refer to the falling water level of the Dead Sea resulting in a flattening in the frequency of the local Dead Sea Breeze. The Dead Sea Breeze usually tempers the local climate in the area.

Mediterranean Sea winds penetrated the Dead Sea area over time, displacing the neutralising effect of the Dead Sea Breeze on which increased evaporation followed. According to the researchers, flattening of the local wind factor was the dominant cause of increased evaporation between 1970-90. As a result, the temperature rose and the relative humidity decreased. However, at the present stage, global heating plays a crucial role in increasing evaporation, while the local factor is of secondary importance.

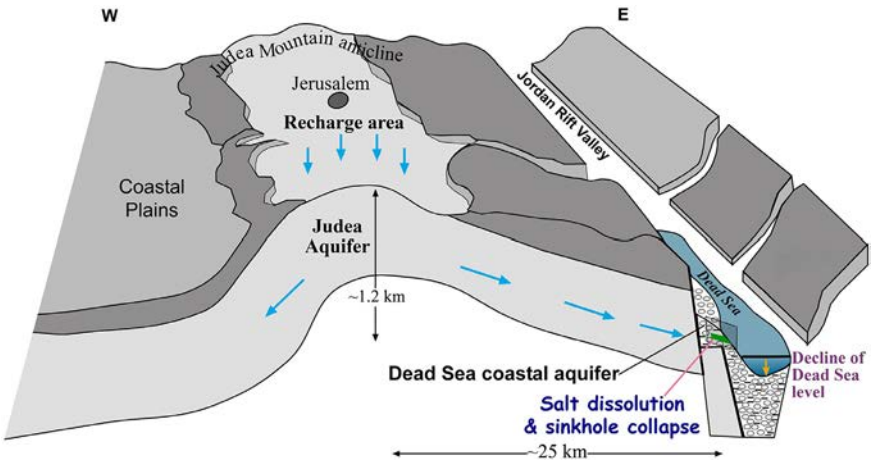
Effective water management in the Jordan River Valley

The natural flow from the Jordan River to the Sea of Galilee is estimated at 50-550 million m^3 annually (Katz 2022). In addition, the river receives an average of another 300 million m^3 annually due to direct rainfall, direct inflow of surface water, and spring water. It is then also more or less equal to the volume of water lost through evaporation. The lower-lying areas of the Jordan (between the Sea of Galilee and the Dead Sea) are fed by smaller connecting rivers such as the Yarmud, for example. The total annual discharge from the Jordan to the Dead Sea is estimated at 1 200-1 350 million m^3 per year.

The Jordan River Valley is currently under intense water pressure (hydric stress). Further complicating the assessment of the situation is the limited nature of the diverse sources of information and datasets available for research purposes, which greatly complicates their reliable interpretation. Obtaining reliable and long-term data related to climatology as well as water availability and use patterns is almost an impossible task (Comair, Gupta, Ingenloff, Shin, and McKinney 2013).

Becker, Lavee, and Tavor (2012) propose supplementing the 300 million m^3 of water pumped annually from the Sea of Galilee via a canal system to the central parts of Israel supplemented with water from desalination plants on the coastal strip of the Mediterranean Sea. This solution should prevent the water level of the Sea of Galilee from being constantly reduced. As a result, more water will be placed in the Jordan River drainage system and at the same time, provide a greater downflow to the Dead Sea.

Against this backdrop, Israeli water planners have begun to design a reverse national water channel system (Katz, 2022). The idea is that desalinated seawater is transported from the Mediterranean coast to the Sea of Galilee using a pipeline (located directly next to the canal system that carries water from the Sea of Galilee) from the Mediterranean coast to the Sea of Galilee. However, there are quality differences between desalinated water and the water of the Sea of Galilee in terms of



Schematic relationship between the eastern Judea aquifer and the Quaternary coastal aquifer of the sedimentary fill of the Dead Sea rift. (Source: Abelson, M, Y Yechieli, G Baer, G Lapid, N Behar, R Calvo, and M Rosensaft. 2017. Natural versus human control on subsurface salt dissolution and development of thousands of sinkholes along the Dead Sea coast. Journal of Geophysical Research: Earth Surface, doi:10.1002/2017JF004219.

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acidity and other parameters. Thus, desalinated water cannot be let directly into the Sea of Galilee. It was then decided to release the desalinated water into a dry course (wadi), after which it flows over several 100 m using gravity to the Sea of Galilee. In the process, the desalinated water absorbs minerals and in this way, the chemical composition changes on its way to the Sea of Galilee. An artificially perennial tributary of the Jordan is thus created, from which the Jordan Valley and the Dead Sea consequently benefit immensely in terms of inflows.

The purpose of innovative water management in the Jordan region (Comair ea 2013) should meet the following criteria: (a) to promote reverence and respect for water in the consumer; to encourage reduced consumption; to better check the consumption of water; to use water more efficiently; to exploit unconventional water resources; to promote the use of purified greywater. (b) Improving the quality of existing data and information production systems to correct the current information imbalance. However, it is important to bear in mind that water management plans must be interpreted in terms of the complex context of these arid environments, intense needs for more water for local urban and rural consumption, profound cultural and political-ideological issues, suspicion, militarized boundaries, lack of trust and the frequent surge of disputes between the interested riparian countries.

Plans to connect the Mediterranean with the Dead Sea, or the Red Sea with the Dead Sea have been around for more than 100 years (Katz 2022). According to Comair ea (2013), this remains an important and relevant consideration for the essential addition of additional water to the system. However, the plan to finalize a canal link between the Red and Dead Seas was unilaterally canceled by Jordan in June 2021 because Israel (according to Jordan) "does not really show interest in the plan". The initiative was delayed for years by bureaucratic obstacles, funding issues, objections by environmentalists, and a lack of a properly functioning government in Israel over a two-year period at that time.

According to a recent online article (June 22, 2022) by Nir Hasson in Haaretz/Israel News, the Israeli Ministry of Environmental Affairs once again called on the Israeli government to dust off this infrastructure project again and put it on a fast track soon.

Concluding perspective

Is it possible that a meaningful turnaround can be accomplished? Is the return to the paradisiacal landscape described in Genesis 13:10 feasible today? "Lot looked around at the fertile plains of the Jordan Valley toward Soar. The whole area was water-rich, like the garden of the Lord or fertile Egypt".

A simplistic answer to this question is impossible, due to the nature of the underlying complex systems being worked with. Various issues such as physical, chemical, geopolitical, military, economic, psychological, and anthropological factors all contribute proportionately to the maintenance of a multi-faceted dilemma. These factors threaten to maintain the status quo and consequently the "death march" of the Jordan River-Dead Sea ecosystem.

Simply releasing larger quantities of water into the Jordan Bowl, either via canal connections from the Red Sea and/or the Mediterranean, should provide temporary relief for the Dead Sea, but it is not necessarily a sustainable long-term solution. The crux of the problem lies in consumers' internalised attitudes towards efficient water management and consumption. Echoing this, Lipchin (2006) points out that the centralisation of the Jordan River's water management system forces policymakers to look through a clouded lens at the way in which consumers respond to current water management policies.

This short-sightedness prevents the consideration of new policies such as the devolution of power to local authorities (provided that characterized by thorough, adequate, and professional management). The water use culture of communities should serve as the foundation on which amended and sustainable water policies are built. In short: by increasing the volume of water added to the system and modifying the current water use patterns using well-thought-out training programmes, then a gradual and realistic reversal of the death march is possible.

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ROODEPLAAT DAM – PROVIDING ESSENTIAL WATER FOR URBAN USE

The Roodeplaat Dam was constructed in 1955-1959 by the then Department of Water Affairs, originally to serve farmers in the Pienaars River area. The dam is located 25 km northeast of Pretoria at the confluence of the Pienaars River, Hartebees Spruit and Edendal Spruit. Roodeplaat is a 54 m-high concrete arch dam with a marked vertical curve, and features a spillway section of 143 m long. The dam has a storage capacity of 40 million m^3. At the time of its completion, it was the highest dam of its type in the country. The dam has a crest length of 351 m and features Roberts' splitters, a uniquely South African intervention first used on the Loskop Dam in the 1930s to dissipate the energy of water flowing over the dam wall.

In the construction of the dam, a blend of ordinary Portland cement and milled granulated blast furnace slag was used for the first time by the department. This pozzolan, or cement extender, is a blast furnace waste product, and made it possible to reduce the quantity of cement used. Today, the dam serves as an important urban water supply. In 2006, two new layers of outlets were added to create a five-level abstraction facility under full operational level. Water quality has been an issue, with Roodeplaat Dam receiving treated effluent from nearby wastewater treatment works, causing eutrophication. The dam has also been invaded by alien invasive water hyacinth, impacting recreational activities.

Tony Moore

A close up of the Roberts' splitters on the dam wall.

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

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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