LEGACY

CELEBRATING SA'S WATER PIONEERS,
PATHFINDERS AND MAVERICKS

WATER
RESEARCH
COMMISSION

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FOREWORD

By the WRC CEO, Dr Jennifer Molwantwa

South Africa's complex water situation has called on the local water and sanitation community to continuously explore innovative and creative solutions in the country's pursuit of water security for its entire citizenship.

Over time, some of these specialists have risen to become world renowned and award-winning pioneers – doyens who have dedicated their careers to new discoveries, trailblazing a new path towards South Africa's sustainable development. In the process, these thought leaders and innovators have not only steered the South African water sector in their respective fields but have inspired whole new generations of young water professionals to follow their example. In recent years, their generous mentor contributions have also aided the transformation of the sector.

The dedication of these experts to their craft have laid the foundation of South Africa's ground-breaking water policies and legislation, and underpinned the methodologies and tools used to manage water for the good of society and the environment.

By 2021, the Water Research Commission (WRC) had enjoyed 50 successful years of servicing the water research, development and innovation needs of South Africa with major contributions to the global environment. It has over this time become a 'glue institution' for the South African water research and innovation community of practice comprising some 3 000 researchers, innovators and entrepreneurs operating from universities, public research entities, large corporates and SMMEs.

The Commission is commemorating a handful of South African water and sanitation specialists, whose remarkable careers have left a lasting legacy on the South African water sector. This publication is a small attempt at sharing their inspiring careers and preserving some of their wisdom and knowledge for future generations. Many of those featured in this publication started their careers as students on WRC-funded projects. Their tales are truly remarkable, and speak of passion, dedication and hard work. While all their life stories might be unique, their goal has been the same – to make South Africa a better place for all who live in it through practical application of water security research, development, innovation and technology.

We are grateful for the time spent in sharing their stories with us for this publication. The compilation of this book was not without tragedy – two 'legacies' passed away during the compilation of this publication, Prof Chris Buckley and Rowena Hay. We

Legacy (noun):

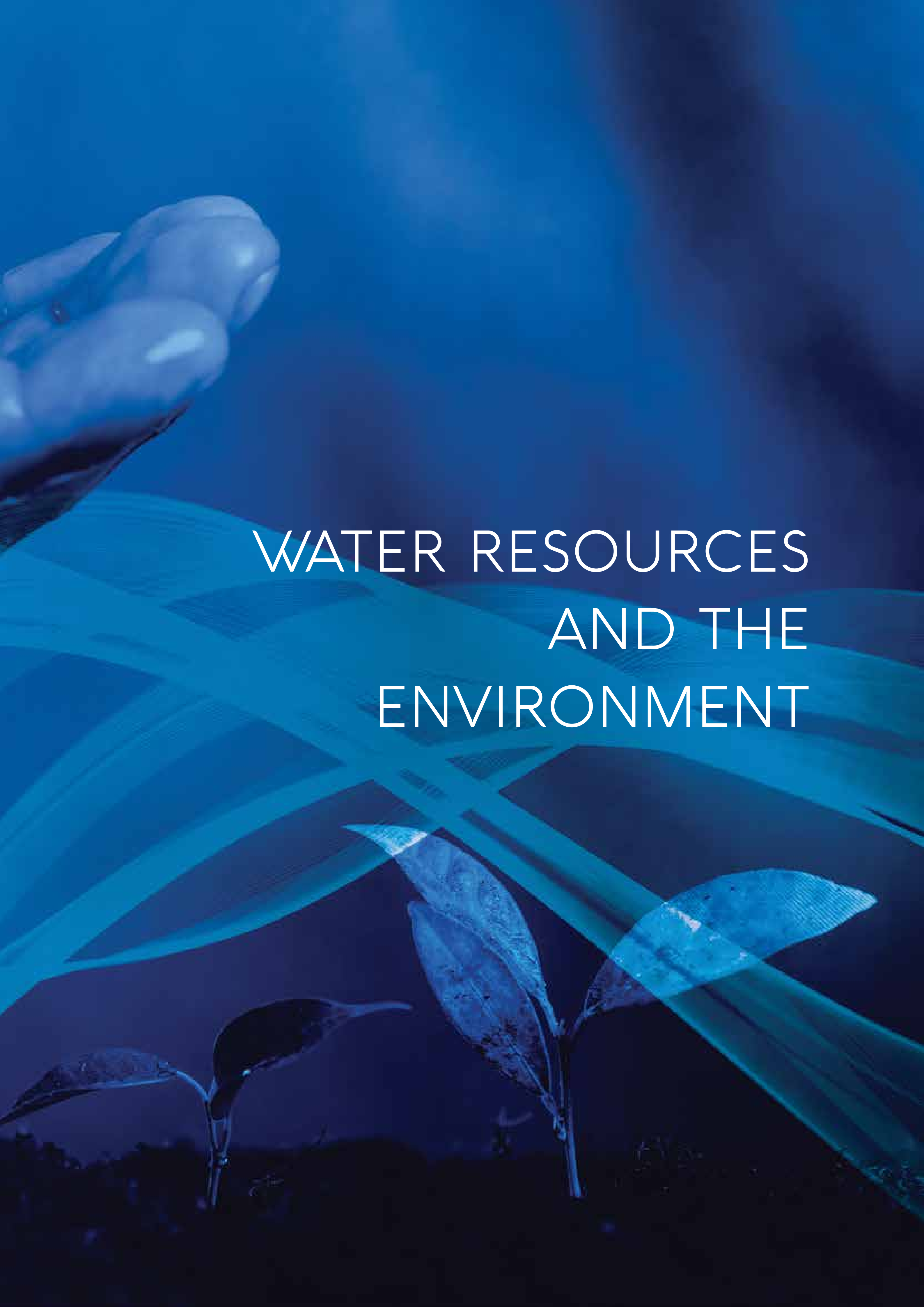
Something transmitted by or received from an ancestor or predecessor or from the past.

are deeply appreciative to their colleagues, friends and family for allowing us to publish their stories.

In the next 50 years WRC commits to transforming the landscape of researchers by committing to developing and supporting young upcoming researchers from universities that have not enjoyed much support in the past. The WRC researcher output will be biased towards females and youth in the production of highly skilled water sector professionals that will contribute to meeting the National Development Plan and 2030 Vision targets.

Dr Jennifer Molwantwa

WATER RESOURCES AND THE ENVIRONMENT



Dr Joel Botai

Photo credit: Petro Kotzé

JOEL BOTAI

Working in the clouds to
make a difference on the ground

Current position:
Chief Scientist at the South African Weather Service (SAWS)

Research interests:
Data science, advanced numerical and computational techniques as well the development of early warning systems with climate sensitive sector applications

Award

AWARDS

2021: WRC Legend Award

From small beginnings, Dr Joel Botai's career has taken him to the ionosphere and back to earth. He is the Chief Scientist at the South African Weather Service (SAWS), and is driven to use his knowledge of what happens in the atmosphere to improve the lives of communities on ground-level.

Botai is interrupted midway through his explanation of the intricacies of the upper atmosphere by a cock that lets rip with a deafening crow in his backyard, where the interview is taking place. An expert in space sciences, he knows the sound well, he says. That's how he used to wake up every morning at 03:30 to take the cows out to graze. "We were toughened up from the beginning". Botai grew up in the small Kisii village in the mountains of rural Kenya, where his father grew onions, tomatoes and tea on their family farm. Still, even as a kid, Botai had a knack for academics. When his duties on the farm were done, he would still revise his work before leaving for school, so he was always a step ahead of the rest.

Botai was initially sent to study to become a teacher, but university opened his eyes to worlds far beyond the Earth's surface, propelling him right to the edge of space.

Going to 'space'

At the Moi University in Kenya, Botai combined his Bachelors degree in Science Education with majors in mathematics and physics. After he won a bursary for a Master's in Engineering at the Chalmers University of Technology in Sweden, his

Since 2015, Dr Botai has been leading a team of scientists that research and develop weather and climate products and services to support strategic sectors of the economy.

Photo credit: Petro Kotzé

focus was set on advanced space techniques and earth observation satellites. Sweden was already part of the International Square Kilometre Array (SKA) steering committee (together with Australia, Canada, China, Germany, India, Italy, the Netherlands, Poland, the United Kingdom and United States) an initiative with its roots in the Large Telescope Working Group, a worldwide effort to develop a next generation radio observatory. In 2005, the year that Botai joined Chalmers, the committee expanded to include 21 members, including South Africa.

It was an immense opportunity for the young student, though the benefits were hard won. Fresh from Kenya, Botai was the only black person in class, with no prior computer skills

...university opened his eyes to worlds far beyond the Earth's surface, propelling him right to the edge of space.

and, since the bursary only covered tuition, he had to find work in the comparatively alien city of Gothenburg to support himself. Regardless of the challenges, he did well in the programme that largely contained engineering content, and became well versed in the specialist equipment that the course gave him access to, namely part of the network of large telescopes scattered across the globe.

These skills made him a star attraction to facilities with similar equipment. On completion of his year in Sweden, he joined Rhodes University for a second Master's in Astrophysics, the branch of space science that applies the laws of physics and chemistry to explain the birth, life and death of stars, planets, galaxies, nebulae and other objects in the universe. Botai conducted his research on ionosphere modelling for Radio Astronomy applications, while working as a research assistant at the Hartebeestshoek Radio Astronomy Observatory.

On completion of his second Master's in 2006, Botai accepted a position as a junior lecturer at the University of Pretoria. He describes his near decade stint there as a career highlight, one during which he would be promoted to Senior Lecturer and, his personal research interests would take a turn to a whole new level of the airspace.

The University of Pretoria years

Botai was tasked with establishing a remote sensing undergraduate programme at the university to grow capacity in the field of earth observing satellites. He based his teachings on the principles of physics. "We could apply remote sensing techniques for various analysis, including environmental monitoring and even water resource mapping."

Botai himself felt like he wanted to take a new approach to his research. He wanted to do work that had a real impact on people. For his PhD he made a "huge jump". To date in his academic career, he had been dealing with the upper atmosphere, the ionosphere, there where Earth's atmosphere meets space. Now, he moved to the lower, neutral atmosphere, where multiple parameters, including air temperature, atmospheric pressure, humidity, precipitation, solar radiation and wind determines the weather. He did his PhD in Meteorology, focusing on the movement of electromagnetic waves between the sun and the surface of the planet.

With his PhD, Botai moved his field of specialisation to the lower atmosphere, and launched his career in meteorology.

Photo credit: Petro Kotzé

“We try to develop solutions that will help society.”

Key project: Sustainable water-based agricultural activities in rural communities, from theory to practice: Developing a case study and guidelines for Water-Energy-Food (WEF) nexus implementation in Africa

The aim of the project is to conduct a state-of-the-art WEF nexus assessment for any region in the African continent. Two case studies were identified, one in South Africa’s Limpopo Valley and another in the Mara catchment in Kenya, that will form the basis for the development of guidelines for WEF nexus implementation in Africa. Basically, we want to create a system to account for water, energy and food resources in the future, Botai says. We are looking at the interdependencies of the three resources and their current and potential future states in order for planning on country, district or municipal level. The tool will allow different scenarios to play off, including for example, the potential impact of renewable energy.
The multi-institutional project will run until 2023.

On top of his studies and teaching responsibilities, this period also introduced Botai to consulting work. Their unit at the university developed solutions based on tenders from partners or government departments, unexpectedly providing a gateway into new issues such as air and water quality.

The university was a humbling experience, Botai says. Upon his exit, it was heartwarming to see the network of students that he helped build up through the years, many of whom he still collaborates with. Botai admits that, as much as being a researcher, he is also a teacher. Today, he remains affiliated at the UP as an extra-ordinary lecturer, an honorary research fellow and more recently, an Honorary Associate Professor, at the school of Agriculture, Earth and Environmental Sciences at the University of KwaZulu-Natal and Adjunct Professor at the Department of Information Technology at the Central University of Technology in the Free State.

Yet, after eight years at UP, he felt like it was time for a change. Over and above that, when the position of Chief Scientist at the SAWS came his way, he saw it as an opportunity to express his need to work closer still with communities. Since 2015, Botai has been leading a team of scientists that research and develop weather and climate products and services to support strategic sectors of the economy.

Taking his science to ground level

The purpose of the SAWS Research and Innovation Applications group, managed by Botai, is to develop new and improve existing meteorological solutions to inform wise socio-economic choices. The group generates new scientific insights in atmospheric and related sciences in collaboration with relevant

His research has shown that the price of non-funding is much higher than the funding itself. "There's a lot to lose if communities are not prepared for the impacts of weather and climate."

stakeholders and works to expand the existing knowledge base and intelligence related to climate change.

"We have moved away from just generating weather and climate information, to translating or adding value to the data that's being collected, or to just build models that generate data," Botai explains. "We try to develop solutions that will help society." Initially, they worked in the water, energy and agriculture sectors but, as new questions arose, they also included socio-economic, health, aviation, marine and Disaster Risk Reduction sectors.

Botai can list many highlights. One is the Malaria Prediction System, which produces alerts for authorities on the possible outbreak of malaria. It incorporates climatic, environmental and socio-economic variables to enhance the implementation of interventions and so reduce the number of expected malaria cases and associated deaths. The system will be integrated with the Infectious Diseases Early Warning System, the bureau of which will be co-hosted by SAWS and The National Institute of Communicable Diseases.

It's typical of the types of projects that Botai is spearheading, many of which are collaborative efforts between multiple institutions and countries, in the latter case, ranging from South Africa to Japan. "We network, and we build strong collaborations," he explains.

Another ongoing project that Botai highlights is a comparison of the climate change impacts on future development and economic growth for priority water linked sectors in the local Limpopo River Basin and the Mara River Basin in Kenya. The project will result in, among others, recommended adaptation strategies and policy actions. What he really likes about the project, he says, is that his younger researchers narrated stories told to them by the local farmers. This indigenous knowledge system has been captured as part of the project and will be used to the benefit of the SAWS and the communities they serve in future.

A lot of their work is aimed at protecting and minimising weather risks to vulnerable communities and to provide sector specific decision-making products on weather and climate, Botai says. It's an integral service forever under threat due to budget cuts. He hopes he has a solution for that too. One of his projects is the development of a system to demonstrate the cost of further government funding cuts. His research has shown that the price of non-funding is much higher than the funding itself. "There's a lot to lose if communities are not prepared for the impacts of weather and climate."

Still, he also sees the opportunities in the commercial products they now have to develop to generate income. "It gives us the opportunity to collaborate with businesses," he says and, it is one that his consulting days at the UP prepared him for well.

A legacy in the making

Botai says he hasn't succeeded in establishing his legacy yet. Ultimately, he wants to have made a change for the better in the communities around him. He hopes that it will be encapsulated in another project that he is leading at the SAWS, launched in 2020. "It's Disaster Risk Reduction from the ground up," he says.

"From my perspective," he explains, "early warning systems are not as effective yet." According to Botai, they lack "completeness". If they were effective, we could have seen farmers responding to drought immediately. "It's one thing to give them information. It's another for them to react and respond to that information. Early warning systems can provide the information but we should have a system co-developed by the users that helps them decide what to do. That's why people are not responding."

Supported with funding from the Government of Flanders, the project is called the Integrated Climate-driven Multi-Hazard Early Warning System and it aims to integrate all early warning systems that exist in South Africa and beyond. The system will also incorporate information generated together with community members. "The bottom line is, it's about the communities," he says.

Key project: Citizen Science Weather Stations Monitoring Network for Early Warning and Resilience

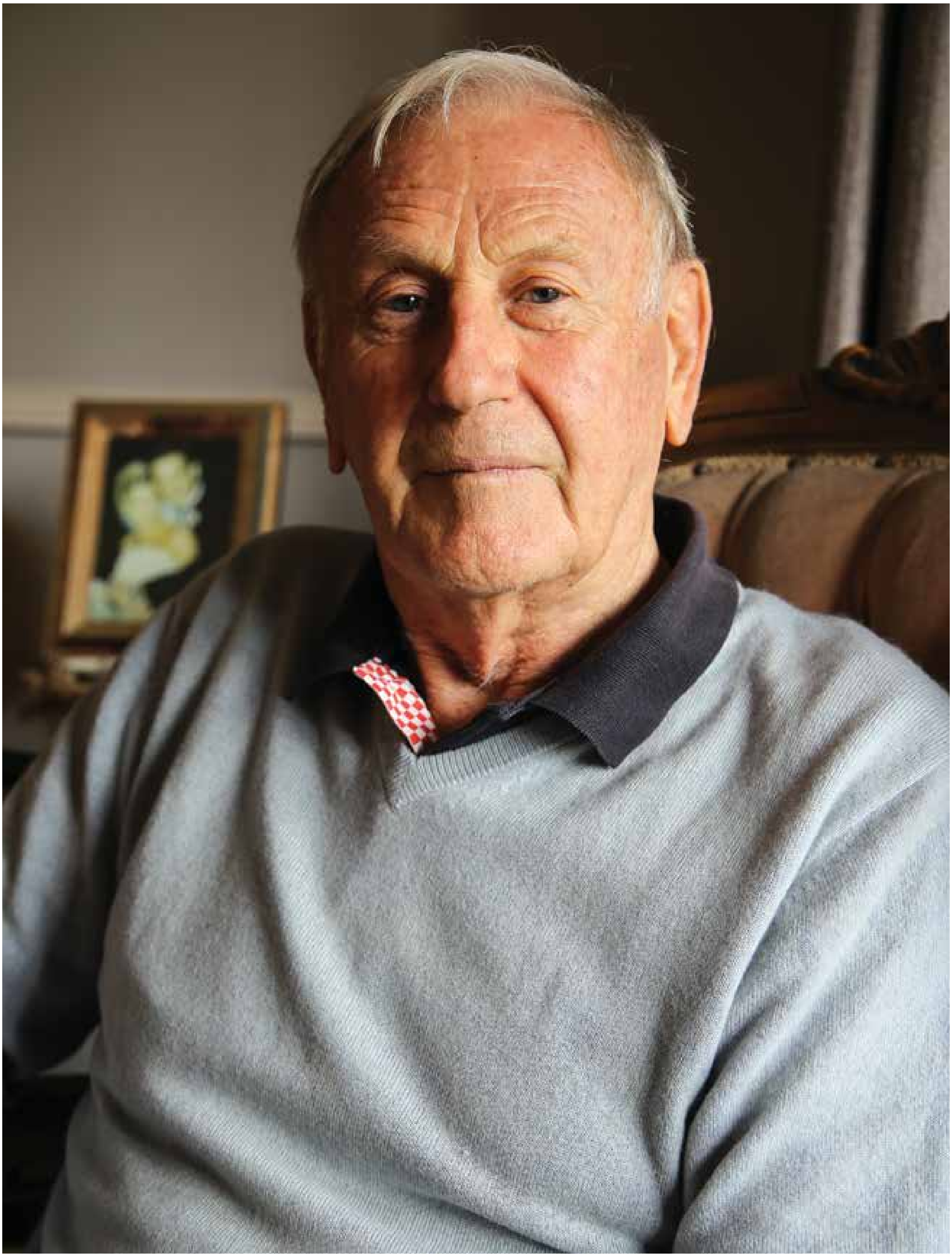
"This is an exciting project," Botai says. Climate sensitive sectors such as water, agriculture, health, human settlements and energy are experiencing impacts of climate change and variability. In countries like South Africa, these impacts are likely to be felt at the community level due to the triple challenges of in equality, poverty and unemployment. The project aims to develop human capital at community level for citizens to be more proactive, and build their resilience to extreme weather events through citizen science. The key aspect of citizen science is to involve communities to collect data with you, and interpret the data together, Botai explains. The project will provide communities with the opportunity to collect and share weather data in support of climate change research. The idea is to install low-cost weather sensors in communities, and train volunteers to continuously collect data on our behalf. Communities will jointly work with researchers at all stages of the research project, collectively co-creating knowledge that will serve the community. The SAWS has already partnered with an NGO in Mamelodi.

For Dr Botai, his work boils down to the impact that it has on communities.
Photo credit: Petro Kotzé

"From my perspective... early warning systems are not as effective yet.. they lack completeness."

Once he sees that completed, Botai says he will be able to say that his job is done. He looks across the yard at his chickens. It's one of the few hobbies that he cultivated in later life. He does not have much time for sidelines. Just this morning he was up at 3:30 to complete and submit an assignment to Gibbs (he is studying business strategy), respond to his emails, answer messages from the students that he is supervising (about four at Master's level and one PhD) and recounted the story of his life before running for a meeting, all before lunch.

It's tempting to say that he has come full circle, back again to rising long before dawn to work and study. This time, however, the scope of his reach is much, much wider. This time, many more farmers, families and whole communities far beyond those of his father's farm will benefit from his labours.



Prof Roland Schulze

Photo credit: Petro Kotzé

ROLAND SCHULZE

The visionary that changed
water resources management in South Africa

Current position:
Emeritus Professor at UKZN, Senior Research Associate of the Centre for Water Resources Research

Research interests:
Hydrological modelling, climate change, hydro-climatic mapping, integrated water resource management

Awards

AWARDS

2021: WRC Legend Award
2018: Lifetime Achievement Award by the African Utilities Industry
2013: Voted South Africa's top water researcher
2009: Inducted as a member of the Academy of Science of South Africa
2003: Life membership, international Water Academy, Norway
1993: Fellowship of Royal Society of SA
1991: Fellowship of University of Natal
1990: Gold medal by the SA Institute of Agricultural Engineers

Vision and perspective enabled hydrologist Prof Roland Schulze to foresee South Africa's water management needs like few others. It is his belief that you always have to be ahead of your time. This philosophy runs through his career like a fine thread.

"Success doesn't come served on a platter."

From a "one-and-a-half-person show" Schulze grew what is now the Centre for Water Resources Research into arguably southern Africa's largest academic and research hydrology department. He was one of the first South African scientists to look at water use in catchments, developing the integrated hydrological model ACRU now used extensively around the globe in decision-making for water resources. In the eighties, he pioneered South Africa's first university degree course in hydrology, creating a cohort of many hundreds of hydrologists. Since writing South Africa's first hydrology-related paper on climate change in 1991, he has become an internationally recognised authority in the field.

Touching on eighty at the time of the interview, Schulze has been trying to retire since the "big bash" his colleagues gave him at age 65. He counts it as a career highlight, a "wonderful day" in which hundreds of people from South Africa and beyond came to honour the revered professor. It points to another distinguishing trait. He is a mentor to many and, in recounting his celebrated career, lays down a blueprint of lessons for young researchers. The first lesson, he says, is that you have to realise that success doesn't come served on a platter.

Schulze came from a poor family, and though he has fond memories of his childhood in Harburg, KwaZulu-Natal, he had to put himself through life. After school, he trained as a science teacher, as that was the only job that loans were available for. He taught for

Emeritus Professor at UKZN and Senior Research Associate of the Centre for Water Resources Research, Prof Roland Schulze, in his Pietermaritzburg home.

Photo credit: Petro Kotzé

"Your work has to be practical"

Prof Schulze with wife, Waltraut Schulze, at the African Utilities Industry ceremony where Roland received the Lifetime Achievement Award.

three years, completing his Master's degree in physical geography part-time. He still remembers long nights pouring over maps with Waltraut, his wife, who has remained an important source of support throughout the years. The pair still live in Pietermaritzburg where, from an earshot away, she ensures that Schulze gets the facts straight.

In 1969, he accepted a position as a junior lecturer in physical geography at the then University of Natal (now the University of KwaZulu-Natal). The money was less than he was getting as a teacher, but it was a long-term move. After finding tremendous inspiration in Prof Roy Ward's book, ***Principles of Hydrology***, Schulze decided his future lay in water. In 1975 he completed his PhD on catchment evapotranspiration modelling, and then left for a 7-month stint in the UK to work with Roy Ward.

At the time, South Africa was experiencing extreme water shortages with little coordinated research and development direction to guide the way forward. A special government commission of enquiry gave birth to the Water Research Commission (WRC), established under the terms of the Water Research Act of 1971. When the Commission identified the most important constraints in the present and future water economy of South Africa, the management and practices in catchment areas were highlighted as one.

The University of KwaZulu-Natal's Professor of Agricultural Engineering, Piet Vorster (one of the WRC's first members), was awarded funding for one of the first projects on catchment hydrology. Returning to join the project and university as senior researcher, Schulze's work in the field of water officially started.

The project called for the establishment and operation of five small hydrological research catchments in the midlands of KwaZulu-Natal. For Schulze, this was significant, as his mother was raised in those very catchment areas, riding 12 kilometres on horseback through the hills to school and back every day.

The objective of the project was to develop a hydrological model, and they were allocated a grand budget of R5 000 to do it; a significant amount for the time, Schulze remembers, and much more than his monthly salary of R200. For the purpose, the then recently established Agricultural Catchment Research Unit (ACRU), initially a one-and-a-half-person show (the "half" being a data programmer), became his home. The project results led to the development of the SCS (Soil Conservation Service) model, an American model adapted to South African conditions.

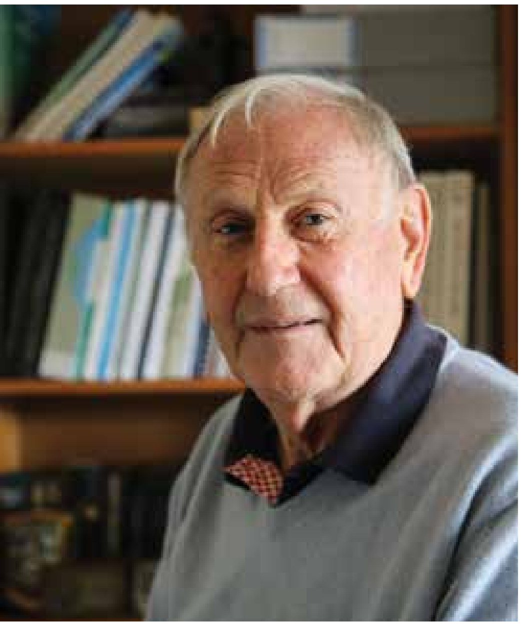
Based on the success of the model, Schulze was invited to the United States Department of Agriculture (USDA) hydrology laboratory, an inspirational time with top American hydrologists. Filled with new ideas on his return to South Africa, he tackled his next WRC-funded project, titled 'Hydrological Investigation of Rural Catchments in Natal with Specific Reference to Flood Events', which kicked off in 1979. Schulze was progressively moving away from small catchment research into hydrological modelling and, in the early eighties, based on the project results, developed the ACRU model. It would be a game changer.

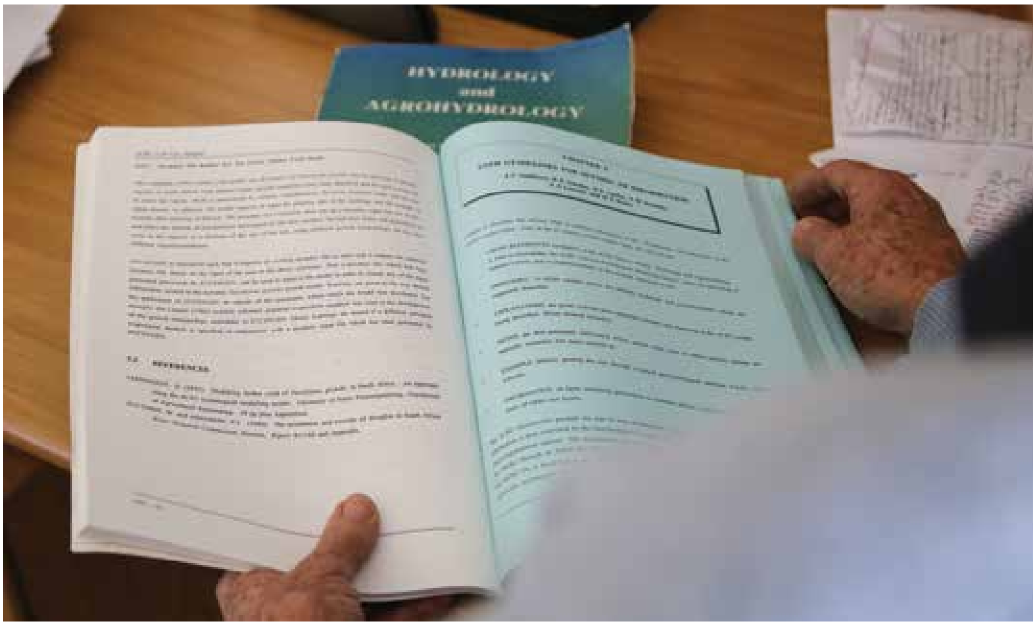
Building on from the SCS, ACRU is a multi-purpose water modelling system that revolves around multi-layer soil water budgeting with specific variables governing the atmosphere-plant-soil water interfaces. It has since been adapted to multiple purposes, and can now simulate total evaporation, soil water and reservoir storages, land cover and abstraction impacts, snow water dynamics and streamflow.

ACRU has been used for land use impact studies in many parts of South Africa and internationally, including Zimbabwe, Eritrea, New Zealand, Germany, Chile, the USA and Canada. More recently, the model has also been adapted to simulate the potential impact of elevated CO_2 and temperature levels and to study shifts in water resources and crop production in southern Africa due to global climate change.

"Roland's passion for agrohydrological modelling has been apparent from when I first met him about 25 years ago. It's no surprise, therefore, that the ACRU model, which was being conceptualised at that time, now occupies an important niche in operational hydrology and water resource management in South Africa, particularly where land-use, land-cover, climate-variability and climate-change impacts are issues in question. But of equal significance has been the role of ACRU in capacity building. Countless young hydrologists under Roland's close supervision have, through the years, faced and met the dual challenge of improving the understanding of complex hydrological processes as represented in the many algorithms which make up ACRU and of ensuring, despite the growing complexity of the model, that ACRU remains convenient and easy to use."
– Dr George Green, then-Deputy CEO at the WRC, 2004

The model requires considerable spatial information but, Schulze says he has learned that the model doesn't necessarily need to be easy to run. "What is more important is that it





Prof Schulze is the father of multi-purpose water modelling system ACRU, one of his many revolutionary contributions to the fields of hydrological modelling, climate change and integrated water resource management.

Photo credit: Petro Kotzé

gives practical results that are realistic". In fact, Schulze lists this as an important characteristic of all research outputs of significance, and he credits wife Waltraut for constantly reminding him that theoretical research is worth little, if it's not of use.

It's a philosophy that has marked the output of the expanding Agricultural Catchments Research Unit. In the early eighties, the unit's work expanded into spaces such as agrohydrology, when the first agrohydrological and agroclimatological atlas for Natal was published. The atlas has been continuously updated, and now maps in detail issues such as climate, agricultural and water issues, design hydrology, water resources and variability of flow for the entire country.

Concurrently, the unit expanded from small research catchments to include provincial and eventually countrywide catchments; from the first agrohydrological atlas to supporting integrated water resource management, and from land-use to climate change impacts modelling. In 2012, the unit was transformed into a Centre of Excellence within the UKZN and is now called the Centre for Water Resources Research.

Schulze progressed through the ranks too, appointed as associate professor in 1981, full professor in 1987 and post-level 7 professor in 1993.

"You've got to be five years ahead of the rest"

"I gradually saw the need to teach hydrologists at an academic level," says Schulze, who first motivated that the university start the discipline of hydrology as a degree course in 1981. The qualification wasn't available in South Africa at that point, and reception to his idea was initially lukewarm. After about three years Schulze got "his" course, with a blessing to "go ahead" as the only support then offered from the university.

It wasn't a problem for Schulze, who already had a clear vision of what he wanted to achieve. Established under the Faculty of Science, Schulze, his Master's and PhD students taught the early classes. The course grew to become one of the bigger science disciplines on the Pietermaritzburg campus, earning the envy of many others for its enthusiasm, success and cohesiveness. The discipline would produce hundreds of hydrologists for South Africa, and the course was emulated by other institutions. For Schulze, the experience counts as a highlight.

In the late 1980s, he had another opportunity to lay the foundation for future research, when Prof Peter Tyson from the University of the Witwatersrand's Climatology Research Group invited him to a meeting of international researchers in Swaziland (now Eswatini) on climate change. This was 1989, and the topic was not born yet, says Schulze, but Tyson said they were thinking ahead. Schulze published South Africa's first hydrology-related paper on the topic in 1991 and he has developed into an internationally renowned expert on the topic.

Schulze has served on the Intergovernmental Panel on Climate Change (IPCC), placing him as a leading scientist globally (as nominated by their governments), contributing to three IPCC reports. On his IPCC involvement Schulze explains: "My IPCC experience was one of insights, excitement, extreme demands and an eye-opener with scoping meetings, writing sessions, adaptation meetings and post-IPCC think-tanks.

Prof Schulze's vision of what research should focus on in the next five years

"Obviously, climate change is important but we have to look at the smart issues and climate change. What is important is that our number of very hot days will increase exponentially and that our rainfall is likely to become more intense. But, for example, what does that mean for a city? The next five years will be about keeping it practical. Academics have to write papers that can be translated into the real world. The role of a researcher is to identify who is vulnerable, where they are vulnerable and what they are vulnerable to. Broad generalisations, so-called 'motherhood statements' from people working on vulnerability means nothing if it cannot be translated into specific impacts on people on the ground. We all have different vulnerabilities. That's what we have got to work on."

“You have to create your own luck”

“It started as far back as 1995 as an IPCC reviewing author on water and agriculture chapters, progressing a decade later to being a lead author in IPCC Working Group II in its 4th Assessment, taking me from Cairns in Australia to San Jose in Costa Rica, from Dakar in Senegal to Vienna in Austria, to 10 years later being a contributing author on the Africa chapter in the 5th Assessment.” Having a vision of what to focus on takes knowledge but, Schulze maintains, also a bit of luck. However, in life, he says, you have to create your own luck.

He has been incredibly lucky to have travelled all over the world, and to give his family the opportunity to explore so many countries, Schulze notes. At last count, he had been overseas 176 times throughout his career, including trips to Iceland, Nepal and Chile. He did this by also making use of every sabbatical leave that he was entitled to. His kids went to kindergarten in Yorkshire, England and later attended school in Washington and Utah. Sabbaticals have taken his family to Hull (UK), Washington, Logan (Utah, USA), Bonn (Germany), Wallingford (UK) and Wageningen (Netherlands). He has also travelled extensively through international programmes such as the International Geosphere-Biosphere Programme (IGBP), the International Dialogue on Water and Climate and the UNESCO IHE in the Netherlands, where he lectured 10 days each year for 17 years, the UNESCO-HELP (Hydrology for the Environment, Life and Policy) initiative and the IPCC.

In his career, Prof Schulze has made use of opportunities to see the world as much as possible, travelled (at last count) overseas 176 times throughout his career.

Photo left credit: Petro Kotzé. Photo right supplied.

“One has to listen to great advice”

As you build a career over time, you become somebody that opportunities are given to, he says. Such an opportunity came his way once, on a plane, when he received the best advice ever given to him. If this happens, Schulze says you have to listen to it.

At the pinnacle of his career, shortly after turning 58, Schulze was in America working with Prof Pete Hawkins of the University of Arizona. Hawkins remarked that the years between 60 and 65 should be the best time in anyone’s life. During those years, Hawkins said, people should aim as far as possible to do only what they really liked to do.
At the time, being head of the department and sitting on the University Research Committee were only a few of Schulze’s positions, necessitating many administrative responsibilities.

On the plane back to South Africa, Schulze made a list of the things he no longer wanted to do. Over the next two years, he progressively weaned himself of admin-heavy duties, stepping down from the Board of Science and University Senate. From age 60 to official retirement at 65 he had no formal university functions, other than lecturing and supervising post-graduate students. It was “absolutely fantastic” and left him to focus on his first love, namely research.

“An important thing we often forget as researchers is that research means to re-search, to look again, and to improve,” he points out. That is something else he has learned in his career; to not just go with whatever is in fashion, but to stick to what he was doing.

Prof Schulze is considered an international expert on hydrology, climate change and integrated water resource management.

Photo supplied

In present day South Africa, Schulze says, he often sees young people change careers and positions often. The problem with this is that you neither leave nor take with you any institutional memory. "You don't leave a legacy, and you don't take a legacy."

The increase of the value of Schulze's work over time is proof. He has a list of 647 publications behind his name. At the last check, his work over the years has over 5 000 citations according to ResearchGate, and 8 000 on Google Scholar. Schulze says this makes him feel very blessed.

Yet, for him, his legacy lies only partly in his body of work. He would like to be remembered for three things. First, for being a visionary in his field both in a South African and international perspective; second, as someone who always had an open-door philosophy. "The human element often gets lost in academic work, and we have to learn to listen to others' problems" he says, and he would like to think he never fell victim to shutting himself off. Last, he would like to be remembered for being a good husband, because Schulze says, "you've got to support the people who support you and who make sacrifices for you."

"Leave a legacy by sticking to what you are doing"

Prof Schulze's advice for young researchers on building a career that will make a difference

Ask yourself the following questions:

- Are you serious, and are you inspired?
- Is the area that you want to go into important, or just interesting?
- Do you think you can make a difference?

Dr Thomas Gyedu-Ababio

Photo supplied

THOMAS GYEDU-ABABIO

A true leader in integrated water resources management

Current position:
CEO of the Inkomati-Usuthu Catchment Management Agency (retired)

Research interests:
Water resources and aquatic biodiversity management

Awards

AWARDS/ACCOLADES:

2021: WRC Legend Award

2018: World Water Leadership Award as one of 50 Most Impactful Leaders in Water and Water Management

2002: The Golden Arrow Award, presented by PMR (Professional Management Review) for the most admired individual in the South African Water Supply Industry

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Lauded for his herculean efforts to bring all walks of people together for the good of water, Dr Thomas Gyedu-Ababio has spent the decades of his career laboriously advancing the implementation of integrated water resources management (IWRM) in his adopted country. The Ghana-born biologist ultimately made it is his mission to see a fundamental tenant of the National Water Act of 1998 applied in practice, to shift management from a central government to a decentralised approach and give local communities a say in how the water they so intimately depend on should be managed

Gyedu-Ababio is modest about how he would like to be remembered. Just "a humble guy that contributed to water resources management in South Africa," he says but, he has been awarded both locally and internationally for his ability to lead and what he achieved as a result. In addition, he pulled many up the ladder with him through the years, to ensure that the legacy of his work in water resources and aquatic biodiversity management continued each time he advanced.

Being a leader is not about being the boss, he says. Instead, his success is built on his exceptional ability to build relationships, extreme dedication to his profession and a deep-seated belief that his work holds a key to unlocking efficient and sustainable water resources management in South Africa – a water-scarce country in which economic development and social cohesions rely so heavily on this preciously scarce resource.

Despite his dedication and impressive track record, Gyedu-Ababio fears that not enough has been done to achieve successful water resource management in the country.

Giving the power to manage water to the people

South Africa's National Water Act of 1998 translates the hopes and dreams of a new democratic country into law. A cornerstone of the legislation is encapsulated in the establishment of catchment management agencies (CMAs), a personification of post-apartheid water management. Through CMAs, water resources management is delegated to the regional or catchment level, involving local communities in the protection, use, development, conservation and control of water resources.

The implementation of the Act has been fraught with challenges, but the first CMA, the Inkomati Catchment Management Agency (ICMA) was established in 2005. The water management area served by this CMA is complex. The international basin is shared with Eswatini and Mozambique, and includes the Sabie-Sand, Crocodile East and

> "When the opportunity came my way, I saw it as a chance to further my aim of applying proper water resource management in South Africa."

Komati rivers as well as the Nwaswitsontso and Nwanedzi catchments drainage region. In 2014, the CMA was extended to include the Usuthu Catchment. Land uses include conservation (sections of the Kruger National Park and Sabie Sand Game Reserve Complex), commercial and small-scale farming, forestry, mining and significant urban, rural and industrial developments. Water quality is an ongoing problem, as is the poor state of water infrastructure.

The IUCMA's early years were rocky, placing a question mark over any future such an initiative had in water management in South Africa. Gyedu-Ababio was appointed as Acting Chief Executive Officer (CEO) and Chief Operations Officer of the IUCMA in 2013 and in 2016, he officially took the reigns as CEO. "When the opportunity came my way, I saw it as a chance to further my aim of applying proper water resource management in South Africa," he notes. Describing himself as an avid believer in the concept of the CMA, he says he wanted to create a pioneering example that the vision of the National Water Act can work.

He fought for what he believed in. "Sometimes it felt like I was fighting solo," he says in memory of meetings where he was the sole defender of the work they were doing. Many would say he became the face of CMAs in South Africa. Some people mockingly called him 'Mr CMA', he says but, under his helm, the IUCMA became the flagship of what the implementation of this aspect of the Act could achieve.

The organisation went from strength to strength. Not only did water quality in the catchment improve, but so did the relationships between water users and government. Trust in the IUCMA grew so much that water users who previously defaulted, paid monies owed to the national department again, via the IUCMA. Tariff setting workshops with stakeholders included more and more water users, expanding on this relationship of trust.

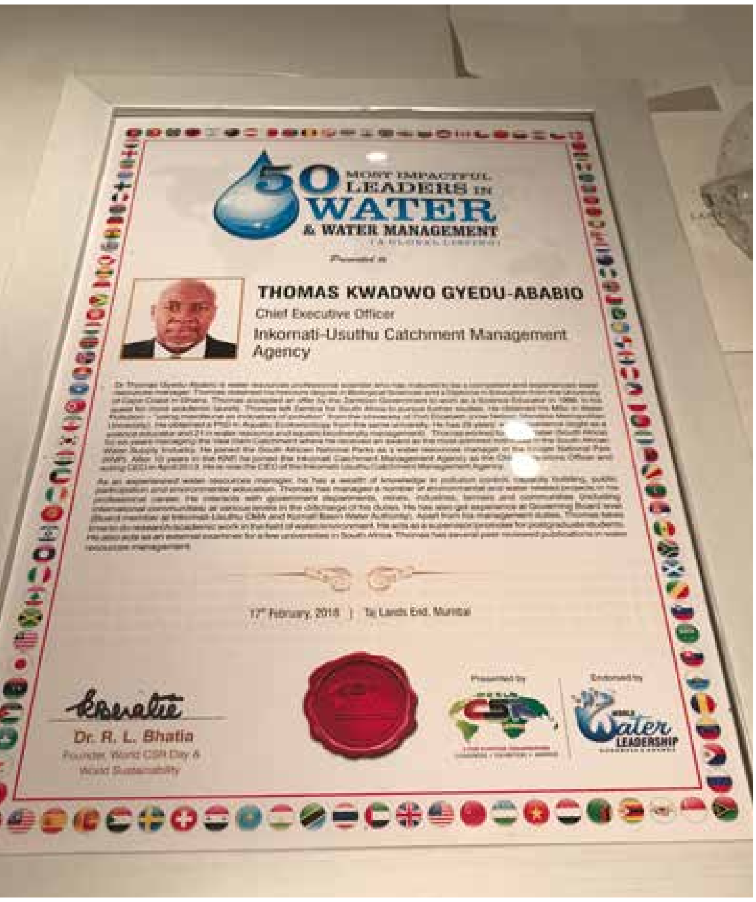
Another example of their success is the vast improvement in the processing of water use license applications facilitated by the IUCMA. The speed and the assistance given to the water users, including the historically disadvantaged people to ensure that they have access to water is one of his crowning achievements, Gyedu-Ababio says. "When people are happy with the service delivered to them, it inspires me to keep going."

Under his management, not only did trust between the CMA and water users improve, but also between its management and board, and management and staff. Over and above, the CMA doubled in staff to over 100 employees and became known as the employer of choice in Mpumalanga and water resource management in South Africa. He also helped ensure that there will be a pool of experts to continue the work in future. Bursaries for postgraduate studies were made available, with Gyedu-Ababio personally supervising four Master's and a PhD student.

"I made sure that every function that we were supposed to do every day, we did excellently, in the hope that others too could emulate it going forward."
As a result, the IUCMA has become the exemplification of a successful integrated water resource management agency in South Africa and the broader Southern Africa Development Community. Recognition for his achievements have been won from far beyond the borders of the CMA and the country. In 2018, Gyedu-Ababio was selected as one of the "50 Most Impactful Leaders in Water and Water Management" in the World Water Leadership Awards, placing the IUCMA and South Africa on the world map of integrated water resources management.

He says he looks back over his career and achievements both with pride and a touch of sadness. The one thing that he is sorry about is that he was not able to see through the full implementation of the National Water Act. Irrespective of the example set by the IUCMA, only two CMAs have been created in the country, from an original vision of 19.

Despite the challenges in rolling out water resource management nationally, the IUCMA remains a shining example of what can be achieved when stakeholders in a catchment come together for the sake of the resource. "In some ways we were successful, but I hope the government will finalise the establishment of CMAs to ensure that water



Thomas Gyedu-Ababio's World Water Leadership Award as one of 50 Most Impactful Leaders in Water and Water Management.

Photo supplied

resource management is taken to a different level," he says from his house in Ghana where he returned to on his retirement from the IUCMA in 2021. It's here where the seeds of inspiration were planted that would grow to fuel the passion for his eventual work.

As a young boy already, he decided what he wanted to do. "From my school days in Ghana, I loved water," he says and, that is what he dedicated his future to.

Setting course with a vision for a better future

Gyedu-Ababio grew up in a small village. He remembers drinking water and fishing from the river on the farm where his grandmother lived. A different reality hit home when he went to a nearby larger town for his secondary schooling. "I saw the impact of sewage treatments and industries on the rivers, and I became so worried." Then, a teacher took his class to a river and showed them how organisms can indicate the quality of the water. The young student was hooked. "I found it so interesting, but I was also concerned. What could we do, so we could save our water going into the future?"

Gyedu-Ababio promised himself that he would study to become knowledgeable in water, so that he could contribute to the proper management of this precious resource. He started this journey straight after school, and obtained his Honours degree in Biological Sciences with a Diploma in Education from the University of Cape Coast in Ghana. The university offered him a position as teaching assistant, but since they could not guarantee that this would lead to a scholarship for his Master's, he decided to start working elsewhere to save the money he needed to do so himself. After completing his two years national service in Ghana, he was employed by the Zambian Government to

Gyedu-Ababio on how to build a career in an area that you feel passionate about: "Never give up on your dreams. Be persistent and patient whilst working hard towards achieving your goal."

work as a Science Educator. After eight years, in 1989 he had enough funds to start applying for his Master's studies.

Gyedu-Ababio remained on track to continue the mission he set himself on years earlier. The proposal that he sent to universities to study the use of living organisms as indicators for pollution, secured him a spot in the Nelson Mandela Metropolitan University (then the University of Port Elizabeth) Master's programme in Water Pollution.

"And that's how it all started."

He excelled and received a scholarship to spend three months in Belgium where he completed his thesis on "using meiofauna as indicators of pollution". Even before he finished, the quality of his work led to the university registering him for his PhD in Aquatic Ecotoxicology with funding for his first year. Pushing through was not easy, and he sometimes relied on friends to help the grateful student with funds. Still, at the end of the year, his reserves were depleted and in 1997, he accepted a position at Rand Water to save money towards his education.

As Water Resources Manager, Gyedu-Ababio was at the helm of the strategic management of the Kruger National Park rivers.

Photo credit: Petro Kotzé

An introduction to applying integrated water resource management

In his position as Catchment Coordinator for the Vaal Dam, he managed quantity and quality aspects of the water that keeps South Africa's economic heartbeat pumping. The dam supplies water to about 10 million people in Gauteng and the surrounding areas, including some of the country's key industries.

"Rand Water gave me the opportunity to grow."

Dr Thomas Gyedu-Ababio has retired to his native Ghana to continue his work as chief of local villages.

Photo supplied

Early on, he became heavily involved in the development of Customer Management Forums – an initiative launched by Rand Water around the time Gyedu-Ababio joined the organisation. The forums are a foundation for Rand Water to build partnerships with customers and stakeholders within their area of supply. Initiatives like these are integral to successful IWRM. In Rand Water's case, the forums are a platform to discuss topical water related issues such as acid mine drainage, challenges to water supply, climate change and water demand management, to name a few. They also serve as education tool for customers to learn more about the diverse nature of the water sector and, in addition, they are as a tariff consultation vehicle.

"Rand Water gave me the opportunity to grow," Gyedu-Ababio says. It's also here that he learned lessons vital to the success of his future career, on the multiple, causative agents that impact water quality. He had the chance to explore this in depth when he was tasked to study the impact of human activities on the Waterval River. The exercise counts as highlight during his time at Rand Water.

The Waterval River is an important source of water for the Vaal Dam. Due to its geographical position in a rapidly expanding urban and industrial area, the river is subject to the influences and effects of various developments, including farming, gold and coal mining. The research project considered all aspects in the catchment, from sewage treatment to farming activities, explains Gyedu-Ababio. Township dwellings, abattoirs, mining, Sasol activities and many more were included in the investigation, as were plant and animal life in the catchment. It was a first for Rand Water. Leaning heavily on the use of biomonitoring, the assessment serves as a benchmark to measure the success or shortcomings of any remedial actions to improve areas of concern in future. The success of the project was such that software was developed to help Rand Water identify deteriorating catchments under its management with the indices based on the Waterval River study.

Based on his achievements at Rand Water, Gyedu-Ababio was rewarded with a coveted PMR (Professional Management Review) Golden Arrow Award as most admired individual in the South African Water Supply Industry in 2002. However, regardless of being offered positions higher up along the corporate ladder, in the new millennium, he felt like his experience had helped him grow wings and it was now time to fly. He accepted an offer as Water Resources Manager for the Kruger National Park in 2003.

Getting closer to rivers, and the people that depend on them

From his home in Ghana, Gyedu-Ababio drags something in front of the computer screen. It's a large crocodile carved from wood. "I cherish this so much," he says of the trophy. He has had it since 2013, and flew it home with him from South Africa. It's a reminder of what he describes as one of his greatest achievements during his decade of employment in the Kruger National Park.

When he arrived at Kruger, relationships between the park and its neighbours were at a low point, fueled by conflict about the water that they all had to share. Discord followed the flow of water into the park along most of the five perennial rivers that grace the protected area. The issues were many and broad in nature, Gyedu-Ababio explains. For one, Lepelle Northern Water (that supplies bulk potable water in the Limpopo province) was locked in a dispute with the park as they were being accused of polluting the Olifants River. Then, the Letaba Irrigation Board (as it was known at that time) wanted Kruger to pay for the water released to them to meet the rivers' Ecological Reserve. Along the Crocodile, the major irrigation board was unhappy because the national park did not allow them to build a weir at a certain point that they wanted to.

The Crocodile River Forum presented Gyedu-Ababio with a cherished trophy now on display in his home in Ghana.

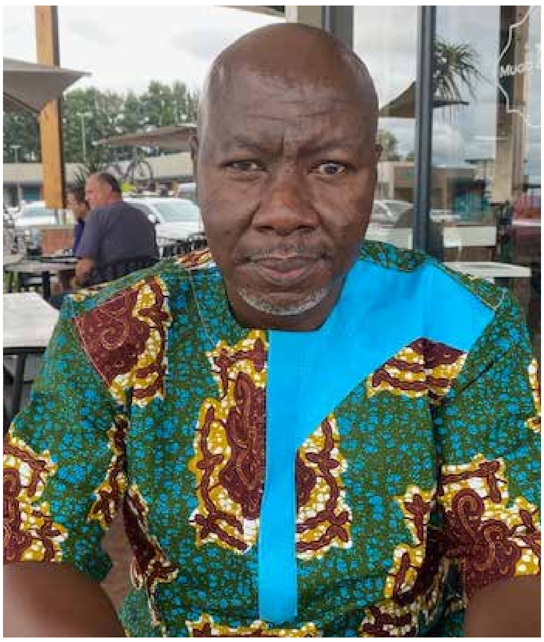
Photo supplied

Gyedu-Ababio knew that resolving these issues were key to the success of his new post. As Water Resources Manager his position entailed facilitating the management of park rivers in a strategic and adaptive manner, to ensure their sustainability and that of the associated ecosystems. But, to manage the rivers within the park, he had to work outside of the park. "If you want to manage the resource, the relationships with people are crucial," he says.

> "If you want to manage the resource, the relationships with people are crucial."

For one, he commissioned a research project to confirm that releases from the Lepelle Northern Water were not the only cause for the silt entering the park from the Olifants. Based on these results, new ways of releasing water from their Letaba storage were agreed upon. "Everybody was happy thereafter, until today," he says. Meetings with the Letaba Irrigation board were held to explain that the park was withing their right for water according to the Water Act of 1998, seeing as it was water for the environment and not water for consumption.

He also called a meeting with farmers along the Crocodile River, sending word that there was “a small black guy” that wanted to talk to them. They were mostly annoyed, Gyedu-Ababio remembers, but showed up out of interest. After a friendly beer or two, he launched into his ‘sermon’ on why they needed to collaborate, and explained the potential impact of the proposed weir from the park’s point of view. After listening to the farmers’ grievances too, he offered an alternative, win-win solution by suggesting a new location for the construction. “Now they were nodding their heads,” he remembers. He also suggested the establishment of the Crocodile River Forum, which would allow for the open sharing of information and maintenance of relationships going forward. The forum would ensure that all water users were involved in the river’s management and sustainable future. The newly arrived manager was promptly made chairperson and, at times under duress, he admits with a laugh, would stay in the position until he left the employment of the South African National Parks (SANParks).



“You can’t fight your way to conserve water. You have to collaborate. You have to understand that sometimes the win-win situation entails compromises here and there. That’s what worked for me.”

He points to the wooden reptile that the Crocodile River Form presented him with when he left the park after ten years, and eventually had to give up his position as their chairperson. “To bring harmony between farmers and water users along the national park, and park management has been one of my greatest achievements,” he says.

From here, Gyedu-Ababio moved to his last position in South Africa, when he took on the troubled IUCMA and built it into a flagship of successful IWRM as envisioned in the National Water Act. Another of his greatest achievements has been to keep the concept of the CMA in South Africa alive, regardless of seemingly unsurmountable challenges, he says.

Going back to the water of his youth

Though he spent the bulk of his productive years in South Africa, Gyedu-Ababio says he wanted to return to his roots and his responsibilities in Ghana. As chief presiding over three villages, it is time to meet his commitments there. Over and above this, he is also running a drinking water purification company with his wife. “After this interview, I will start my day at the office again,” he says with a smile.

Yet, even though he does not reside in South Africa anymore, the vision he set to achieve as a child continues. “It is important to leave a legacy when you go,” he says. His not only sets an example of what can be done, but also lays down a roadmap to follow for those that will continue his work to build our sustainable future by applying true integrated water resource management.

“Adequate knowledge in the chosen field, willingness to continue learning, humility and integrity,” is what Dr Gyedu-Ababio believes is necessary for a successful career.

Dr Jackie King

Photo credit: SIWI

JACKIE KING

The riverkeeper

Current position:
Honorary Professor in the Institute of Water Studies at the University of the Western Cape.
Owner, Water Matters, Cape Town

Research interests:
Inland waters, ecological research and management

Awards

AWARDS

2021: WRC Legend Award
2019: Stockholm Water Prize
2019: WARMA, Zambia. Environmental Management Award
2016: WWF South Africa Living Planet Award
2016: Gold Medal of the Southern African Society of Aquatic Scientists
2003: National Women in Water Award: Research category
1996: Silver Medal of the Southern African Society of Aquatic Scientists

“Rivers are logical, changing in predictable ways from source to sea and through the seasons. They illustrate perfectly how complex and organised natural ecosystems are,” says Dr Jackie King. “They are also the lifelines across vast landscapes, but are vanishing or drastically degrading globally at a higher rate than any other kind of ecosystem.”

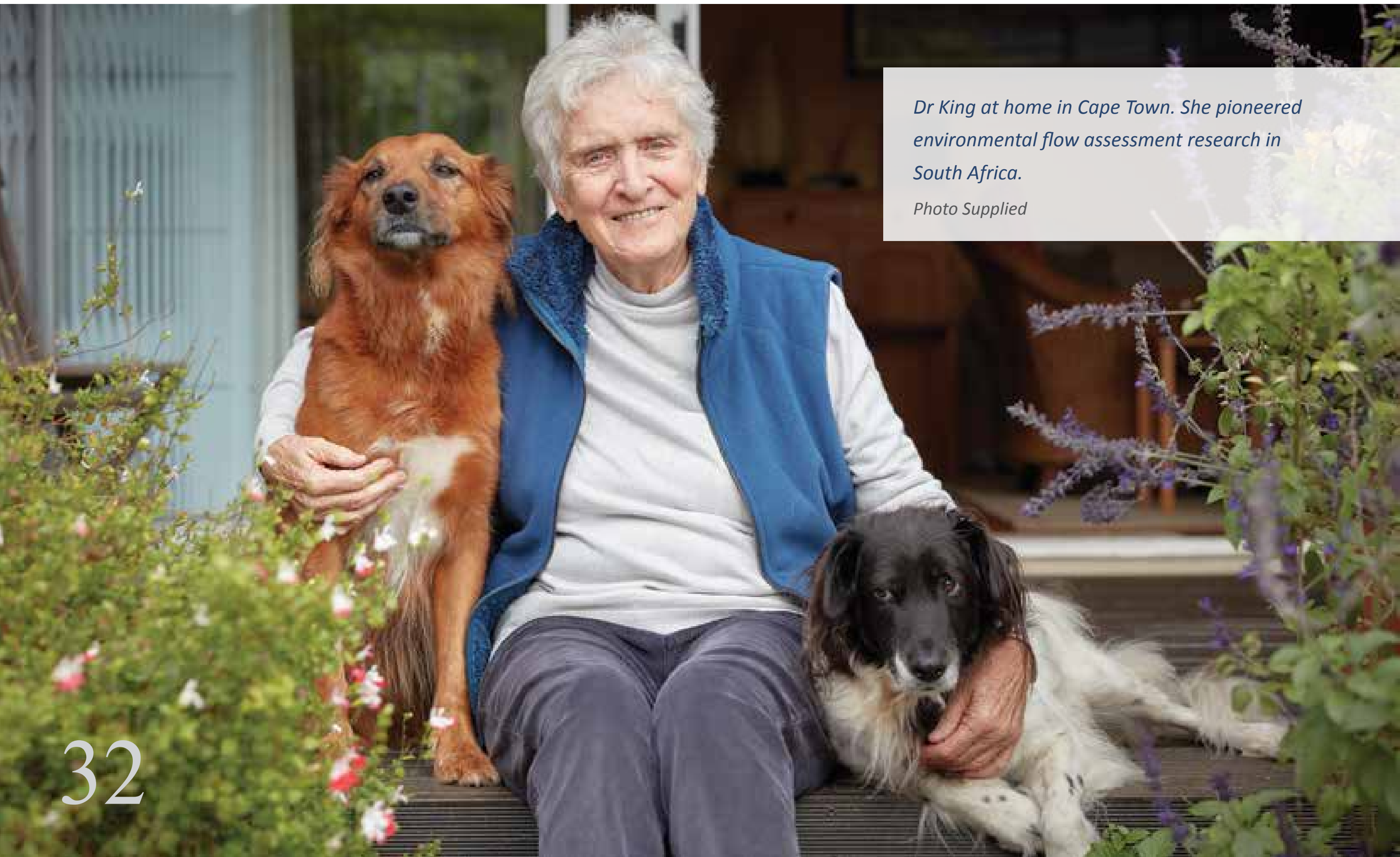
King is synonymous with river ecology in South Africa. She was one of the first ecologists to be funded by the WRC and, decades later, was chosen as the 2019 Laureate of the world’s most prestigious water award for her contributions to the field. In its citation, the Stockholm Water Prize Nominating Committee noted that “Dr Jacqueline King has, through scientific rigour, selfless dedication and effective advocacy, transformed the way we think, talk and work with water as a flow of and for life.”

A matriarch of river ecology, she helped expand the discourse of how we live on our planet, through developing concepts and techniques that allowed the ecological and social costs of water-resource plans to be predicted, as a balance to the predicted engineering and economic benefits. King’s work has provided decision-makers with tools that support more informed and equitable decisions than was possible even 20 years ago.

Yet, she came to the research world relatively late, in her thirties, when she was introduced to the then unfamiliar field of freshwater ecology. Her story, she says, is proof that it’s never too late to start.

An unexpected introduction to river ecology

King’s first job on arrival in South Africa from England was to clean kennels for the SPCA in Bryanston, Johannesburg. Then, when she relocated to Cape Town with her husband she worked as an insurance clerk. At this point, she determined to do something with her life, lest she regret it when she was



Dr King at home in Cape Town. She pioneered environmental flow assessment research in South Africa.

Photo Supplied

old. At the age of 27, and without a matric qualification, she was accepted to study at the University of Cape Town (UCT) as a mature age student on the strength of her British O-level results.

Because she loves the natural world, King settled on zoology and botany. Though admitting she knew "absolutely nothing" about what awaited, she excelled. In her first year, in 1971, she won the class medal for B.Sc. Zoology and in 1974 she was awarded UCT's Purcell Prize for the best dissertation on any zoological subject. After completing her BSc (Hons.), the university offered her a number of marine-related PhD projects but she couldn't guarantee that she would always live by the sea.

Instead, she accepted an offer from the Percy Fitzpatrick Institute of African Ornithology, to study the small aquatic life of Stellenbosch's Eerste River. King says the Institute's interest focused simply on how much food was available for Black duck along the river, but she followed the advice of her mentor at UCT, Prof George Branch, closely – "you will never understand an ecosystem unless you analyse it at the species level," he said. With no freshwater ecologists initially at UCT to guide her, she conducted a meticulous and detailed study of the river, learning how to identify all the small aquatic species and noting how these changed along the river and through the year. Eventually she understood the river and a lifetime's dedication to the welfare of rivers followed.

She completed her PhD in 1983, with two babies born along the way. By this time two more freshwater ecologists, Profs Bryan Davies and Jenny Day, had arrived at UCT. Together, the trio founded the Freshwater Research Unit where King would remain Principal Researcher for almost three decades. She was funded initially by CSIR's Foundation for Research Development (FRD, now the National Research Foundation) to do fundamental ecological research, the beginning of a career conducted entirely on 'soft' money with no appointed employment.

In 1988 change was on the horizon, not only for King, but also for South Africa and the field of freshwater management. There was increasing concern over the state of South Africa's rivers. In the Kruger National Park and elsewhere rivers were degrading severely as urban and agricultural development blossomed. Here and internationally, people started questioning how much water should be left in river ecosystems targeted for development, in order for them to continue as healthy ecosystems. Added to this, changes to the FRD funding model forced King to seek elsewhere for research funds.

She and her colleagues turned to the WRC, which was not funding ecosystem research at that time. Needing to propose research with a management focus, she approached them with a proposal on a topic so obscure that it did not yet have a scientific name – how much water does a river need? Isolated scientifically because of apartheid, South Africa was nevertheless registering both locally and globally that the world's rivers were in trouble. The WRC accepted the proposal and tasked King to research world trends on the topic and then make recommendations as to what South Africa should do. The work would become part of the global scientific endeavour that led to the discipline of Environmental Flow Assessments. This discipline now plays a crucial role in guiding governments in their management of river basins.

Back then she was, she says, a young mother with hardly any relevant science behind her, and scant understanding of the topic. There were no textbooks or manuals and barely any thinking and concepts to support the work. Those available were from industrialised countries focused more on maintaining game fish, such as trout. They were not addressing the issue so important to South Africa – maintaining healthy river ecosystems to support people's livelihoods and biodiversity in all its forms. With very little to guide them on how to do it, she and her PhD student, Rebecca Tharme, set off in UCT's Zoology Department four-wheel drive truck and disappeared down the dirt roads launching their mission to figure out how much water a river needs.

Setting in place the building blocks for ecological flow measurements

The road to success was bumpy. The first time King recommended an environmental flow (for the Lephalale River) to the Department of Water Affairs, they replied that she had asked for more than the natural flow of the river. Back to the drawing board!

She remembers her early WRC steering committee meetings as challenging, partly because she didn't yet understand the necessary engineering terminology, but she persevered. She was boosted by unwavering support from the WRC and the then-Department of Water Affairs and Forestry (DWAF), with the WRC specifically nurturing and believing in her. This gave her the determination to continue until she got it right.

To help King gain insights of this new water-management world, she attended hydrology symposia and remembers one symposium very well. As she rose to present her paper, the session chair explained there were three great lies in life: the cheque is in the post; I'm from Head Office, I'm here to help you; and… some of his best friends are ecologists. To hoots of laughter many left the session leaving King to present to a greatly depleted audience. Undeterred, a couple of years later that session chair was the co-author of her next paper. In 1995, she was awarded Best Paper at the Queensland Hydrology Symposium in Australia.

King pointed out to water managers that there is no magic number that represents the amount of water that should be left in a river. Rather, as we change its natural flow, sediments and water chemistry the whole river ecosystem will respond by changing also. It becomes a choice of society what that future river should be like. There will be a tradeoff between the natural attributes of the river system that could be lost and the artificial benefits (like food, jobs and energy) that could be gained.

In work that was completely new in the 1990s, King, DWAF and the WRC brought together interdisciplinary teams to address the topic for river after river across South Africa that were targeted for dam development, honing their skills and methods as they did so. Experts in hydrology, hydraulics, geomorphology, sediments, water quality, fish, invertebrates, birds, trees, resource economics, and social structures and cultures provided input. Key to the process was King's realisation in the early-1990s that the social and ecological consequences of the development of water resources should be addressed at the same level as the engineering and economic aspects, so that decision-makers can assess the full spectrum of costs and benefits before making a decision. Looking after people is not just a matter of providing them with water from a tap. There is a myriad of benefits provided by healthy rivers that could be lost, such as natural flood storage, water purification, fish, firewood, medicines, *Dr King with Phana Chheng, her Mekong River Commission driver film maker and eventually adopted son on the Tonle Sap.*

Photo supplied

"The overall health of the living river was a crucial aspect for us because of the role that rivers play in our peoples' lives."

construction materials, water for washing, tourism income and cultural importance and much more.

"This," King says, "is where we began to diverge from the industrialised countries also starting to tackle the problem of degrading rivers. The overall health of the living river was a crucial aspect for us because of the role that rivers play in our peoples' lives."

The result was the Building Block Methodology (BBM), which recommended how much water should stay in the river to achieve different levels of ecological health. With King as main architect, it was the first method in the world that offered both a holistic assessment of the whole river ecosystem and a manual to explain its use. It became an international benchmark for instream flow assessments in the 1990s because of its simplistic approach, and had profound ramifications in South Africa where it led directly to the inclusion of environmental protection (in the form of the Ecological Reserve) in the 1998 National Water Act. For this and other reasons, the Act was seen globally as one of the most advanced and visionary in the world.

Next steps in predicting the effects of changing river flow

By the late nineties, King had moved on, developing with colleagues Drs Cate Brown and Alison Joubert the DRIFT (Downstream Response to Imposed Flow Transformation) eco-social model.

This includes a strong socio-economic component for predicting the impacts of changing rivers on peoples' lives. Importantly, DRIFT addresses many of the shortcomings of the BBM, offering scenarios of different levels of development/management, rather than recommending how much water should be allocated to the river.

It was an important shift as it allowed us to start making neutral predictions of the impacts of a range of development and management options, King says. These are communicated in a simple way that can be understood by a wide range of stakeholders, not just decision makers. "Now everybody has a chance to see those possible futures, and negotiate for the one that they want."

"In the end, the decision makers decide, but we've given them the chance to see both sides of the development picture. We hope this will lead to more informed and balanced decisions about dams and other developments than was possible a decade ago." That's the way we've been working for the last 20 years and, she says, it is working beautifully, rapidly gaining international traction.

DRIFT is now commonly seen as the most structured, detailed and technically advanced of the environmental flow methodologies globally. It is a step up from the early holistic methods because it centres on ecosystem and social modelling, and the DRIFT model now takes its rightful place alongside hydrological, hydraulic, economic and other models in water-resource planning.

Since those uncertain first steps in South Africa, King has advised on environmental flows in over 20 countries, constantly developing and refining her work. In 1997, she led the environmental flow assessment for the Lesotho Highlands Water Project in the first international application of the DRIFT methodology. According to the World Bank, it resulted in the first recorded recognition globally of the rights of downstream communities to compensation for declining river health.

Dr King with local children at the Usanga wetlands, Tanzania in 2009. She has undertaken environmental flow assessments around the world.

Photo supplied

Dr King receiving the Stockholm Water Prize from the King of the Sweden, in 2019.

Photo credit: SIWI

South African scientists, led by Dr King, with their security team for field work during the Kishenganga Court case.

Photo supplied

Since 1997 King has led scientific teams working on environmental flows and river system management for the Pungwe River in Zimbabwe, parts of the Zambezi Basin (Kafue and Luangwa), the Pangani Basin in Tanzania, the Okavango River system (Angola, Namibia, Botswana) the Indus headwaters (Pakistan), the Lower Mekong (Lao PDR, Thailand, Cambodia and Vietnam), and more. She has done similar work for the World Commission on Dams, IUCN, WWF, and has worked ***inter alia*** in Taiwan, Ethiopia, Costa Rica, USA, Guatemala, Australia, Mozambique, and the UK.

She was global Team Leader of the World Bank Advisory Group on environmental flows from 2000 to 2003, before taking the position as scientific consultant on integrated flow management with the Mekong River Commission.

From 2009 to 2014 she acted as scientific advisor to the Government of Pakistan in a dispute with India over the Kishenganga Dam in the Himalayas. King points to the phone next to her front door at her Bergvliet home. It rang in the middle of the night a few winters ago, she says. "A voice said: Dr King, this is the Government of Pakistan. We're having a border conflict with India. Can you please help us?" I thought somebody was joking, she says, but the call led her to serve as expert witness at the Pakistan v India court case at the Permanent Court of Arbitration (PCA) in The Hague in August 2012.

It also led to the DRIFT Methodology being approved by the PCA as an appropriate tool in transboundary conflicts of the magnitude and complexity of the one under their consideration. Indeed, this was said to be the biggest potential conflict between India and Pakistan since partition in 1947.

A moment of reminiscence at the Bergvliet home

King says she is happy with the advances she has helped bring about. "People are stopping, thinking and treading forward more carefully today. To see my work become part of the body of knowledge in the world, to see my words used in other people's papers and arguments, is satisfying."

“Follow your dreams and if you are lucky you will end up being paid to do what you love. ”

She is very proud of the fabulous bunch of scientists she has helped train, now roaring past her in the fast lane and working across the world.

Dr King’s words of wisdom for young people

- Follow your dreams and if you are lucky you will end up being paid to do what you love.
- In your work, reach beyond your grasp, and soon what you reach for will become normal and easy. Then reach again and again.
- Just keep going. Failure is not trying, rather than not succeeding.

Still involved in her work through her younger colleagues she also makes time for other endeavours. She is a SANParks Honorary Ranger, and recently led a team creating a detailed online course on Table Mountain National Park for the organisation. She is an international member of the American Academy of Arts and Sciences (AAAS), and Senior Scientific Advisor to the International Crane Foundation.

But there is another project simmering. King is using her prize money from the Stockholm International Water Institute to launch the Africa’s Living Rivers Project with close colleague Cate Brown. There are six modules to the project, including upgrading the DRIFT model in partnership with global water company Xylem; WRC-funded development of generic algorithms for DRIFT; and a module close to her heart called ‘The silent voices of rivers and their people’. This initially focuses on the Luvuvhu River in Kruger National Park and the Makulele people who were displaced from the area when Kruger was expanded but have now reclaimed it. The story of the people’s loss and gain of their land, linked with the loss and gain of a river that died but was revived by science, environmental flows and the National Water Act, is a story of South Africa’s history and of hope.

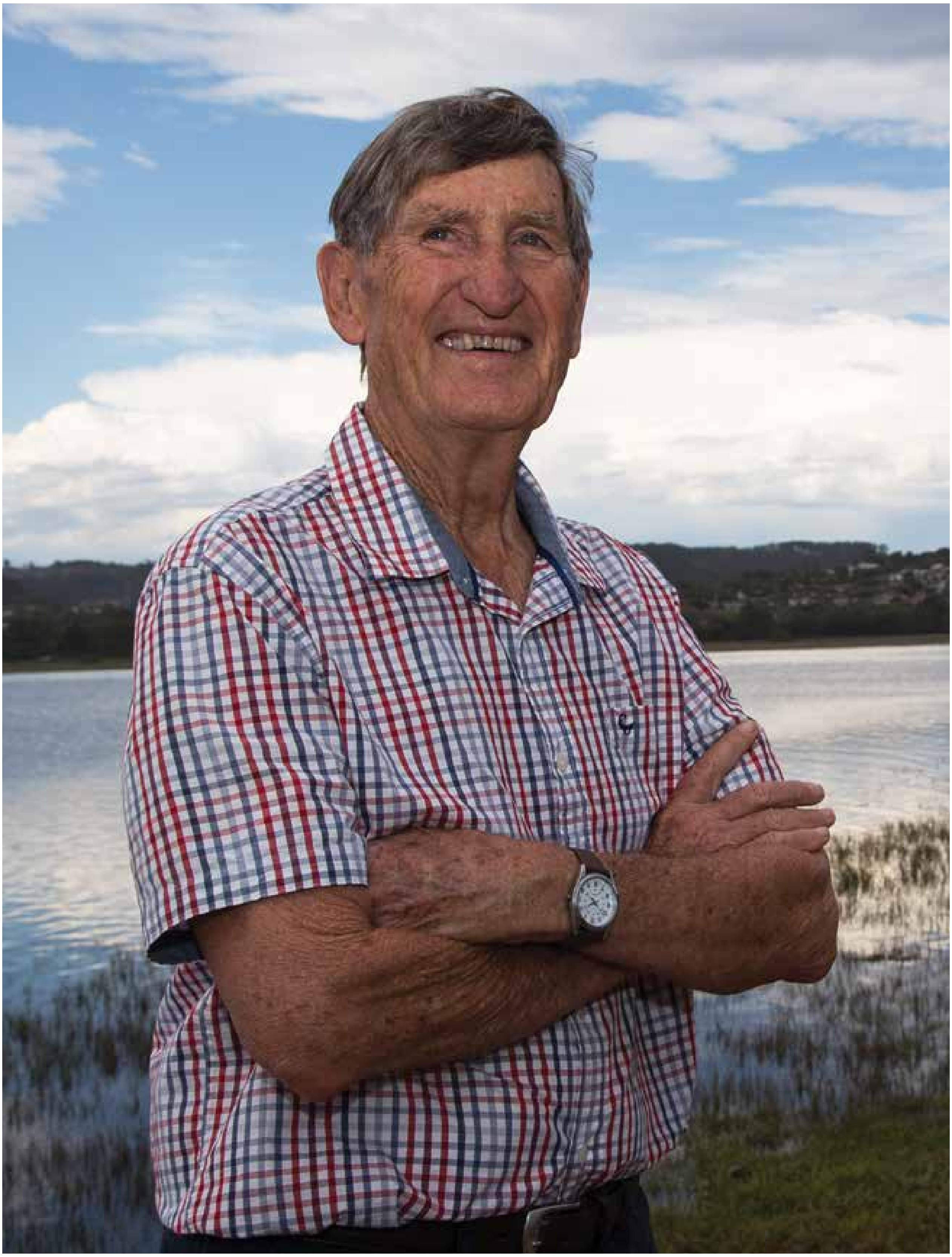
If she could encapsulate her work, King would say she has tried to ensure that all uses of river systems are brought into decisions, and the concept of no net harm adhered to. Future decision makers have been given the opportunity to acquire a more balanced set of information than was available in the past and to be able to explore more deeply the implications of their decisions. They should not need to face ecological and social tragedies and say “I did not know this could happen”. King says “I am not pro-development or anti-development. I just want to make sure that they know all the implications before making decisions.”

Dr King speaking at the Opening Plenary of the Stockholm Water Week in 2019.

Photo credit: SIWI

Dr King on how to achieve success in your career

- Know your discipline – deeply
- Believe passionately in what you are doing – you will do more than you are ever paid for!
- Seek a common language – communicate widely and effectively
- Do your homework before meetings – most people do not
- Look for solutions, not just problems
- Stand your ground, be firm – do not retreat in the face of opposition or rudeness
- Show courtesy and respect to all



Prof Charles Breen

Photo credit: Petro Kotzé

CHARLES BREEN

Shaping aquatic science for the sake of environment and society

Current position:
Emeritus Professor and Fellow of the University of KwaZulu-Natal

Research interests:
Aquatic ecosystems, including estuaries and their relationships with society

Awards

AWARDS

2021: WRC Legend Award

2014: Mondi Wetlands Award for Wetland Science and Research

2000: KwaZulu-Natal Conservation Award

1999: Gold medal by the Southern African Association of Aquatic Scientists

Praised by colleagues for his sharp mind, creativity, 'unsurpassed' innovation and vision, Prof Charles Breen has been recognised internationally for building much of the foundation of the South African aquatic science sector. During his decades-long career he laid the cornerstones of modern conservation management in which ecosystems are understood as complex and ever changing, requiring management to be strategically adapted over time.

Breen's long and illustrious career started in Northern Rhodesia where he grew up close to nature. This led to a degree in Botany and Zoology, followed by Honours and Master's degrees. As a newly appointed lecturer with a full lecturing load, he set about his PhD drawing on technical support from his wife, Anne. Breen teases: "[Actually] Anne did a PhD in plant physiology for which I claimed the credit!" This partnership was to continue for the rest of his career as Anne and their two sons were included in the field work, bringing a sense of family to Breen's research teams whether at Lake Sibaya, in the Drakensberg or on the Pongola floodplain.

Ecology in the late 1950s and 1960s was in a state of transition, moving from a mostly descriptive discipline to a more dynamic ecosystem approach. Breen embraced this change enthusiastically. Opportunity knocked unexpectedly. Chair of the Zoology Department at Rhodes University, Brian Allanson, needed a botanist to accompany him on a trip to Lake Sibaya. "I'd learnt how to spell zoology by then, so I qualified," Breen says. The trip would change his life.

Lake Sibaya

Lake Sibaya is a crystal-clear body of water tucked away against the forested dunes and fed by groundwater flow from the coastal plain. Located along the iSimangaliso coastline, the 7 750 ha-lake is the largest of its kind in South Africa, and the RAMSAR Wetland of International Importance has attracted researchers from near and far.

The project left Breen astounded. "The world opened," he says. For the first time, he understood the practical application of the theory that he was teaching. Not only that, but he met different experts collaborating on understanding the same system and, the lake itself was being studied as part of a global picture. He describes it as a remarkable discovery, and one that awakened an old longing. He enjoyed the intellectual engagement of teaching and research but wanted to be out in the field. But that would have to wait.

In 1970 he took up a post-doctoral Research Fellowship at Indiana University, in the US. While he enjoyed the intellectual engagement of teaching and research, Breen found himself, once again, working in a lab. "I wanted to be out in the field," he says. However, the "horror" of spending a career behind a lab bench was relieved when on his return to Rhodes University he was invited to take up a post as Senior Lecturer in plant ecology at what is now the University of KwaZulu-Natal. Breen was surprised. "Having had hardly any practical experience, I felt I knew nothing about ecology!" he says. Breen seized the opportunity.

What he found was "just unbelievable." The university was a meeting place for researchers that brought the real world to the lecture halls. They came with questions on ecology from the Drakensberg to the Namib desert and many places in-between. These were the kind of projects where he came into his own. It was therefore no surprise that he jumped at the chance to work on a project on what was to become a world-renowned aquatic ecosystem. At the time, however, Breen had never heard of the Pongola Floodplain that was to be a focus of

“Sometimes people will say we were probably among the first to develop ecological flow requirements.”

ecological study for the Botany Department. Hoping the opportunity would offer a new direction in his career, he accepted.

The Pongola Floodplain

The Pongola Floodplain is a complex mosaic of meandering river channels, levees and floodplains interspersed with pans and wetlands, between the Pongolapoort Dam and the Usuthu River. Breen remembers a system with abundant wildlife. White faced ducks and hippos were plentiful, and flocks of pelicans would come in from St Lucia, beating their wings on the water to drive the fish into the shallows. “At night, we would sit around the campfire and enjoy the sounds of drums and singing that flowed from surrounding villages,” he says.

Concerns by environmental scientists over the potential impact of the Pongolapoort Dam and associated irrigation development on the floodplain and the surrounding communities dependent on its services prompted one of the most comprehensive environmental studies ever undertaken on a freshwater system at the time. The multiyear project was placed under the directorship of Breen and Jan Heeg.

The researchers were tasked with working out how the system functioned, in order to advise how the water could be allocated in order to keep it doing so. For the first time, Breen was given the opportunity to think about the way a freshwater system operated. Not convinced that a number of disconnected studies would provide the required answers he designed a series of projects on the functioning of the system and the importance of different amounts of water in it over time.

Crucially, he looked beyond the water. “I was watching the cattle grazing and people fishing, and I became aware that it’s a social system.” The researchers then also tied in the movement of water related to grazing availability and other activities of the people that depended on the system.

The Pongolo River Floodplain study was part of a wider national response to growing awareness of eutrophication. This led to the constitution of the Committee for Inland Water Ecosystems (members included the CSIR, DWA, researchers, and later the WRC) to focus on inland impoundments such as the highly turbid Wuras Dam, the extremely eutrophic Hartbeespoort and also the Vanderkloof dams. The Pongola Floodplain was included because of concerns about the impact of impounding the river on the floodplain. Breen was later also involved with studies on the eutrophication of Midmar Dam.

The final report for the landmark Pongola Floodplain project, which recognises the central role of people in the system.

Photo credit: Petro Kotzé

"We applied a systems approach to understand the links between the ecological and social subsystems." Their work resulted in a procedure for estimating environmental water requirements of rivers and floodplains and, crucially, the introduction of what we now term social-ecological systems. This was considered revolutionary at the time.

"Sometimes people will say we were probably among the first to develop ecological flow requirements," notes Breen. "That is possibly true. But more important is that we tried to determine the water that would keep the ecosystem functioning as a resource for the social system."

The Pongola floodplain project offered the perfect environment to test his concepts with researchers, both locally and internationally. In South Africa, and across the globe, people were interested in what they were doing and so "we found ourselves exchanging ideas in this wonderful environment, and I was able to draw confidence from people who were working at the coalface." Breen says although they did not know the term then, what emerged was a strong community of practice characterised by friendship and professionalism.

Though their recommendations were never implemented, the study of the Pongola Floodplain, that ran until 1982 became a defining project in the history of aquatic science in South Africa. It set the platform for then Department of Water Affairs and Forestry to appreciate the importance of environmental flows and to start collaborating with aquatic ecologists. It also introduced people as integral parts of river ecosystems – a concept that would later be formulated as 'socio-ecological systems' and find expression in further WRC-funded research. This approach also softened the boundaries between disciplines, making inter-disciplinary research and learning an exciting challenge rather than a threat.

For Breen, the Pongola Floodplain heralded a new approach to research. "That's where

I began to think about systems and the complexity both in content, in structure and function, but also in variability over time."

In 1986, Breen was appointed as Director of the Institute of Natural Resources (INR) at the University of Natal. Established in 1979 to conduct applied research in the environmental sector, it was described as a "highly unusual and high-risk venture" at the time.

When the INR joined the Kruger National Park Rivers Research Programme (KNPRRP) in 1993, Breen was appointed to lead the programme's second phase. This was Breen's opportunity to test the ideas and lessons learned during the Pongola Floodplain project.

The rivers that flow through the Kruger National Park

At the time, it was becoming clear that we were running our already water scarce country dry, compelling national government to ask serious question about how water in the country was managed. There was major concern for the perennial rivers flowing through the iconic national park too. The consequences of unchecked development flowed into the protected area via its rivers, and managers feared that some of the freshwater systems were close to collapse.

The KNPRRP's aim was to address major concerns about water quantity and quality of the perennial rivers that flow through the park, with the principal objective to understand how to manage them.

Initially, Breen's interdisciplinary approach, that included social sciences, was not welcomed. "It took a little while for us to gain respectability." Breen says he remembers saying, and not being very well received, that water is shared and that we cannot manage the water itself, only what we do with it.

Regardless of management insisting on one, Breen maintained there would never be an absolute figure to the rivers' water

Major concern for the rivers that run through the Kruger National Park was raised in the nineties.

Photo credit: Petro Kotzé

requirements. Instead, it would be a negotiation, with demands fluctuating over time. “During dry periods, we accommodate upstream farmers and during wet periods, we reconstruct the system and get its resilience back up,” he explains.

In the process, Breen introduced the concept of adaptive management which was taken further by Kevin Rogers (who had “cut his teeth” on the Pongola with Breen) creating another landmark concept, what we now call strategic adaptive management. It’s about being able to justify your request for water, he says. The management of water is a trade-off between how much you are willing to give and take depending on the amount available. “I was trying to move the project to thinking about rivers in a human management adaptive way.”

Breen’s perseverance paid off.
The programme received wide acclaim for having raised awareness of the importance of and vulnerable conditions of rivers, in biodiversity conservation and elsewhere. They contributed significantly to the knowledge levels around river issues especially in ecosystems and biodiversity context.

Furthermore, they partly brought about major changes in cooperative governance concerning rivers in South Africa and contributed to the renowned and progressive National Water Act of 1998.

Their insistence on close collaboration with park management led to many changes in thinking, even around terrestrial ecosystem management. Years later, the South African National Parks (SANParks) would formally adopt a strategic adaptive management paradigm and the application has since spread to other protected areas and other natural resource management situations within and beyond South Africa.

In his position as INR director, Breen’s work would find application in the management of many more aquatic systems. In 1998 the INR led the Eastern Cape Estuaries Management Programme. This resulted in estuaries securing a specific chapter in the Integrated Coastal Management Act and in the establishment of an Estuary Management Protocol to guide planning and management at an individual estuary scale. In the same year, he also helped establish the Consortium for Estuarine

Research and Management (CERM) with Piet Odendaal (then CEO of the WRC). CERM is an organisation of South African scientists who collaborate in promoting the wise management of estuarine systems through joint participation in directed research, training and technology transfer.

In 1999, the now-celebrated professor stepped up to the podium with then Minister of Water Affairs, Kader Asmal, when they were both honoured with Southern African Association of Aquatic Scientists gold medals. The rarely awarded accolade recognises an exceptionally high standard of research in the aquatic sciences or valuable contribution to the management, conservation or development of aquatic ecosystems or resources over an extended period. They were the only two people to receive gold medals from 1997 to 2002.

Now approaching retirement and mulling over the growing tensions between development and the environment, Breen started discussions on how this might be introduced into the university curriculum. Perhaps unsurprisingly "They said to me, well, why don't you do something about it?" Without ever having left, Breen was about to get back to work this time, focusing much of his attention to shape the next generation of systems thinkers.

Training a new generation of systems thinkers

In 1995, the INR initiated and led the establishment of the Centre for Environment and Development (CEAD). At its core were Master's programmes that comprised both course work and a thesis. Breen was tasked with addressing the Social Sciences Faculty and smiles as he recalls the first comment "But this does not correspond with our rules" to which he replied "I did not start with the rules. Now we can rewrite them".

Between 1996 and 2014, the period of CEAD's existence, 196 students graduated with Master's degrees, leading several to environmental and conservation leadership positions in the private, public and NGO sectors.

> "I did not start with the rules. Now we can rewrite them"

Then, a chance meeting with then Head of Parks, Dick Parris, at the World Wilderness Congress at the University of Montana led to a collaborative research programme between the UKZN, the University of Montana and SANParks. Dubbed the Treehouse Research Programme for People and Conservation (TRPPC), it had Breen's systems approach at its core.
The programme maintained that protected area management agencies would not be successful until they were equipped to manage relationships with stakeholders in a strategic and adaptive manner. Growing awareness of the tenuous link that often exists between management and governance provided a focus for his research in later years which would also come to fruition when Breen was contracted through The World Bank to help plan and evaluate the Mozambican Transfrontier Conservation Areas development project and, later, to review the MozBio Project.

The TRPCC ran for ten years, and ignited interests in a larger university consortium. The result, Insaka, was inaugurated in 2010 with the purpose to facilitate joint effort directed at building capabilities in natural resources higher education. It consisted

Breen joined the Institute for Commercial Forestry Research Board as chairman in 2003, only the second since the board's inception in 1984. Prof Colin Dyer paid tribute to Breen at the end of his tenure in 2014 as follows: "On meeting Charles, I realised that this relationship with the chairman was going to be very different. He immediately started by asking the "difficult" questions, many of which I'd been dealing with intuitively or by the "seat of my pants", and he didn't stop with just asking the questions; he also offered guidance and wisdom to address these. This was never in a prescriptive way, but rather in a subtle, persuasive manner that would make me think differently – true leadership."

"I would like to be remembered as somebody who helped others achieve their goals."

of a consortium of five institutions: the universities of Namibia and the Copperbelt (Zambia), IIE MSA, Montana and Clemson.

"The thing that I liked so much about it is that I just feel I had so many opportunities created by other people", Breen says, "and now I was able to create opportunities they might never have had in their own home environment, for many others." This remains important to him. "I would like to be remembered as somebody who helped others achieve their goals."

What comes around goes around, maintains Breen. So it was when one of the "Insaka graduates", Bimo Nkhata was appointed Director of the Water Node at Monash South Africa. He recruited Breen with the particular responsibility for supervising post-graduate research, a position that he held until recently.

Looking back over his decades-long career, Breen says he is aware of how fortunate he has been. "I appreciate that realising one's potential is as much a reflection of the support of colleagues and institutions as it is of one's own abilities." In the process, he founded the systems approach for ecosystem research, establishing that the whole is greater than the sum of the parts. The perspective is as relevant to his own life. He used to think his work was centered on ecosystems but, taking a step back, he sees that people and the relationships between them has been as important to this journey.

Photo credit: Petro Kotzé

Prof Breen's advice for young researchers

To be successful, collegiality is important. You also need self-confidence, to believe in your identity; and to admit when you are wrong. Integrity is important. Design way ahead. Be that person that others feel comfortable talking to.

Dr Kevin Pietersen

Photo credit: Petro Kotzé

KEVIN PIETERSEN

A life dedicated to helping the Cinderella of water resources shine at the ball

Current position:

Private consultant and extraordinary Senior Lecturer in the Institute for Water Studies at the University of the Western Cape

Research interests

Integrated water resource management; strategy and policy development support in the water resources sector; exploration, development and management of groundwater; groundwater governance; capacity building and technology transfer of scientific information; Africa-wide water resources assessment

Awards

AWARDS AND HONOURS

2021: WRC Legend Award

Senior Fellow of the Water Institute of Southern Africa (WISA)

Fellow of the Geological Society of South Africa

WISA Certificate of Appreciation for Service and Dedication as President for the term 2009 – 2011

Dr Kevin Pietersen has dedicated over three decades of his career to improved groundwater and integrated water resources management

Photo credit: Petro Kotzé

"Knowledge is incremental," maintains hydrogeologist Dr Kevin Pietersen, "Wow moments happen in a space that has slowly built up over time," he elaborates, and from that space is where innovation can move forward. That is why support in the form of research funding and institutions are so critical.

His own career is a case in point. Pietersen is a specialist in groundwater; a resource once cheekily called the 'Cinderella' of the South African water industry; working hard in the background, but still waiting for its true potential to be recognised and brought to the proverbial ball. His own introduction to the topic was as junior scientist, sampling and monitoring groundwater, but he has since continuously chipped away at the knowledge gaps, assumptions, institutional and legal barriers in place, to afford the resource a sustainable future in South Africa and further beyond in the Southern African Development Community.

An introduction to groundwater

It started by accident, Pietersen explains. Initially he wanted to be a teacher but fell in love with geology instead. As was common for this study direction, he was geared up for a position in mining, and had a job lined up with Goldfields on completion of his Honours degree. This abruptly changed when the CSIR phoned the University of the Western Cape, where Pietersen was studying at the time, looking for candidates for their equal opportunity programme in their groundwater division. They required a geohydrologist.

Pietersen shelved a future in mining and relocated to the CSIR in Stellenbosch. He was appointed as trainee geohydrologist in 1992. The next year, he was sent to the University of the Free State for his MSc degree in geohydrology, which he completed as part of a WRC-funded project to use chemistry and isotopes to understand the groundwater flow regime of the Table Mountain Group Aquifer. He was the first non-white person to obtain a Master's in Geohydrology in South Africa, and the graduation, three months after South Africa's first democratic election, is still one of his fondest recollections. "A memory that will be with me forever is when Nelson Mandela walked into our graduation and congratulated me on receiving the qualification."

“A memory that will be with me forever is when Nelson Mandela walked into our graduation and congratulated me on receiving the qualification.”

It was a transformative time to step into water resources management in South Africa and his career, Pietersen says, is inextricably linked to the democratisation of South Africa. The vision for a new future of water management was just being set, led by water minister, Prof Kader Asmal, through the White Paper on Water Supply and Sanitation, the Water Law Principles and White Paper on a National Water Policy.

“Minister Kader Asmal called surface water the masculine resource – of dams, pipelines, concrete and engineers, whereas groundwater for him was the feminine resource, laboured for by the most vulnerable of society, the women and children of Africa. From this vision, groundwater changed from a source, largely for small towns and for mining and commercial agriculture in the arid parts of the country, to a strategic resource covering 60-90% of community water supply across the whole country.”

At the CSIR, the budding geohydrologist cut his teeth on the renowned Atlantis Water Resources Management scheme, currently part of the largest managed aquifer recharge scheme in South Africa. Revolutionary for its time, the system entails the recharging of stormwater and treated wastewater into aquifers that was, for a period, sampled and monitored by Pietersen.

Soon, his path would cross with a project that would come to define him. Pietersen got involved in the development of a monitoring and evaluation programme for the then Department of Water Affairs and Forestry, which received funding from the European Union Programme for the development of rural water supply and sanitation in the Eastern Cape. “It was focusing on real issues and people’s day-to-day lives. Coming from an urban water management background, where water quality is a given, it really inculcated the importance of water for all.”

Pietersen was also involved in a groundwater supply and assessment strategy for sustainable use in the semi-arid Namaqualand region. The project focused not only on understanding the groundwater resource, but also on the socio-economic implications for rural communities in the Northern Cape. Pietersen had his first glimpses of water’s social dimension. “That’s where I really started to understand those issues, concepts and what it entailed,” he says. It would become a thread throughout the rest of his career and, in his next position, he could expand on it to the fullest.

A career with the Water Research Commission

In 1998, Pietersen sat for an interview with the WRC for a position as Research Manager for Groundwater. The job would entail the coordination of groundwater research in South Africa in order to contribute to the optimal use of the resource in a sustainable manner. The organisation offered him the post soon thereafter, prompting Pietersen to phone his wife Leezall. “We’re moving,” he announced to her surprise. The trek to Pretoria heralded in a second landmark phase for both his career and for groundwater research in the country.

The WRC is a “fabulous” organisation to work for, Pietersen says of the nature of work that he was involved with there. “You conceptualise and think about the future, then you try to understand where the knowledge is required to deal with our water issues.”

At the time that Pietersen joined the WRC there was a big focus on gaining a better understanding of groundwater in fractured rock aquifers. Pietersen continued this work, guiding resources to develop techniques and protocols for groundwater exploration, applying innovative techniques to estimate aquifer parameters and developing systems for better management of the resource.

Pietersen started expanding the suite of groundwater related work funded by the WRC. The Commission started funneling funds towards understanding the interaction between surface water and groundwater, the measurement of low flows and activities that reduced streamflow.

Under his guidance, they also moved towards protection of the resource, working to identify, predict and manage those intensive land-uses that impacted on groundwater. It resulted in a better understanding of the origin, pathway and ultimate fate of pollutants, and the management options available to mitigate the impact of intensive land-uses on groundwater.

In his position as Research Manager at the WRC, Dr Kevin Pietersen managed over 100 research projects.

Photo credit: Petro Kotzé

"My passion was capacity development and building a new generation of people to deal with our water issues."

In his position as Research Manager at the WRC, he managed over 100 research projects. As a result, a significant proportion of hydrogeologists in the country earned their stripes on WRC-funded research projects.

Pietersen then became the organisation's Director for Water Resource Management. He provided research support for information systems, guidelines, decision support systems, prediction tools, technologies and methodologies. First, these supported the protection of water resources and second, the fair allocation of water to meet the needs of the environment, social and economic development. He was also tasked to position the WRC globally, and provide wider application of South Africa's water centered knowledge. This was followed by a position as Director for Water Centred Knowledge in which he supported the strategic positioning of the organisation with stakeholders through the management of the WRC's crosscutting impact areas.

During his time at the WRC, Pietersen was a major driver for capacity building, and this passion is something that he is still remembered for. He wrote *The need for a comprehensive approach to improve capacity of designate persons in the water sector – A framework for action* that formed the basis of the capacity building outcomes as formulated in subsequent years.

The paper stipulated that the successful implementation of water legislation depended on available and skilled specialists. It made the radical and bold (for the time) proposal for the role that water research could play to fulfill that gap. To do that, a dedicated programme to maximise human resource development was necessary to meet water-related priorities. The programme was to cut across functions of government agencies, DWAF, WRC and NRF.

"My passion was capacity development and building a new generation of people to deal with our water issues," Pietersen says. "For me it's just about having had an opportunity to create space for people to develop." Pietersen would like to be remembered for being a catalyst in people's lives, but his legacy will carry more weight than that. During his time at the WRC he was appointed in various positions that indicated the impact of his now, years of expertise and knowledge. Pietersen became the Chairperson of the Groundwater Division, the President of the Geological Society, and the President of the Water Institute of Southern Africa. In between, he also managed to complete his PhD, a continuation of his earlier work on groundwater supply in the rural Namaqualand areas in the Northern Cape.

Again, this would be a breakthrough in the history of South Africa. "As far as I know, Kevin Pietersen, Rian Titus (featured elsewhere in the publication) and myself were the first three black South Africans to receive Doctorates in groundwater sciences (Hydrogeology)," Dr Shafick Adams, Executive Manager at the WRC remembers.

Pietersen says he did not achieve these successes alone. He pays tribute to mentors such as Dr Gideon Tredoux at the CSIR, and later Dr George Green at the WRC, who played a significant role in the early years of his career. Later, former WRC CEO, Dr Rivka Kfir, helped him to develop his skillset further.

"Groundwater is a hidden treasure, often under our very feet, but little recognised and acknowledged for the strategic role it plays. I have called it the hidden treasure – though we may not be able to see it, yet it provides life-giving water to people and ecosystems across the globe. It is truly, blue gold, a resource that must be used wisely to ensure sustainable livelihoods for millions of people"

– Minister Ronnie Kasrils at the Groundwater Opening Ceremony, Osaka, 2003 (as read by Christine Colvin)

He also mentions Ronnie Kasrils (Ministers of Water Affairs and Forestry from 1999 to 2004), who introduced the concept of groundwater as 'blue gold'. "Under his leadership, I flourished as a water person," Pietersen notes. He recalls a particular memory, which involves the former minister and the smoking of Cuban cigars. "I recall a sore throat having not smoked for ten years," he says in memory of the grand occasion. In 2007, Pietersen left the WRC to open his own groundwater consultancy, and moved back to Cape Town.

"Already groundwater's role in South Africa has undergone a major change during the water sector transformation post-1994, from an undervalued resource and a 'private water legal status' to a source of domestic water and general livelihood to more than 60% of communities in thousands of villages and small towns country-wide as part of the national drive to meet basic water needs. These changes present a major challenge for the resource which occurs mainly in hard rock aquifers in which yields are limited and a water sector which had treated it largely as an emergency water supply by drilling boreholes during drought emergencies. Its sustainable utilisation by many different role players at thousands of locations will require a very unique approach."
Department of Water and Sanitation, National Groundwater Strategy

The consultant years

Pietersen became Director for a consultancy later bought by international company SLR Consulting. He currently works as a private consultant at his own company, L2K2 Consultants (Pty) Ltd. "My work after the WRC focused on the integration of groundwater in national water resources planning." He has also become progressively involved in issues related to groundwater governance and understanding the broader context of groundwater, beyond a technical perspective. For one, he was the lead in the Strategy and Guideline Development for the National Planning Requirements, that resulted in the National Groundwater Strategy.

"He is selfless and he is well liked and respected by everyone that has been privileged to have received his guidance."
- Dr Shafick Adams,
Executive Manager at the WRC.

Dr Pietersen being awarded with the Knowledge Tree Award in 2021.

Photo supplied

Pietersen has also gradually evolved to become a regional groundwater consultant in the Southern African Development Community (SADC). Among others, he served as project leader for the SADC Hydrogeological Mapping Project that resulted in the SADC Hydrogeology Map and Atlas. It provides an overview of the groundwater resources of the SADC region by means of an interactive web-based regional map. The map is a first, but necessary, step to support groundwater resource planning at multi-national level as well as regional transnational scales.

More major projects since he has left the WRC include work on unconventional gas exploration and prediction and its impact on South Africa's water resources. Most recently, he has expanded into big data analytics and groundwater. This entails using remote sensing and data driven technologies to see to what extent one can use regional information to localise groundwater resources. For him, this has simply been a continuation of his work with the WRC. "I went from managing WRC research projects, to being director, then team leader for research projects and as part of that, closing the loop in terms of capacity development and involving students in the work."

Pietersen insists success does not depend on how clever you are. "A distinguishing factor is a strong work ethic," he says. That, and the guidance of mentors. "You need people to guide you, to bounce ideas off of, and to help you to rectify the mistakes that you make."

Pietersen himself continues to provide this service to the next generation of groundwater and integrated water resources management specialists. He still supervises students through his position as extraordinary lecturer at the University of the Western Cape. "He is selfless in this regard and he is well liked and respected by everyone that has been privileged to have received his guidance," Adams says.

After more than three decades of dedication to groundwater management in South Africa, Pietersen is modest about his achievements when asked about it. Like the resource that he has committed his professional career to, the impact of his years of hard work is not easily recognised by the uninformed. But, after all this time, his body of work that has resulted in such a vast improvement of our understanding of the resource and how to protect is, should result in a well-deserved 'wow'.

Prof Tally Palmer

Photo supplied

TALLY PALMER

The researcher that helped pen environmental science into water law

Current position:
Director of the Institute for Water Research (IWR) and African Research Universities' Alliance (ARUA) Water Centre of Excellence at Rhodes University

Research interests
Adaptive water resources management; water governance; water quality and pollution; aquatic ecology; transdisciplinarity

Awards

AWARDS

2021: WRC Legend Award
2018: The Rhodes University Vice Chancellor's Excellence award in Engaged Research
2016: Gold medal by the Southern African Society of Aquatic Scientists
2002: South African National Women in Water award
1999: Silver medal by the Southern African Society of Aquatic Scientists

"It was unimaginable," says riverine ecologist Prof Tally Palmer. "Almost while we were creating it, the research went into policy." Palmer was one of those at the forefront, a doyen of aquatic ecology in South Africa that helped write the revolutionary concepts in water management ensconced in the National Water Act of 1998. While you often work in a plateau grinding away, every now and again there's a big enough shift for radical change, she says. "I just happened to catch one of those moments."

In the process, Palmer helped write one of the most progressive pieces of water legislation in the world, most specifically penning the concept of an 'Ecological Reserve'. At the time of its promulgation the Act was hailed as a major step forward in the translation of the concept of integrated water resource management (IWRM) into legislation. It has been widely quoted and referred to, and a number of countries ranging from China to Zambia have used it as an example in the revision of their own water legislation.

Since then, she has continued to be instrumental in mainstreaming environmental water science into practice. In 2016, when she was awarded a coveted gold medal by the Southern African Society of Aquatic Scientists (SASAqS) she was described as "the most effective and influential game-changer of her generation of aquatic scientists". Still, Palmer remembers her younger self being filled with "a proper degree of terror" at her initial involvement in the review of our country's water law. In fact, she says, until she began to coordinate aquatic scientists, and was appointed to the Water Law Review Panel, the law had never crossed her mind.

To write a new law

Straight after completing her PhD, Palmer landed her first WRC-funded project to build and run artificial streams to test water quality for aquatic invertebrates. At that time there was substantial research on environmental flows taking place, focusing on water quantity, but Palmer's research project was the first to link environmental flows and the water quality requirements of organisms living in water.

In an unanticipated chain of events, Palmer's journey to the law started at that project's hydraulics lab. The budding scientist invited the so-called "shiny shoe brigade" that she attended a conference with there, landing herself an invitation with the departmental officials to dinner. I was "tremendously cheeky and opportunistic" Palmer recalls with a laugh and, over dinner, she continued to engage in "an impassioned conversation about environmental flows as practical options in water management and dam design" with engineers seated around the table.

The interaction would lead to her submitting a document of input from SASAqS members to the Water Law Review Panel. To her surprise she was appointed as the Vice Chair for the South African Water Law review process at their very first meeting.

> "All the way along the line, you were dependent on people being willing to step beyond their boundaries."

Prof Palmer has not only led water policy in South Africa, she is also an inspirational leader and mentor to many.

Photos supplied

From the beginning, former minister Kader Asmal was determined that the 1956 Act was not simply to be tweaked, but that a new Act must be written out of new thinking for a new country. He was adamant that the law should be principle-based, and reflect sustainability and equity. "We were in the middle of facing our national shadows and looking for a new way forward," she says of an experience that was "unimaginable".

It was there that the seeds for the idea of the Ecological Reserve were planted. "The idea of the Reserve, that there would be water that was sacrosanct both for sustainability and for people was a transformative vision, and we were the first country in the world to do it," she notes.

Except, not all the science was in place yet to make it into law. Palmer acted as vanguard between researchers and policy, ensuring that the ideas from one was signed and sealed in the other. It wasn't smooth sailing. Engineers and lawyers argued that water for the environment was a nice idea, but questioned whether it could actually be done.

The results, that allowed the quantification of environmental flow, came from the then still-ongoing WRC-funded Kruger National Park Rivers Research Programme. Now, they had robust figures that could be legally defensible in a court of law.

Yet, though environmental flow work was being quantified, the necessary water quality was still an ongoing process. "Now, sometimes in a career you have to ***vat 'n kans*** (take a chance)," says Palmer. "I didn't actually lie, I just implied that quality was an integrated part of the environmental flow package." The methods for water quality were developed on the run.
In a way, this was typical of the ongoing process. "All the way along the line, you were dependent on people being willing to step beyond their boundaries." Palmer herself had to do so repeatedly.

To write from a human needs angle when your history is from an environmental perspective was like grasping from a knowledge base that was not in existence yet, she says. Palmer could only rise to the occasion by bringing her whole self with her into everything. "Often, we only call up particular bits of ourselves, like the professional ecologist in me," she says, "but in that moment my interest and passion in social justice was allowed to be as important as my interest in ecosystem conservation."

A foundation for people and the environment is set

When she was a teenager, Palmer went on a Wilderness Leadership School Trail, a concept founded by Dr Ian Player and Magqubu Ntombela in KwaZulu-Natal, to provide a pure wilderness experience for people of all backgrounds, races and nationalities. "It was a real Road-to-Damascus experience for me," recounts Palmer. "I basically fell in love with the world." She developed a driving force based on a "deep, profound personal connection with the earth and the natural world, and the recognition that we needed to see people as part of it."

She later enrolled for a degree in environmental science at the University of KwaZulu-Natal in Durban that provided her with "fabulous" undergraduate training. Durban was pioneering and teaching an integrated biological sciences double degree at the time, taught in a very integrated and imaginative way many years ahead of the pedagogy or the teaching styles of now, she says. It gave her her first taste of innovative, integrated thinking.

She then pursued a Master's degree in Zoology at Rhodes University. Head of Department, Prof Brian Allanson, was a profoundly influential figure in the water sector in South Africa and Palmer landed in the midst of the next generation of academics and students that would benefit from his training. She thanks him for teaching her the rigor of commitment to dedicated, meticulous, high-calibre work.

Following the completion of her Master's degree, she left research to focus on her family, which would soon grow to include two children. "This matrix of experience is very often part of particularly women's careers," she says. From 1982 to 1988 Palmer joined the Diocesan School for Girls in Grahamstown as Senior Biology Teacher. "Many people thought that that was a step down from academia," she says but she describes it as a fantastically generative time, during which she learned many skills and lessons. Says Palmer, "there are pathways through careers that are often not talked about." Still, while teaching, she started on her PhD fieldwork, later completing it full-time, taking her small kids on field trips, writing up papers in playrooms with cartoons blaring in the background.

Straight off her PhD, she was introduced to the WRC and that fateful project. It was to be a transformative encounter both for Palmer and aquatic sciences and management in South Africa.

From one crucial click to another

Kader Asmal was convinced that the new law should start from principles, Palmer remembers. They were, first, sustainability and equity as central guiding principles in the protection, use, development, conservation, management and control of water resources. The guiding principles recognise the basic human needs of present and future generations, the need to protect water resources, the need to share some water resources with other countries, the need to promote social and economic development through the use of water and the need to establish suitable institutions in order to achieve the purpose of the Act. Palmer was appointed as co-editor and

“How to practice transdisciplinary research to catalyse change has been the main focus of my work since.”

author of the eventual White Paper on a National Water Policy for South Africa, accepted by Cabinet May 1997. It was “a totally mind-blowing experience,” she says of helping to write such transformative and beautiful policy and legislation. Not only were they changing the face of freshwater management across the country and beyond, but Palmer too would be changed profoundly. “It changed me from focusing on advocacy for protection into the recognition of the enormous complexity of what it means to manage water resources and include multiple users,” she says. “It was the transformative moment where I stopped being a focused ecologist wanting to protect aquatic resources, to wanting to understand how we could live creatively with a water sector as an art.”

She was progressively carving out a niche and professional position to apply this. In the nineties, Palmer helped found the Institute for Water Research (IWR) at Rhodes University and, as she developed her interests in water quality and ecotoxicology, initiated and directed the Unilever Centre for Environmental Water Quality (UCEWQ) within the IWR in 2000. She was a Board Member of the WRC from 1999 to 2004 (acting as Vice Chair for the last two years) and a member of the National Water Advisory Council South Africa until 1998.

Once the Water Act, “this imaginative groundbreaking law” was complete, we had to ask how we are actually going to do it, she says. Based on this question, the National Water Resource Strategy was published in 2004, but at this point, her life took a completely different turn.

She was offered the position of Professor of Water Resources, Director of the Institute for Water and Environmental Resource Management, and Director of the Centre for Ecotoxicology at the University of Technology in Sydney (UTS). Palmer and her family moved to Australia in 2005.

The move was to catapult her into a new direction when she was introduced to another “crucial click” in her career and research path, namely the field of transdisciplinarity. This connotes a research strategy that crosses many disciplinary boundaries to create a holistic approach and crucially, includes non-academic stakeholders in the process of knowledge production. “How to practice transdisciplinary research to catalyse change has been the main focus of my work since,” she says.

Facilitating change back in South Africa

In 2008, back in South Africa, Palmer accepted a position as Executive Director for Applied Research and Innovation with the National Research Foundation. At the same time, she was invited by then-Minister of Water Affairs, Edna Molewa, to serve as chairperson on the National Water Advisory Council, which she did from 2011 to 2013, becoming a primary source of scientific advice to the minister.

Palmer's work increasingly focused on general complexity theory and transdisciplinarity, and she committed herself to community-engaged action research that is practice based, draws on knowledge across a wide range of academic domains as well as from practitioners and communities to effect behavioural change.

Many of these ideas and theories were tested in the WRC-funded project, Integrated Water Resource Management (IWRM) in South Africa: Towards Practising a New Paradigm (TPNP), which ran from 2013 to 2017. The four years of funding became the foundation out of which she was able to practice, show and develop how to put multiple transdisciplinary research projects together.

The research is built on the understanding that people live in complex social ecological systems. The characteristics of these complex systems give rise to most of the intractable problems in water resource management. Therefore, the solution also lies in complexity thinking (because the systems are by their nature complex) and transdisciplinarity (because it offers methods for concurrent knowledge development and sharing across disciplinary boundaries, and among communities, researchers and practitioners).

"It is profoundly hard to do this, and it takes time" Palmer says. But she adds that the shortcuts that we've been taking don't work. "Some problems can be solved, for example, with excellent engineering, and we must have that but if we don't place it into social contexts, we lose the possibility of sustainability." The TPNP project recognised that IWRM has largely failed in South Africa since it was first embedded in the National Water Act of 1998. It's core goals of equity, sustainability and efficient use have frequently not been met, but can be with the practice of these new concepts.

Palmer is now working to apply results from the TPNP project, as well as those from the follow-up project Tsitsa (by the Department of Forestry, Fisheries and the Environment), in different locations across Africa, including Ethiopia, Rwanda, Senegal, Tanzania, Uganda and Nigeria. The project aims to apply novel research theory, methodologies and practice to meet the UN Sustainable Development Goals and realise the Africa Water Vision for 2025. The latter calls for an Africa where there is an equitable and sustainable use and management of water resources for poverty alleviation, socio-economic development, regional cooperation, and the environment.

This type of work is hard, she says, but it is without a doubt possible. "When I stood up in the Water Law Forum and said that we could quantify Environmental Flow, I spoke from a vision of what research could do." Now, Palmer says her vision of what research can do rests on transdisciplinary work. "I believe it's the only way to effect change."

A changemaker looks back

On the cusp of retirement, Palmer says she hopes that her work will help lead society to find a way to live fairly among humans and with the planet. She has chased this vision tirelessly, pushing forward to realise her beliefs regardless of immense challenges. "From the first WRC project, when I suddenly had a million Rand to spend over three years to build streams and run a pilot project, I woke up terrified every morning for a year," she says.

Yet, she has never wanted to quit. "From the start, I have been a crazily, passionately, driven person." She has been exhausted, terrified and uncertain, but she has never wanted to give up. She now sees the willingness to jump into deep water and learn by swimming as one of the tools of the trade.

> “When I stood up in the Water Law Forum and said that we could quantify Environmental Flow, I spoke from a vision of what research could do.”

Fantastic mentors and supporters have helped, as has the community of practice created by the WRC. Ultimately, water is a profoundly integrating medium, says Palmer. “The integration of our thinking brains and our whole selves, our heart selves, is held in water in a way that is the same as the way water connects landscapes. For me, it’s been a fantastic medium always to work in.” Palmer says she feel immensely grateful for the ride that she has been on- that “serendipitous rollercoaster that provided a mix of opportunities” that would forever change the way we see water, the law and eventually, how to make it come to life.

Prof Tally Palmer’s advice for young researchers

Perseverance, very hard work, generosity and having fun are integral to achieving a successful career. Because if you’re not enjoying it, you can’t sustain the grinding hard work and perseverance that it needs to build a career and make a difference. You have to be brave. You have to work hard. You have to be generous. Enabling a supporting space is totally important.

Prof Denis Hughes

Photo credit: Petro Kotzé

DENIS HUGHES

A lifetime of model behaviour

Current position:
Professor Emeritus at the Institute for Water Research, Rhodes University

Research interests:
Hydrological and water resources modelling, evaluation of available water resources and hydrological design of water resources schemes

Awards

AWARDS

2021: WRC Legend Award

2016: The Volker medal of the International Hydrology Prize of IAHS/WMO/Unesco

2012: Rhodes University Vice-Chancellors Senior Research Medal

Prof Denis Hughes is somewhat embarrassed to admit that he has only had two jobs in his decades-long career. "I never went anywhere," he says jokingly. However, from his positions at Rhodes University where he did the bulk of his work, he moved the fields of hydrological modelling, environmental flow requirements and uncertainty quantification in the assessment of water resources availability forward substantially. He has been recognised internationally for his leadership and outstanding contributions to the fields, and more specifically, for advancing the interface between science and practice. Furthermore, he helped create a cohort of hydrological modelers throughout the sub-Saharan African region.

Tipping point 1: A PhD on floodplain inundation dynamics

Hughes laid the foundation for his career with his PhD on floodplain inundation dynamics at the University College of Wales in Aberystwyth in the UK. He credits mentor, John Lewin, with teaching him a great deal about conceptual thinking in geomorphology and hydrology, and employing him as research assistant in the Department of Geography in 1977. Unfortunately, the economic climate in the UK at the time resulted in few academic positions being available, leading to a second, major, tipping point in 1979.

According to Hughes, instead of job changes, his career journey can best be described through key tipping points along the way.

Prof Hughes did his PhD on floodplain inundation dynamics at the University College of Wales in Aberystwyth.

Photo credit: Petro Kotzé

He has been recognised internationally for his outstanding contributions to the fields of hydrological modelling, environmental flow requirements and uncertainty quantification.

Tipping point 2: A new opportunity in a new country

Hughes made the bold decision to move to South Africa, accepting a five-year contract on hydrological modelling research at Rhodes University's Hydrological Research Unit (HRU). It wasn't an easy choice. He had never left the UK before, knew little about hydrological modelling and even less about the semi-arid environments that he would be conducting research in. Plus, South Africa was in a state of political and social turmoil. The move was "a bit of a traumatic experience," he recalls.

Fortunately, his fears were laid to rest on arrival at Rhodes. Colleagues like André Görgens guided him through the science and political issues, mentoring the young research officer on hydrological processes in semi-arid areas and incorporating these into hydrological models. The development and application of different types of catchment rainfall-runoff and water resource models would remain a central thread of Hughes's career.

Tipping point 3: Love and marriage

Three years into his five-year contract, Hughes met his future wife Ros, who was completing her PhD in Pharmacy. "It was the dominant reason why I stayed in South Africa, and am still here today," he says. They were married in 1987, and by 1989 the family had grown with two boys. Contrary to his initial plans to return to the familiar social and political life of the UK, Hughes settled into family life in the small city of Grahamstown, South Africa.

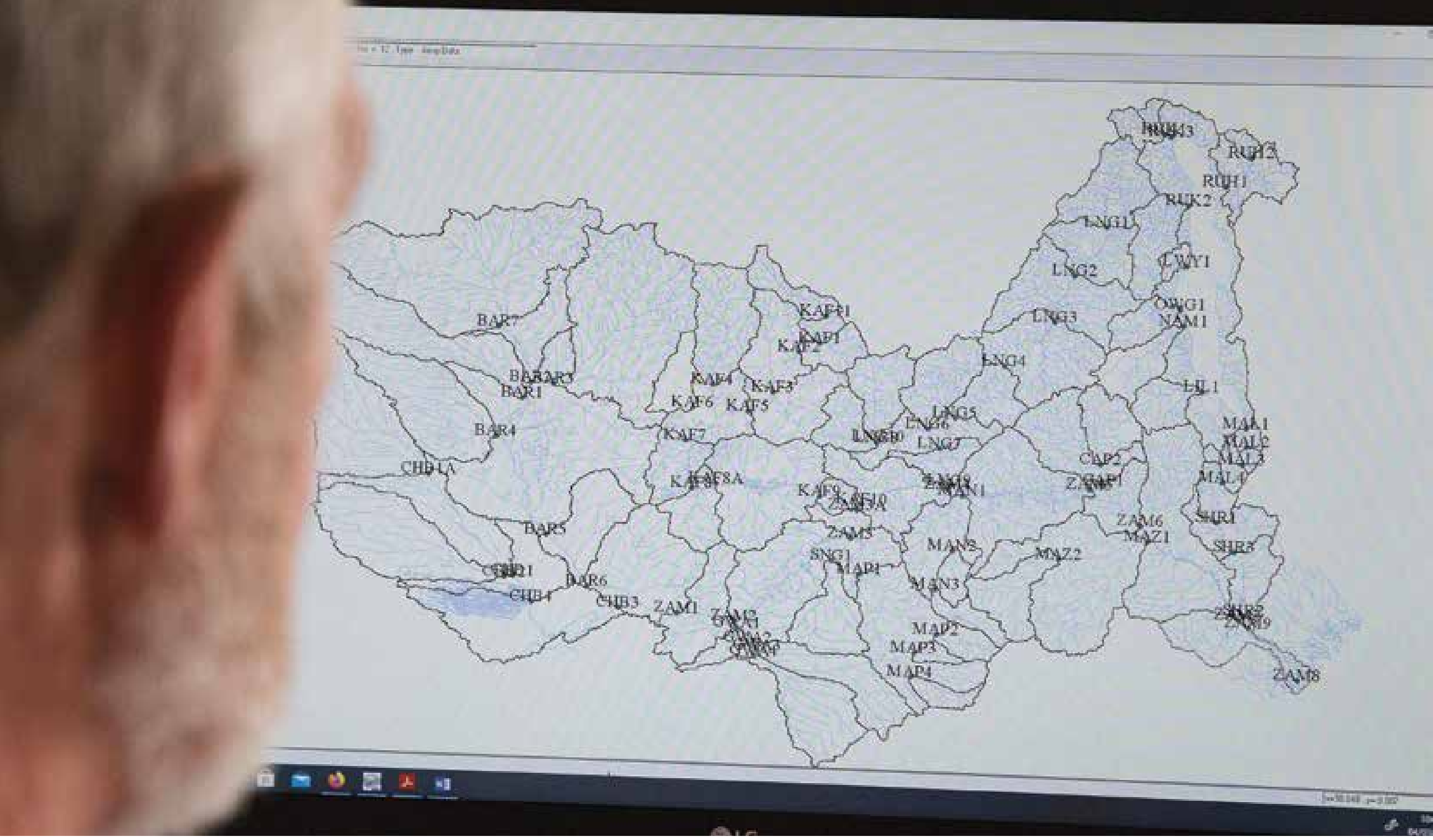
Tipping point 4: The Institute for Water Research is established

By the late eighties, as South Africa was entering a new political era, Hughes was promoted to Senior Research Officer at the HRU. The looming democracy heralded in a new age of water resources management too, shifting towards ecologically sustainable water use.

Until then, the HRU mostly conducted work for water resources engineering, in line with the country's prevailing focus on the development of its scarce water resources, including the construction of large dams and irrigation schemes. On the other hand, the university also housed the Institute for Freshwater Studies (IFWS), directed by Prof Jay O'Keefe, who was at the forefront of the ecological perspective.

The initial announcement that the IFWS and HRU would merge was met with serious objections, Hughes recalls. Regardless, the multi-disciplinary Institute for Water Research (IWR) was established in 1991. With Hughes as Associate Professor, the institute now offered the skills of different water science specialists, including in the fields of hydrology, freshwater ecology and environmental water quality. This enabled them to contribute more effectively to the growing demand for expertise in the broad field of environmental water management.

The post-1994 government called for a complete overhaul of the country's water legislation, introducing the Ecological Reserve. The revolutionary concept ensures that a proportion of the natural flow regime



Prof Hughes has won international renown for advancing the interface between science and practice.

Photo credit: Petro Kotzé

of rivers are reserved for sustainability of the resource. The IWR offered the ideal combination of hydrological and ecological expertise to support such novel ventures.

Hughes became intimately involved in the hydrological issues associated with determining the environmental water requirements of rivers (a subject that would remain one of his main research areas).
It was an exciting time in freshwater-related science. The IWR was developing new approaches as they were applying them in practice. Often, this placed hydrologists as referees between ecologists and water resources engineers in the battle to deciding the fate of water, Hughes says.

“As far as the water resources engineers were concerned, anything that flowed past the weir to sea was a waste; which was like a red rag to a bull for ecologists. As scientific hydrologists, we needed to help find the compromise.”

In the process, Hughes pioneered relatively simple desktop approaches to determine the Ecological Reserve, designed for rapid assessments in data scarce situations.
This parallel developments of research and practical implementation of hydrological and water resources science would become a landmark characteristic of his work since.

Hughes also recognised the need for integrated modelling systems that could apply a wide range of models through common data processing and visualisation tools. Should additional models and data analysis procedures be added easily, the research hydrologist could concentrate on the hydrology of the research problem, instead of computer language coding.
The concept came to life in the development of the HYMAS (HYdrological Modelling Application System) software package, which became the main vehicle through which models and supporting data analysis procedures were applied within the IWR.

“The opportunity gave me real feel for the problems that exist in doing hydrological science and practical water resources assessment and management in Africa.”

Tipping point 5:

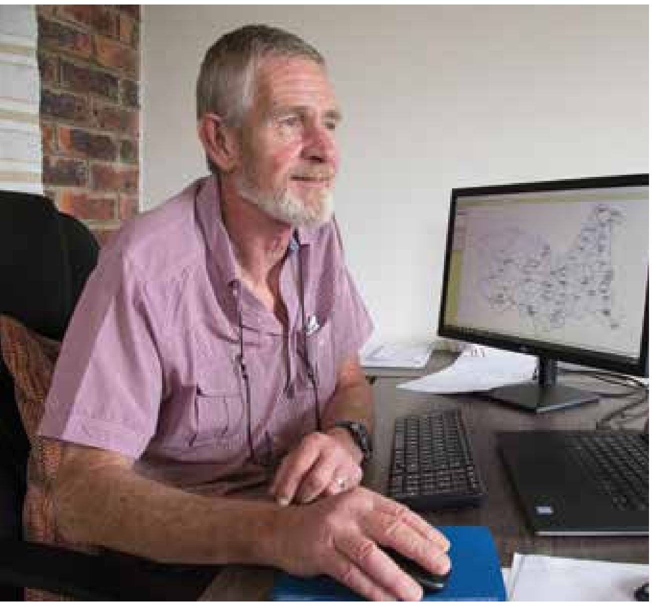
The UNESCO FRIEND project

In 1994 the WRC funded Hughes’s involvement in the South Africa FRIEND (Flow Regimes from International Experimental and Network Data) project, part of an international programme that fell under the UNESCO IHP (International Hydrological Programme). The project’s central objective was hydrology and water resources for sustainable development.

The programme brought together a large network of international collaborators, including all the SADC countries (Angola, Botswana, Democratic Republic of Congo, Lesotho, Malawi, Mauritius, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe) to build research capacity in the fields of water resources science and management. The IWR’s main contribution was the assessment of monthly and daily hydrological models for simulating the water resources of representative catchments in almost all of the SADC countries.

“The opportunity gave me real feel for the problems that exist in doing hydrological science and practical water resources assessment and management in Africa,” Hughes notes. It also highlighted the value of the HYMAS software which, when eventually updated to Windows, and to incorporate a spatial interface, led to the development of the SPATSIM (Spatial and Time Series Information Modelling) package. It remains the primary software platform used by IWR staff and students for running hydrological models. By now, the IWR was recognised as one of the major institutions in Africa for hydrology and, through the FRIEND project, was connected with key international groups in the fields of hydrological science. These included the Centre for Ecology and Hydrology in the UK and notably, the International Association of Hydrological Sciences (IAHS), a community with more than 9 000 members in over 150 countries.

Along with increasing recognition of the IWR, Hughes’s profile grew on local shores and beyond. In 2003, the same year he became Full Professor at the IWR, he accepted the position of vice-president of the IAHS International Commission on Surface Water. He would later (from 2009 until 2015) serve as Vice President with special responsibilities for promoting hydrological sciences in developing countries. From 2000 to 2011 he served as IAHS National Representative for South Africa. Then, he assumed the responsibility of chairperson of the Professional Advisory Committee to the South African National Council for Natural Scientific Professions for the Water Resources Science field of practice. He also served on the South African Committee of the UNESCO IHP.



Prof Hughes has been honoured for his outstanding applications of hydrological science for the benefit of society at large.

Photo credit: Petro Kotzé

Throughout, he continued to contribute to the science and practice of determining the environmental water requirements of rivers. One result was a computerised decision support system for a preliminary estimate of the quantity component of the Environmental Reserve, based on a hydrological extrapolation of past instream flow requirement workshop results. The model was later revised to incorporate the links between hydrology, hydraulics and ecological response, and it has since seen international uptake.

In 2003, Hughes also developed a new groundwater recharge and discharge algorithm for the Pitman model, in answer to the relationship between surface and ground water hydrology in the fractured rock aquifer systems of the country and the lack of tools to evaluate the relationships.

Tipping point 6: An uncertain future

"There's a famous expression," Hughes says, "that models are always wrong, but sometimes they're useful. The harsh statement is unfortunately fairly close to the truth too, he says, in reference to the huge uncertainties in the structuring and output of models." Around 2005, Hughes experienced a Road-to-Damascus moment in his career when introduced to the international concept of uncertainty modelling.

Accounting for uncertainty in hydrological and water resource estimates was of major international interest, and the IWR brought the concept and its implementation to South Africa. The key motivation for this research focus was the recognition that we are always dealing with data scarcity or data accuracy problems in the use of hydrological models in Africa. These include uncertainties in the climate forcing data, the model structure and the model parameters. Uncertainty modelling allowed for all of the associated uncertainties to be explicitly included, wherever possible.

Led by Hughes, the work has focused on adding local context to northern hemisphere research, and applying internationally published research ideas in data-poor areas like southern Africa.

Hughes describes it as a liberating time, because it allowed them leeway in their predictions. “It was a relief to say that there is no certainty, when you were expected throughout your career to present it.” It also allowed them to blow new life into old models. A flexible uncertainty version of the Pitman model that can be used in many different situations was developed, and included in the SPATSIM software framework.

Tipping point 7: Training the next generation of sub-Saharan research hydrologists

At the end of 2008, the IWR was awarded a three-year funding stream by the Carnegie Foundation of New York to initiate the sub-Saharan Africa Water Resources Network as part of the Regional Initiative for Science Education (RISE) programme. This project was designed to promote post-graduate education. Until then, the IWR mostly functioned as a self-contained research unit, without a large focus on students.

Suddenly, they welcomed in scholars from different cultures and countries of sub-Saharan Africa, many who would otherwise not have had an opportunity to get started on research careers. Their success resulted in a total of nine years of funding, supporting 21 PhD and 16 MSc students who worked on many different projects, typically large scale and regional – including climate variability and food security in the Zambezi basin, hydrological modelling of the Congo River and the whole of Swaziland and modelling the floodplain and wetland inundation dynamics of large rivers. These contributions have been significant in a region with relatively few research hydrologists available to provide supervision support for post-graduate research studies.

“This has been a very rewarding period in my career, particularly watching young people, from generally disadvantaged academic backgrounds, develop their science and research skills,” Hughes says.

Tipping point 8: Retirement

Shortly before his retirement in 2017, when he assumed an emeritus position at the IWR, Hughes was presented with the prestigious Volker medal of the International Hydrology Prize, awarded for outstanding applications of hydrological science for the benefit of society at large. The accolade saw Hughes recognised for his vast contribution to the field of hydrology science. This includes the improved application of hydrological models in the diverse climate conditions of sub-Saharan Africa; the development of uncertainty approaches to hydrological modelling, in scientific hydrology and water resources practice; his contribution to the determination of environmental flow requirements; and, for the supervision, training and mentoring of a large number of young African scientists.

Yet, he is modest when asked about his achievements in person. It’s very satisfying to know that you have had students who probably against great odds have achieved what they set out to achieve, he says.
A reasonable number of published papers in good journals has provided him with confidence. Last, it’s good for him to know that they managed to get the IWR up to a level that it is reasonably sustainable.
In all of these ways, from once laying the groundwork for his own career in the UK, Hughes has now built an inspiring foundation for others to take his renowned work further into the future.

Rowena Hay
Photo supplied

ROWENA HAY

The maverick that created a
new landscape for groundwater use

Position at time of passing:
Umvoto Africa Founder and late Managing Director

Research interests:
Hydrogeological exploration, wellfield development, water supply, disaster risk reduction, integrated water resources management, social hydrogeology

Awards

AWARDS

2021: WRC Legend Award (awarded posthumously)

2016: National Science and Technology Forum-South32 Award for Research Leading to Innovation by a Team or Individual in the category 'SMME' (awarded to Umvoto Africa)

2015: Water Research Commission Knowledge Tree Award in the category Empowerment of Communities

2014: Umvoto Africa projects (Stanford, Hermanus and Oudtshoorn groundwater development) selected as part of the Cape Town World Design Capital

2012: WISA Professional Development award and Umvoto Africa voted Best Company in Southern Africa for Young Water Industry Professionals

2009: Businesswomen's Association Regional Business Achievers Awards, Cape Entrepreneur Winner

While aquifers lie out of sight and out of mind for many water resource managers, Rowena Hay dedicated her career to raising the profile of this oft forgotten water source. The hydrogeologist imagined, and then expertly executed pioneering projects through the earth sciences consultancy she established and nurtured to international acclaim. Her success was achieved in collaboration with her professional partner and husband, Dr Chris Hartnady, himself an acclaimed structural geologist and expert in the use of remote sensing, geothermal, space-geodetic and hydroseismic studies. When both Hay and Hartnady unexpectedly passed away in July 2021 due to COVID-19 related complications, the integrated water resource management industry was bereft of two mammoth talents.

"Our focus is on discovering to what extent we can use science in real time to solve problems, how we can adapt our behaviours to live more effectively on this planet, and to what extent we can use science as part of our adaptation tool."

– Rowena Hay, in her acceptance speech at the 18th annual National Science and Technology Forum South32 Awards

Rowena Hay and partner in business and life, Dr Chris Hartnady, leave behind deep footprints in South Africa's water resources management industry.

Photos supplied

Of the outstanding character traits that Hay is remembered for, *“maverick”* is most common.

Hay was considered one of South Africa’s foremost disaster risk consultants, and played a key role in the understanding and development of the deep fractured aquifer systems of the Table Mountain Group. She pioneered the drilling of ultradeep exploration and production boreholes to help secure sustainable water supplies across the Western Cape. Her consultancy, Umvoto Africa, is celebrated locally and abroad for its technical excellence and innovation in the fields of hydrogeology, integrated water resource management, disaster risk reduction, geo-risk assessment and prevention, geoinformatics and remote sensing.

Colleagues describe her as a vigorous force. “She had a massive personality,” Umvoto Africa’s Director and Principal Hydrogeologist, Kornelius Riemann says. Of the outstanding character traits that Hay is remembered for, “maverick” is most common and, Riemann says, every member of the Umvoto Africa family can comfortably claim to be a bit of the same. The company that Hay created is not one that associates with the normal rules and expectations of a traditional corporate environment.

Over and above a liking for the unorthodox, Umvoto Africa is set slightly apart from other consultancies by their aim to facilitate real change, over and above producing good, science-based reports. This has resulted in an innovative approach to much of their work. Hay understood hydrogeology, but she also understood that natural resource management actually involves managing people.

Rowena Hay was an acclaimed hydrogeologist that made a lasting impact on drinking water supply in the Western Cape, among other places.

Photo credit: Petro Kotzé

Umvoto Africa Principal Geologist, Dylan Blake, at the consultancy’s offices in Muizenberg, Cape Town.

Photo credit: Petro Kotzé

The application of Hay's technical expertise and academic genius was fueled by a deep-seated love of the job. Colleagues remember her jovial (but strict when required) rapport with even the most hardened drilling contractors, farmers and government officials as a joy to watch, and a learning experience for many a young scientist. "It is all about the theatre, my dear," she would say with a huge grin and conductor-like waving arms, upon doing (or getting someone to agree to let her do) the "impossible".

While her huge smile and boisterous laugh will be missed, many of her exceptional qualities live forth in the work that she produced and the lives that will forever be improved as a result. It started near Queenstown in the Eastern Cape. Growing up on a farm nestled on the northern foothills of the Katberg Mountains, Hay gained a solid understanding of the intimate connection between a community's resilience and the health of the surrounding natural environment. In a nod to the importance of this space to her, Hay would later name her business Umvoto Africa, after the respectful word Xhosa brides use for water.

The founding years

Hay lived close to nature, riding horses and hiking in the mountains on the family farm. Childhood friend, Judy Bryant, remembers how the Hay family lively debated current affairs around the dining room table. A sharp intellect, deep appreciation for the natural world and an environment in which free thinking was encouraged all contributed to Hay marching to the beat of her own drum. She decided on a career in geology – an

Hay and her MSc cohort outside the University of Cape Town geology department in the early eighties.

Photo supplied

“It is all about the theatre, my dear”

Hay conducting fieldwork in Lesotho in the early 1980s (left) and (right) outside her house in Cosmos near Hartbeespoort Dam.

Photos supplied

unusual choice for a woman in South Africa at the time, and obtained her BSc and Honours degrees at the University of Cape Town (UCT). Hay completed her Master’s Degree in Marine Geology in 1984, writing her thesis on Sediment Dynamics on the Continental Shelf between Durban and Port St. Johns (Southeast African Continental Margin).

While there, she worked as a school teacher on the Cape Flats and taught yoga from a house she rented in Wynberg.

> “Complete a comprehensive undergraduate science or engineering degree to the very best of your ability. Read widely. Know enough about related disciplines to be able to realise the worthwhile from the bandwagon. Consider an MSc to be a minimum qualification, only doing a thesis in a subject that actually interests you.” Rowena Hay’s advice to young women aspiring to follow the same career as her (as interviewed by the WRC in 2015)

As Hay was busy with her undergraduate studies, a young Chris Hartnady started lecturing in the university’s geology department. Hay would recall that as he first walked into the lecture hall, the thought that she could marry a man like that promptly crossed her mind. Her vision materialised years later. Already professional partners by that time, they tied the knot in 2006.

A fledgling career with steps in the right direction

Rowena worked part-time on geological investigations on dam and bridge building sites while studying. Her first full-time job was as a site geologist, involved in geotechnical drilling for the Lesotho Highlands Water Scheme tunnel that runs between Lesotho and Clarens. Later, she had stints working at Anglo American, the South African Atomic Energy Corporation and the Chamber of Mines where she developed various expertise, including hydrogeological modelling. In 1992, she established Umvoto Africa, and remained managing director until her passing in 2021.

She started from her home, then moved to a section of what was once a toy museum in the Cape Town suburb of Muizenberg.

Eventually, she transformed the once near-derelict building into an inspirational, light-filled office space that now houses what is internationally recognised as one of the largest groundwater specialty teams in Southern Africa. From earth sciences, groundwater and integrated water resource management, the company later expanded into disaster risk reduction and geo-risk assessment, environmental and climate change studies and social studies in relation to gender issues.

Umvoto Africa's Director and Principal Hydrogeologist, Kornelius Riemann at their Muizenberg offices. The building was once a toy store.

Photo credit: Petro Kotzé

With Hay leading from the front, Umvoto Africa has produced a vast body of noteworthy work through the decades. Among others, they conducted the groundwater resource evaluation for the assessment of water availability in the Berg Catchment; developed (and eventually supported the implementation of) reconciliation strategies for towns in the Southern Planning Region, which required the projection of domestic water demand, available supply, intervention options and strategic recommendations for all populations in the Eastern and Western Cape. Beyond South Africa, they have undertaken a water resource assessment for potash mining activities in the Danakil Depression of northeastern Ethiopia (the hottest inhabited place on Earth); the groundwater assessment, aquifer mapping and wellfield development for the State of Eritrea; as well as a water strategy for agricultural activities in Central Malawi.

Umvoto Africa's local clients include municipalities and the Department of Water and Sanitation, and internationally, the United Nations, Commonwealth Secretariat and the World Bank. They have won numerous accolades through the years. Hay was chosen as the 2009 Cape entrepreneur in the annual Businesswomen's Association Regional Business Achievers awards and was included in the 2009 ***Mail & Guardian Book of South African Women.*** In 2016, Umvoto Africa won a prestigious National Science and Technology Forum award in the category 'Research leading to innovation through an SMME'. Over and above their research and consulting work, the company also set up a successful intern programme to train undergraduate and post-graduate students.

Hay on receipt of the 18th annual National Science and Technology Forum awards, where Umvoto Africa won the category 'Research leading to innovation through an SMME', and (right) with then Minister of Science and Technology Naledi Pandor (left) and Agnes Peter (right) Group Executive, Agency and National Advertising, Independent Newspapers.

Photo credit: NSTF

None of her success was handed to her on a platter. To get to the top, Hay had to fight her way up from the bottom.

Pioneering work in water provision from fractured aquifers

As a start-up, the young hydrogeologist mainly worked with farmers and commercial drilling contractors in the design and construction of groundwater monitoring and production wells. In the late 1990s Umvoto Africa undertook the Citrusdal Artesian Groundwater Exploration (CAGE) project, which would turn out to be a game changer for the company and water resources management in the country.

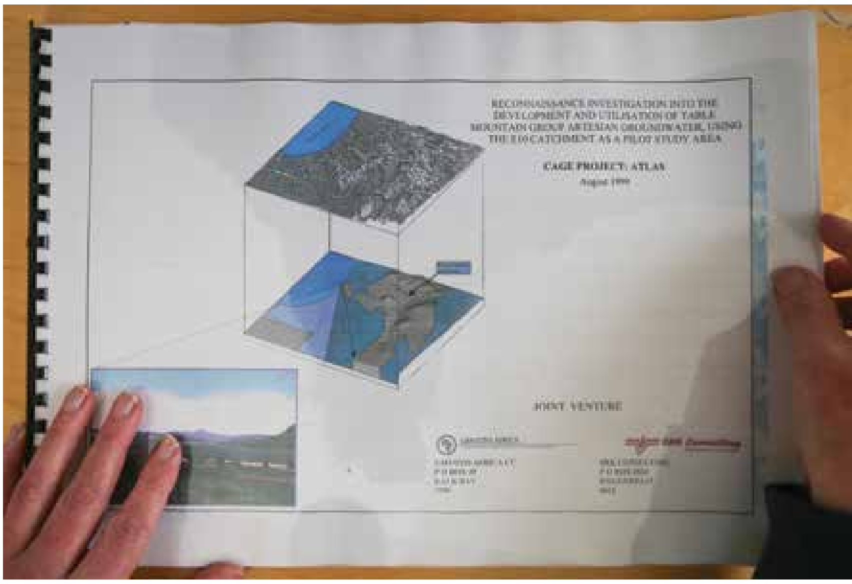
At the time, explains Umvoto Africa's Principal Geologist, Dylan Blake, knowledge around groundwater exploration for municipal supply was mainly restricted to the Karoo aquifers and basement aquifers of the northern provinces, where drilling was traditionally restricted to the upper 100 metres of the subsurface, increasing to about 150 metres as technology improved. People presumed it was the same for the fractured aquifers of the Table Mountain Group (TMG), but Hay with partner Hartnady understood that to find groundwater there, you had to understand the structural complexities of the TMG and go much, much deeper into high-yielding artesian basins. She had little support for her theories but eventually secured permission to drill to great depths through the hard quartz-rich sandstones that comprise the TMG. Blake explains that they now wanted to go from drilling 150-metre holes, up to 600 and 800 metres (later they would drill down over 1 000 metres for City of Cape Town TMG projects). "No-one in Southern Africa other than the mining industry drilled that deep at the time, not for groundwater supply," he explains.

The experiment combined Hay's strengths for modelling and taking risks with Hartnady's expertise in geological structural mechanics. The team successfully demonstrated how the deep fractured aquifer systems of the TMG can be developed. Some of the artesian boreholes in the Oliphant's Valley near Citrusdal yielded up to 100 liters per second of water from the Peninsula Aquifer during drilling, demonstrating that there were significant water reserves in its deeply buried parts.

The exercise helped establish Hay as a leader in the application of computer-based software for three-dimensional numerical modelling of groundwater flow and planning for operational monitoring of wellfields. Furthermore, it led to the establishment of secure water supplies for thousands of South Africans.

In 2001, Umvoto Africa was appointed by the Overstrand Local Municipality to proceed with a groundwater investigation and exploration to augment the water supply to the growing town of Hermanus. The project unleashed a flurry of concern from residents and environmentalists worried about the impact of deep drilling on the sensitive environment. Riemann explains that a large part of the Hermanus project entailed public education and the development of a system to alleviate concerns.

Umvoto Africa eventually completed a drilling and testing programme at the Gateway Wellfield and surrounding area, abstracting groundwater from the fractured Peninsula Aquifer of the TMG. Importantly, a monitoring programme was also developed and implemented using new monitoring boreholes and existing surface/groundwater-



Some of Hay's earliest work involved groundbreaking exploration of the Table Mountain Group at Citrusdal, as part of the Citrusdal Artesian Groundwater Exploration (CAGE) project.

Photo credit: Petro Kotzé

related infrastructure. The success achieved at the Gateway Wellfield led to the development, operation and monitoring of the nearby Camphill and Volmoed Wellfields in the Hemel en Aarde Valley.

Hay would later write that constructive stakeholder engagement was key to the solid foundations established to ensure long-term, sustainable water supplies. Today, groundwater constitutes up to 30-40% of the greater Hermanus region's water supply (with a planned increase to 50%) and the water source ensured that the town remained water secure through the 2009 to 2011 Southern Cape drought and the 2015 to 2018 Western Cape drought. "This is probably the best example of municipal groundwater supply in the country," Riemann says.

At the turn of the new millennium, Umvoto Africa was appointed under the Deep Artesian Groundwater Exploration for the Oudtshoorn Supply (DAGEOS) project. The consultancy subsequently managed the Oudtshoorn Groundwater Project (OGP) from 2011 onwards, drilling numerous high-yielding, deep artesian boreholes. The project resulted in a memorable moment, when strong artesian groundwater flowed from boreholes drilled deeper than 600 metres at the Blossoms Wellfield (part of the OGP). It became one of three Umvoto Africa projects selected for the official World Design Capital 2014 programme, based on their social transformation properties. The project would also lead to the breakthrough discovery that Global Navigation Satellite Systems data, combined with radar satellite and microgravity methods, can detect ground-surface subsidence of only about 15 mm associated with groundwater extraction. Believed to be a first for South Africa, the findings held huge implications for management of precious water sources.

Umvoto Africa has also been the groundwater consultant for the City of Cape Town since 2002, and has undertaken groundwater exploration at various target sites from Steenbras Dam northwards to Wemmershoek Dam. As part of the City of Cape Town's New Water Programme, groundwater development and wellfield implementation has been initiated at the Steenbras Dam and Nuweberg sites since 2017, where borehole yields of between 10-70 litres per second have been encountered in targeted megafault structures within the TMG. The company has also undertaken emergency groundwater development of the Cape Flats Aquifer, which underlies the majority of Cape Town, and upgrade of the Witzand and Silwerstroom Wellfields that target the Atlantis Aquifer along the northern boundary of Cape Town.

According to Riemann, both Hay and Hartnady were technical experts in their respective fields, but what really lead to their success was their ability to integrate technical skills and excellence with the social engagement beyond the requirements of a public participation or stakeholder engagement process. Rowena was passionate about helping communities improve their livelihoods through the betterment of their surrounding natural environment, and was deeply involved in disaster risk reduction (DRR), gender mainstreaming and social hydrogeology. She undertook many such projects for various international organisations, including the World Bank in Malawi, and the United Nations in Lesotho.

She provided key input to several initiatives by the United Nations Office for Disaster Risk Reduction (UN/ISDR, now UNDRR) and the United Nations Environment Programme (UNEP) in Africa. She served on the African Advisory Group, as expert support to the

UN/ISDR Geneva's working committee for detailing and implementing the African Action Plan in DRR, and for mainstreaming gender in DRR globally. She developed DRR strategies for Small Island Developing States for the Commonwealth Secretariat, and was Jury Member for the UN/ISDR Sasakawa Awards for DRR from 2005 until her passing.

Hay with fellow Sasakawa judges Prof Murat Balamir and Franklin McDonald, in 2013.

Photo supplied

Umvoto Africa is renowned for an innovation approach to solutions, including in the area of Disaster Risk Reduction. For a project at Tsengiwe village near Cala in the Eastern Cape, the consultancy also developed a board game to communicate DRR approaches.

Photo credit: Petro Kotzé

Disaster Risk Reduction in the Eastern Cape

Her unique approach to DRR was encapsulated in the two-year WRC-funded study on rural attitudes towards climate change, and how rural communities can increase their resilience. The project was based on a series of community and local authority workshops, focusing on the Tsengiwe village near Cala, a couple of hours from East London. The village is vulnerable to seasonal drought and due to climate change the summer-dominated rainfall is shifting to autumn, associated with episodic downpours. These changes have resulted in agricultural drought, which is exacerbated by poor infrastructure and municipal services.

Umvoto Africa identified and prioritised the hazards facing the community and the available coping mechanisms before developing climate change adaptation and DRR plans with the community. Youths were trained in basic scientific skills such as monitoring and evaluation, surveying, interviewing skills and data collection. Under the company's guidance, the community mapped resources and land uses that they felt were important for their development plans. The participatory map that was created included communal land, water sources, infrastructure, agricultural projects and vulnerable areas with large dongas, alien vegetation, flooding zones and major soil erosion.

Riemann points out that this approach indicates something else about Hay, and Umvoto Africa's work. While technology is important, of bigger importance is the use of the most appropriate technology.

The project resulted in different community development plans that serve as a road map to guide the community and local mentors through procedure and processes to be implemented by the trainees. Possible projects include land care and rehabilitation, accessing groundwater supplies, building a small dam to supply food gardens and livestock, catchment rehabilitation and the selection of new crops suitable to changing climate conditions.

"The take-home message is to work with what is available; have long-term goals; and interface constructively with official channels and processes," Hay said in an interview with media at the time.

Social hydrogeology and the Umvoto Foundation

In the past decade, Hay's passion project had been the rehabilitation of the Cape Flats Aquifer. She was intent on unlocking the potential of the aquifer through a holistic approach, which resulted in the drafting of the Hoerikwaggo Cape Flats Critical Zone Observatory Project. She also established the Umvoto Foundation, a registered non-profit organisation to support the development of community capacity as it relates to achieving clean and healthy ecosystems.

"Be involved to the best of your abilities and in line with your own interests and aspirations." – Rowena Hay on how to improve the lives of communities and the environment through involvement in the water and sanitation sector (as interviewed by the WRC in 2015)

Through the project, the foundation identified degraded urban streams, canals, and vleis and the negative impacts on the water quality of the aquifer. With partners, Umvoto Africa then led the 2019 Great Lotus Canal Challenge, which focuses on working with communities through art, education and supporting grassroots initiatives to improve the environmental health of the canal, and engaging with other local organisations who have started doing similar projects in their own areas. The project recognises that regeneration of the aquifer recharge zone and ecosystem are essential for maintaining water quality and reducing disaster risk while being mindful that this work must involve many communities.

The project is typical Hay – grand in vision and scope, but with a firm grasp on the details. Just like her life, her work allowed vast space for exploration and dreams, with a keen sense of the people behind the projects. Riemann says the Umvoto family is committed to continue and build on her legacy so that it will, together with Hartnady's, now ripple out through their work, the people that were touched by it, and those that will follow in their wake.

Hay's legacy lives forth at Umvoto Africa, in her work, and the many lives she touched.

Photo credit: Petro Kotzé

Prof Janine Adams

Photo credit: Petro Kotzé

JANINE ADAMS

Freshwater custodian there where the tide meets the stream

Current position:
Deputy Director, Institute for Coastal and Marine Research, Nelson Mandela University (NMU). Research Chair, Department of Science and Innovation (DSI)/National Research Foundation (NRF) for Shallow Water Ecosystems

Research interests:
Conservation and management of estuaries, blue carbon ecosystems and responses to climate change, ecophysiology of estuarine macrophytes, water quality management

Awards

AWARDS

2021: Faculty Researcher of the Year Award and Research Excellence Award at NMU.

2021: WRC Legend Award

2015: Silver medal by the Southern African Society of Aquatic Scientists

2013: Nelson Mandela University researcher of the year

She has published the first research in South Africa on carbon capture and storage by blue carbon habitats

Prof Janine Adams started her career in academia just as water management in South Africa roared into a new era. When she put the finishing touches on her PhD on the freshwater requirements of estuarine plants in 1994, the National Water Act of 1998 was being brought to life, the country was leading the science of environmental flow requirements, and research projects were embracing transdisciplinary approaches. The young ecologist dove straight in, and emerged as a forerunner in the race to put the lofty ideals of the Act into practice for estuaries.

Estuarine habitats would remain the focus of her career but, what set her apart from her peers is her dedication to research that successfully links science, policy and management through extensive collaboration and networking. That, and her tireless enthusiasm for training the next generation of research scientists. Her commitment to the job is etched into her credentials.

Prof Adams (back row, second from right) at a research group meeting in 2018.

Photo supplied

She was recently appointed the title of Distinguished Professor by the Nelson Mandela University, an elevated status in recognition of dedication and commitment to her field of expertise. In 2015, she received the silver medal from the Southern African Society of Aquatic Scientists for her contribution to research and training. She is a fellow of the Royal Society of South Africa, and has served on several national and international committees, including as Chairperson of the WRC (2009-2012) and President of the Southern African Society of Aquatic Scientists (SASAqS) (from 2012-2014). Her research group at the Nelson Mandela University is over 30 researchers strong, but she also works with a wide range of collaborators locally, and internationally from Australia, the United Kingdom, France, United States of America, and east African countries including Mozambique, Kenya and Tanzania. She has graduated 35 MSc and 22 PhD students.

Adams's devotion to the job spills over into a packed schedule, brimful of appointments with managers, practitioners, government and non-governmental organisations, slots for field work and teaching responsibilities. She sits down for an interview midway between preparations for a meeting with the Western Cape Government to advise on development plans affecting the Great Brak Estuary, and a virtual London-based meeting

Prof Adams's early work focused on estuary function and sensitivities.

Photo credit: Petro Kotzé

on blue carbon trading systems and climate change mitigation. She's busy, but admits she'll still be the first to put her hand up for an opportunity for field work or involvement in a new project.

"It's part of a researcher's job," she shrugs, before launching into a lively rundown of issues, news and development plans for South African estuaries currently on the go, including the recent controversy on the opening of the St Lucia mouth, where her long-term research counts as a career highlight.

Passion, perseverance and an ability to get on with people has been integral to her success, Adams says, but it has always been built on hard work and dedicated research. She has the second-highest number of publications on estuaries in the country behind her name, and as such, has made a significant contribution to the global knowledge base on aquatic ecosystems. Among her vast body of work, highlights include her early and ongoing work on environmental flow requirements of estuaries. She has also published the first research in South Africa on carbon capture and storage by blue carbon habitats (mangroves, salt marshes and seagrasses). She has conducted landmark work on estuary water quality, and more recently, shifted her focus towards estuary restoration.

Pioneering research on environmental flow requirements of estuaries

South Africa supports close to 300 functional estuaries of varying types, ranging from permanently open or river dominated systems to temporarily open or closed systems, estuarine lakes and estuarine bays. Every estuary is unique and calls for individual calculation of its environmental flow requirements. Adams was at the forefront of this process, leading the team that developed methods to describe and quantify environmental flow requirements for South African estuaries in the early nineties. Results would later be formalised in the National Water Act of 1998.

Following the promulgation of the Act, she helped place South Africa as a forerunner in the application of the methods she helped develop. In 1999, she was appointed team leader of the then-Department of Water and Forestry Estuarine Reserve Group, responsible for testing the methodologies for Ecological Reserve determination to allow for the implementation of the National Water Act.

Under Adams's guidance, considerable progress has been made in our understanding and management of the EWRs of many estuaries. The effects of a dam release into the Kromme Estuary, the importance of the river estuary interface zone in the Gamtoos Estuary, and the EWR of the East Kleinemonde Estuary are some of the other projects that have benefited from her expert touch. The work has been emulated globally. A 2014 global review showed that South Africa is the only country that has applied method to describe and quantify environmental flow requirements for estuaries consistently, and to different types of estuaries, and that countries across the world now use it as a baseline reference.

Her work has also contributed to the Integrated Coastal Management Act of 2008. This law has established a system of integrated coastal and estuarine management for South Africa, including norms, standards and policies to conserve our coastal environment.

Her work on environmental flows in estuaries continues, Adams says, and now focuses on using socio-ecological systems for planning and estuary restoration. Increasingly, the work is also considering trade-offs in the face of growing global water problems and climate change.

Sampling seagrass in collaboration with Stellenbosch University at the Mngazana Estuary for Project SeaStore.

Photos supplied

“We also investigated the vulnerability of coastal habitats to sea-level rise so that mitigation plans can be developed to meet predicted challenges.”

Laying the groundwork for blue carbon ecosystems research in South Africa

Estuarine habitats like mangroves, salt marshes and seagrasses capture and store large volumes of carbon dioxide in ‘blue’ aquatic environments. Though these habitats cover less than two percent of oceans worldwide, they capture up to seventy percent of carbon. Adams’s recent study, the first in South Africa on carbon capture and storage by blue carbon habitats, generated baseline data for potential carbon credit trading schemes as part of an effort to reduce greenhouse gas emissions globally. Later work described the responses of salt marsh to climate change stressors such as increases in storm surges, floods, droughts and reduced freshwater inflow. “We also investigated the vulnerability of coastal habitats to sea-level rise so that mitigation plans can be developed to meet predicted challenges,” she explains. A network to monitor surface elevation change and responses to sea level rise in several estuaries has now been established, which will produce the data necessary to determine whether these habitats are eroding or accreting and will contribute to an ongoing global discussion on the response of coastal ecosystems to climate change.

Shining a spotlight on estuarine water quality

At the turn of the century, South Africa’s estuaries became increasingly degraded due to nutrient imbalances, which lead to eutrophication. This led Adams to focus on estuary water quality, initially describing the response of microalgae to changes in freshwater inflow. The research is ongoing.

Recently, her review paper investigated the influence of deteriorating water quality on the resilience of estuaries and identified the management actions necessary to restore these environments. The research showed an increase in the occurrence of toxic algal blooms and invasive aquatic macrophytes. The effect of these blooms on the transport of nutrient to adjacent coastal waters is now also being investigated. It is thought that primary producers (estuaries with persistent blooms like the Sundays Estuary) act as nutrient sinks while more dynamic systems (like the Swartkops Estuary) serve as nutrient sources.

Her work has also touched on heavy metal pollution in estuaries from industrial water discharge, and more recently, the potential ability of salt marshes and seagrasses to remediate the negative impacts.

Restoring estuaries and the services they offer

Adams is now leading research on methods like treatment trains and artificial wetlands to improve estuary water quality and, in the process, restore ecosystem services such as the provision of nursery habitats and coastal area protection. Some of the work is also focusing on salt marsh, mangrove and seagrass restoration and, with colleagues from Mozambique and Tanzania, using local knowledge to restore blue carbon ecosystems' functioning.

Adams says she has achieved much of what she would have liked to in her career, and is now focusing on those things she most enjoys. Recently she downgraded herself somewhat on the corporate ladder, and is Deputy Director for the Institute for Coastal and Marine Research. "I can do those sorts of jobs with my eyes closed," she says in reference to her earlier position as Director, "but that's not my passion." Instead, she wants to be there where she started her career as a student, on field trips, rummaging around estuaries, for research projects. Her Research Chair position with the Department of Science and Innovation (DSI)/National Research Foundation (NRF) for Shallow Water Ecosystems now allows her to do exactly that – "go out into the field to do research." Only now, she is doing it with a new generation of young researchers.

Prof Adams at the Swartkops Estuary, a heavily urbanised ecosystem that is at the centre of a multitude of anthropogenic pressures.

Photo supplied

It has been one of her greatest achievements, she says, to have helped "build the next cohort of coastal and marine scientists with expertise in water quality management, harmful algal blooms, phytoplankton, salt marsh, seagrasses and mangroves." And, not only that, but to have created opportunities for them to launch their own research careers.

As such, her contribution to the research, conservation and management of South Africa's estuaries will outlive her, not only in the conservation of the systems themselves and the policies she helped put in place to sustain this, but in the students she has graduated that will continue the work well into the future.

> "She sees having helped build the next cohort of coastal and marine scientists as one of her greatest achievements."

Prof Adams's advice for young researchers

- Always use opportunities to learn from experts
- Create opportunities to interact
- Create opportunities for others
- Produce high quality work so that you stand out
- Always go the extra mile

Prof Carlos Bezuidenhout

Photo credit: Petro Kotzé

CARLOS BEZUIDENHOUT

Connecting the dots between
water quality and human health

Current position:
Director: Unit for Environmental Sciences and Management, North-West University

Research interests:
Aquatic Microbiology, water, sanitation, health and energy

Award

AWARDS

2021: WRC Legend Award

For more than two decades, microbiologist Prof Carlos Bezuidenhout has tracked potential disease-causing microorganisms such as bacteria, fungi and viruses lurking in our water resources. His work pin-points areas of concern, but more importantly highlights the interconnectedness between human health and water quality, an important aspect of sustainable water supply that is often overlooked.

Bezuidenhout's work covers various aspects of aquatic microbiology, including surface and groundwater quality and water treatment. He was one of the first local scientists to ring the alarm on the potential dangers of antimicrobial resistant (AMR) microorganisms in South Africa's water resources, which has since become ensconced on research agendas. He also established the Aquatic Microbiology Research Group at the North-West University (NWU) and, as he has built up the group's molecular laboratory facilities from near scratch to international standards, he himself has become known as an expert far beyond our country's borders. Just recently, he was appointed as a member of the United Nations Environmental Programme (UNEP) Expert Committee to consider challenges and potential solutions for tackling AMR within an environmental framework.

Since 2020, Bezuidenhout has been the Director for the Research Unit for Environmental Sciences and Management at the NWU. While he has technically hung up his lab coat, it takes no convincing for him to done one again for a tour through the Potchefstroom campus facilities.

A walk through the NWU molecular laboratory

"When I first arrived here at the NWU the molecular laboratory in Microbiology entrusted to me was terribly elementary." Really, he says, chuckling at the memory, it was like an undergraduate lab. Today, the facilities include three laboratories and house state-of-the-art DNA sequencers that can provide researchers with essential information to help understand diseases better. "It has taken time, but over twenty years we have built [the facilities] up into a so-called pocket of excellence in Africa, in terms of knowledge, expertise and equipment," notes Bezuidenhout.

Bezuidenhout's journey here started in 2002 when he accepted a position at the then Potchefstroom University to lecture the undergraduate microbial and molecular genetics courses. His first research project at the university, and part of the reason why he moved to Potchefstroom, was on the treatment of high-strength industrial wastewater using dual stage ceramic membrane bioreactors. The research was evaluated at a pilot plant, which determined that membrane systems used in combination with biological processes is a plausible method for wastewater treatment, recover and reuse in the industrial sector. The work resulted in an international patent.

Over two decades, the molecular laboratory facilities at the North-West University had been built up from near scratch to international standards.

Photo credit: Petro Kotzé

Laboratory facilities now include state-of-the-art equipment such as next generation DNA sequencers, essential to help researchers study diseases on microbial level.

(credit: Petro Kotzé)

He soon moved on from water treatment to water quality, gradually carving out a niche in research that focuses on the impact of water pollution and drawing the connection to its potential implications for people, the environment and our health.

One of his first WRC-funded projects entailed a large-scale study of microbial and physicochemical quality of the selected groundwater and surface water in the North West province. At the time of the study, the province's water resources had not received much research attention, but the project highlighted various concerning trends. The main hazards identified were nitrates in groundwater and salts in surface water, but a number of the resources were also polluted with faecal matter. Bezuidenhout also started looking at a research topic that he would become closely associated with, when he studied bacteriophage and enterovirus data and found that the resources may contain viruses that could be human pathogens. Furthermore, a large number of faecal coliforms and enterococci isolated in this study were found to be resistant to several antibiotic groups.

A follow-up study focused on the identification and quantification of antibiotic genes from DNA obtained from water samples from the Crocodile West and Marico rivers. Major groups of clinically relevant antibiotics were detected in samples from both rivers. Typical Bezuidenhout, he drew the causal line to why we should sit up and take note. The rivers were found to serve as influx points, reservoirs and distribution systems that disseminate the bacteria that harbour these genes to people through agriculture and urban activities. The project highlighted that we should be concerned about this potential impact on the environment and people.

Initially, funders associated such topics with the medical research field but since Bezuidenhout's work has brought it under their attention, a drive to look at topics like ARB and contaminants of emerging concern in water resources and the environment have gained broader appeal. "We don't know yet what the impacts of these are in such low quantities, but it is a concern not only in South Africa, but globally," he says.

Bezuidenhout and his team have since tackled a number of research projects on the topic, continuously highlighting areas of concern, and the possible implication. In line with international and local studies that demonstrated that trace levels of antibiotics and ARBs in source water and finished drinking water is an emerging health and water quality issue, they conducted a scoping study on South African drinking water. They found antibiotics and ARBs to be present, as some of the compounds were not completely removed during drinking water production processes and ARBs could survive in the distribution systems. A subsequent project investigated the implications for water production and water quality monitoring.

Other projects have included investigating microplastics in South Africa's freshwater resources. The team has also quantified and assessed the fate and hazard of HIV-antiretroviral drugs in freshwater. The medication is broken down to a certain level in people and the metabolites are then discharged, Bezuidenhout explains. For example, as much as 50-70% of fluconazole (used for, among other ailments, the treatment of yeast infections in people with HIV) is not broken down in die body, and is discharged into the sewerage system. With one of the highest HIV rates in the world, and one of the most comprehensive treatment programmes, the amount of such medication to take into consideration measure in their tons, released annually into the South African environment. The question is what is being discharged, how does it travel through the system and what is the potential impact, Bezuidenhout explains.

The research team is now surveying ESKAPE pathogens in the water environment, an acronym for six nosocomial bacteria. Due to their ability to exhibit multidrug resistance these bacteria have the ability to "escape" the effect of antibiotics and antiseptics.

Furthermore, they are one of the few groups that have looked at the consequence of yeast pollution in the environment, a result of domestic and agricultural pollution. As part of the study, they investigated the antifungal susceptibility of potential pathogenic yeasts in river water, using the North West province river water systems as case studies. Here, the water is used

Though he started his career as a high-school teacher, Prof Bezuidenhout has become one of the country's foremost experts on anti-microbial resistance in freshwater resources.

Photo credit: Petro Kotzé

“Those who persevere will overcome.”

– The life philosophy that Bezuidenhout adopted from his school motto.

for agricultural, domestic and recreational purposes and direct contact with the water, especially by immune-compromised people, may pose a health threat and should be further investigated.

There’s still so much that we are uncertain about, Bezuidenhout says. Among other questions, we still do not understand the cumulative effect of these things on people over time. We don’t know how bacteria that takes up free DNA in water, adapts. We have fantastic new medicines available, but their impact once washed down the drain is not a research priority at the moment. There is a lot of work to be done on the links between people, the environment, and animal health, he notes. “There is a lack of knowledge [on this subject area], and it is the role of research to generate it.”

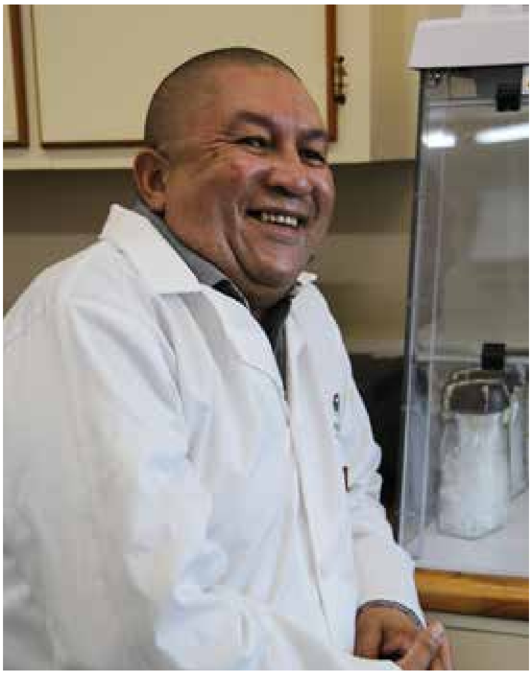
It’s then perhaps of little surprise that Bezuidenhout feels like he has much work still to do. At a time when some of his friends are starting to enjoy retirement, sending early morning messages and quotes for the day on WhatsApp, Bezuidenhout has decided to take a large stride up the corporate ladder instead. In his current position, he manages relationships between people and institutions more than those between problems and their impact. It is also the crowning move in a career of consistent movement forward. His life journey has taken him on many twists and turns to reach this point.

From small town, to research director

“I am from a township in Uitenhage. In those days your career choices were set out for you. The ones that were supposed to bring you success were engineers, doctors and teachers.” Bezuidenhout didn’t want to do any of those. Instead, he chose microbiology. This was, however, the late seventies in apartheid South Africa and, as a non-white person he first had to get permission from the minister to attend the traditionally white Rhodes University to join their Microbiology Department that had one of the leading genetics research groups in South Africa at the time.

What he saw when he arrived boggled his mind. The contrast between the streets of Uitenhage and Rhodes’s beautiful facilities were huge. Bezuidenhout says it awakened a feeling of deep sympathy within him for the people living in poverty back home. “I wanted to go back and make a difference.” However, he wasn’t convinced anymore that the way to do this was as a microbiologist.

Bezuidenhout became a teacher, and joined the Uitenhage High School in 1986, just one subject shy of his degree. He completed this while teaching biology and information technology, before continuing with his Honours degree. The young teacher did very well at research. His work contributed to the further development of a PCR DNA fingerprinting method, when he discovered that a protocol meant for protein



Growing up on the streets of Uitenhage inspired a passion to improve people's lives.

Photo credit: Petro Kotzé

fingerprinting could be applied to DNA fingerprinting. He laughs at the memory of having to elaborate on the finding at conferences. "I did it completely by accident!" Regardless of his success, he says only really found his passion with his PhD, which focused on microbial genetics. When he completed it in 2000 at Rhodes University it also heralded in the end of a career as a high-school teacher. He still remembers it fondly. I enjoyed it very much, he says, describing it as "fantastic" to interact with the kids in his classes. Yet, everything was coming together for him to start carving out a career in academia and research. He signed up for his postdoctoral research at the University of Zululand and later accepted a position as lecturer in microbial and molecular genetics.

At this stage, Bezuidenhout had mainly studied the genetics of ostriches, but he already saw how he could marry his qualification as microbiologist with his longing to still make a difference to people's lives. The answer lay in the water. The uMhlathuze River flowed close by the university and, with so many inflows from different systems, he thought it offered a fantastic opportunity to look beyond the biotechnical applications that their work called for, to the water quality. As a result, one of the first papers on the uMhlathuze River's water quality was published.

Prof Bezuidenhout on building a career in academia

- **Cast your bread upon the waters (from Ecclesiastes 11:1). Be generous with your knowledge. The more people can share in it, the bigger is the chance that it will have an impact.**
- **Use your interests to define your focus area and work towards that goal into the future.**
- **You have to be able to accept criticism and, when it's your turn, offer constructive criticism.**
- **Academia is hard, and you have to develop a thick skin. It can be difficult, but you will enjoy the fruits of your labour over time.**
- **Academia will not make you rich. If money is your focus, this is the wrong place for you.**

Once you have chosen the work to focus on, you have to keep on working at it, Bezuidenhout says. "You will not get there overnight, but you will gain momentum as you move forward." In 2002, he moved to the North-West University, where he could launch his own research group in aquatic

“If I inspire one person in my life to take responsibility for the life and career that they choose, then I will be satisfied.” *– Prof. Carlos Bezuidenhout*

microbiology. Slowly, and over time, he has kept on moving forward. From an initial position as senior lecturer, he was appointed as Associate Professor of Microbiology in 2007, full Professor in 2017 and now, Research Director.

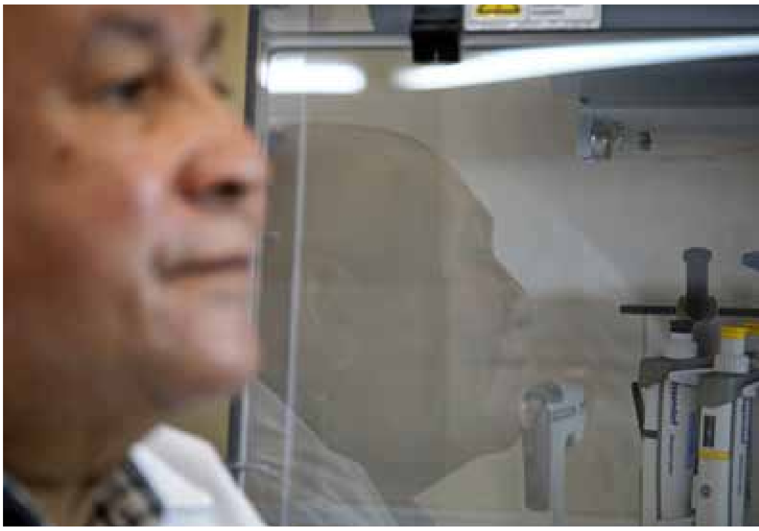
A changing place in science

My role in science has changed, Bezuidenhout says and, so has his passions. His hours in the lab, immersed in bacterial produced smells and chemicals as well as coming into the lab over the weekends to feed microbes are well behind him but, he says, he still loves coming to work.

“To implement research, we need to collaborate and, collaboration is about trust,” he says. “You can’t build that overnight”. In his current position, he can now work from the trust that he has built-up over the years to facilitate collaboration. Still, he says he thinks one of his most important achievement is transforming his research field into one that is appealing to other researchers and stakeholders.

Another is the empowerment opportunities he was able to provide to younger colleagues. It remains an important aspect of my work, he says. Bezuidenhout points out that his journey has also been one of teamwork, and he is grateful for the support he has received throughout.

Though they have laid the baseline for future work to be done from, but they still need bigger buy-in from research colleagues to generate data and information, from funders and potential collaborators. The biggest need is to find the inroads to places where real differences can be made, including the wastewater treatment plants and operators, he says. Sometimes, as I near the end of my career I think about how much work there is still to be done, he says. Pointing out the problem is only the first step to get the right policies in place. However, thanks to his decades of dedication and work, the connections and relationships he has built, steadily over time, is already paving the way there.



Looking back over a successful career, Prof Bezuidenhout says there is still much work to be done.

Photo credit: Petro Kotzé

Prof Colin and Dr Terry Everson

Photo credit: Petro Kotzé

TERRY AND COLIN EVERSON

A marriage of expertise that has delivered long-term benefits to catchment management in South Africa

Current position:

Prof Colin Everson: Honorary Professor, University of KwaZulu-Natal (UKZN) and Extraordinary Professor, University of Pretoria

Dr Terry Everson: Honorary Senior Research Associate, UKZN

Research interests:

Prof Colin Everson: Hydrometeorology, grassland ecology

Dr Terry Everson: Rangeland ecology and management, development of communal grazing systems, community-based natural resources

AWARDS

2021: WRC Legend Award (Prof Colin and Dr Terry Everson in their individual capacity)

2017: Grassland society of southern Africa, best paper published in the ***African Journal of Range and Forage Science*** (Prof Colin and Dr Terry Everson)

2008: CSIR, Environmental excellence award for outstanding contribution to environmental research (Prof Colin Everson)

2006: Department of Water Affairs, Women in Water Awards: First in the Water Research category, and third in the Education category (Dr Terry Everson)

2004: CSIR, Best publication award, ***Journal of Hydrology*** (Prof Colin Everson)

2003: CSIR, Mentorship award for support, guidance and development of the careers of his students and colleagues (Prof Colin Everson)

When Colin and Terry Everson tied the knot, they also unwittingly married a set of overlapping, but unique, scientific skills that would leave deep marks in some of South Africa's most important catchment areas.

Colin is best known for his groundbreaking work in the use of micrometeorological techniques for catchment water balance studies, and the development and testing of numerous evapotranspiration technologies in the country. These including the Bowen ratio, time-domain reflectometry, Eddy covariance, scintillometry, the Heat Pulse Velocity technique, and Cosmic ray probes for soil water measurement. Terry has won recognition for her decades of work in community land rehabilitation projects in catchments, and developed a programme whereby rural people could be awarded financially for their dedication and hard work in improving their environment.

"We work together on just about everything," Colin says. "Though you don't see the continuous threads, they are there."

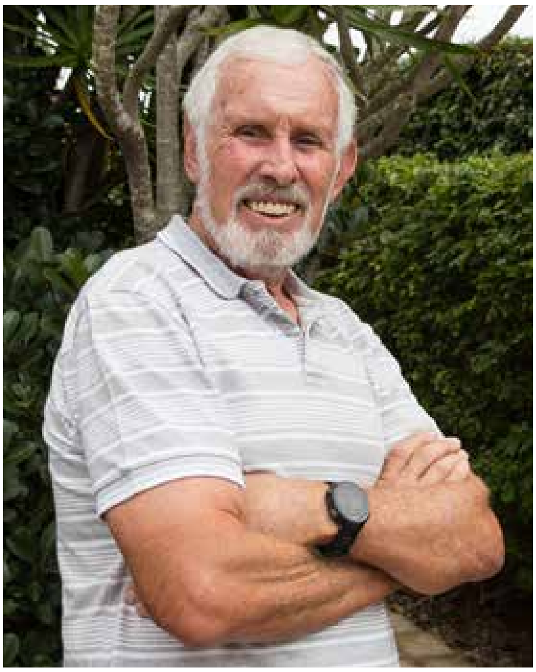
Their collaboration started during their studies at the University of Natal (now the University of KwaZulu-Natal), where they met in the Master's laboratory. After initially studying to be a biology and maths teacher, Terry was "hooked" on research after her fieldwork with renowned aquatic ecologist Prof Charles Breen at the Pongola Floodplain, while Colin cut his teeth on plant-water relations in the Cathedral Peak catchment research area.

Terry loves the outdoors, and dreamed of marrying a farmer but, she says she ended up with an "even better choice." The pair cut their honeymoon short to complete their Master's degrees and, when they sat down for their MSc Botany graduation ceremony in 1979, did so as Mr and Mrs Everson. From that point, the two scientists would function as a team, with Colin's high technological skills complemented with Terry's practical and people skills.

They started at "the most stunning area imaginable," as Terry describes Cathedral Peak, where the pair relocated to when Colin was offered a PhD position on the SCOPE programme on fire in the Drakensberg grasslands. They would spend the next 16 years there, based in a little forest station far from many other people. For the Eversons, it was perfect.

A move to one of South Africa's most important water catchments

Colin's PhD work led to a permanent position with the South African Forestry Research Institute (SAFRI) where he was employed as Forestry Scientist in the Conservation and Forest Hydrology Programme in 1980. Terry was also employed as a Forestry



Prof Colin Everson is renowned for his work in the use of micrometeorological techniques for catchment water balance studies and the development and testing of evapotranspiration technologies.

Photo credit: Petro Kotzé

When Colin and Terry Everson tied the knot, they also unwittingly married a set of overlapping, but unique, scientific skills that would leave deep marks in some of South Africa's most important catchment areas.

Scientist, and working as Colin's technician, the pair focused on the ecological effect of fire in montane grasslands.

They were establishing themselves as fire ecologists, but Colin's career took a sharp turn in another direction when he received a phone call from Dr Fred Kruger, director of SAFRI, enquiring if Colin would be interested in micrometeorology and catchment water balance studies. Kruger was fresh from a trip to Australia, where exciting new technologies were being applied in the field that, Kruger thought, could be of great use in South Africa.

Even then, agriculture and forestry faced increased competition for water by industries, municipalities and other groups. The accurate assessment of total evaporation from land surfaces is essential for fair allocation of water. For this purpose, the Department of Forestry ran long-term water-balance experiments in important water catchments like Jonkershoek and Cathedral Peak. Initially, those experiments only worked at annual timescales. Scientists measured streamflow and rainfall, calculating evaporation by the difference.

However, such estimates were not considered precise enough to enable accurate predictions of water yield from hydrological models. Since the water use of natural grassland largely depends on available energy, accurate estimates of evaporation from the vegetation could only be made by quantifying the catchment energy budget. New technologies offered the opportunity to measure evaporation directly without having to do it by subtraction, Colin explains.

Though it was "a big step change" Colin decided he wanted to take on the challenge. In 1990, the Eversons moved to the CSIR's Land Use and Hydrology programme, with Colin as project leader focusing on the development of water balance models for montane catchments.

His first project with the WRC entailed working with state-of-the-art equipment, pioneering the use of the Bowen ratio energy balance technique to measure the water use of a grassland catchment with Prof Michael Savage. It was also the first long-term study in the country in which all the components of the catchment water balance were measured simultaneously.

The Cathedral Peak-based project allowed for the development of baseline values for evapotranspiration of montane grasslands. "The project provided many new challenges for a grassland scientist converting to hydrology," Colin says but the steep learning curve established his credentials as a micrometeorology and hydrology researcher. Through various projects, he would build up extensive experience in micro meteorological methods for monitoring evaporation and soil moisture, paving the way for process hydrological field research in South Africa.

"A lot of my research evolved around understanding the natural baseline (natural vegetation) and improving the models that assessments are based on," Colin explains. This is relevant to the licensing for cultivating plants for example, for which the incremental change of water use must be measured, for which, again, you have to understand the baseline. In the process, Colin says he's measured "a wide variety of plant communities in South Africa," including wattle, eucalyptus and bamboo. He has put up equipment in a swamp forest among hippos, rhino and leopard, various riparian zones and crops for emerging farmers, to name a few.

Dr Terry Everson developed a programme whereby rural people could be awarded financially for their dedication and hard work in improving their environment.

Photo credit: Petro Kotzé

> "A lot of my research evolved around understanding the natural baseline (natural vegetation) and improving the models that assessments are based on."
> - *Colin Everson*

By the mid-nineties, as South Africa was entering a new era of democracy, change was also on the cards for the Eversons. The family had since grown with two children, and Terry was completing her PhD part-time while working for Forestek, CSIR, at the Cathedral Peak Forestry Research station.

Then, in 1994, a devastating fire ripped through the foothills of the Drakensberg in the Upper Thukela region, resulting in the loss of lives and grazing for livestock, impacting heavily on the Okhombe communities. At the same time, people were increasingly talking about land care. "We were sitting in this pristine area with beautiful grasslands, and next door to the protected area, everything was being washed to sea," Colin says.

> The LandCare project continued, and through Terry's work, involved the community in not only implementing erosion control techniques, but understanding why erosion is taking place and developing solutions.

All the service providers around Winterton got together to draw up a coordinated rescue plan which resulted in an opportunity to work together to assist the communities to manage the area for improved fire management, grazing, food and fuel production, Terry says. For her, "that was the turning point". As part of a national LandCare project at Okhombe, she was given the responsibility for the training of community members on different soil erosion control techniques. "We decided to get an international expert in to train us in methodologies when working with rural communities," she says, starting her long-term involvement in community-based catchment rehabilitation.

Around this time, the government started closing down research centres, including the Cathedral Peak Forestry Research station, and the CSIR was transferring the Eversons to Nelspruit. It was the end of a lovely era for the couple. Colin recalls training for the Comrades marathon (he ran 12) by running to Winterton, when Terry went to church, leaving him soft drinks along the way. She ran 10 Comrades herself, while Colin also completed 18 Dusi canoe marathons, with Terry also joining in one or two during the years.

As they were on their way, packed, with the children registered for their new schools in Mpumalanga, Terry heard that she was accepted for a post as a Lecturer in the Department of Grassland Science at UKZN. The position would allow her to revisit her first love of teaching, while continuing her research. The Eversons abruptly changed track, and instead of Nelspruit, moved to Pietermaritzburg in 1996.

Settling in at the University of KwaZulu-Natal

Terry continued her research programme in community-based catchment rehabilitation while working for the university. The LandCare project continued, and through her work, involved the community in not only implementing erosion control techniques, but understanding why erosion is taking place and developing solutions. In 2002, when the Okhombe LandCare Project ended, funds for job creation dried up. People said the work would stop, Terry remembers, but enthusiastic community members formed the Okhombe Monitoring Group, volunteers who continued with the rehabilitation.

Then, in 2002, the WRC stepped in to fund what Terry describes as "the most rewarding project I have been involved in" with outcomes still evident today. The project entailed the implementation of a participatory monitoring programme, whereby community members recorded and analysed differences in soil erosion and water quality so that they could assess which techniques were most successful in improving water quality and supply. "The focus of this project was the development and implementation of simple scientific techniques that could be used by rural people, many of whom had no formal education, to collect quantitative data, Terry says.

Methods included determining vegetative basal cover using a square metre quadrat subdivided into 25 squares, measuring up- and down-slope erosion using a Morgan Splash Cup, the height of mud splash from falling rain, rainfall with a rain gauge, donga profiles to determine sediment deposited in the dongas and water quality and quantity from the water run-off collected in 2-litre coke bottles connected to square metre runoff plots. To enable community members to fully appreciate the impacts that poor land practices have on natural resources versus the positive impacts of broad and long-term erosion control measures, they have also been monitoring streamflow at a catchment level using "paired catchments".

The project had a major effect on the lives of the community members. Their understanding of the erosion processes, the implementation of solutions and scientific monitoring of their success, eventually resulted in them becoming trainers to teach others the techniques in other catchments in the Western Cape and KwaZulu-Natal.

In addition, the work led to funding by the government's Working for Water programme (that clears mountain catchments and riparian zones of invasive alien plants) the first pilot project of Payment for Ecosystems Services was initiated, whereby people, who volunteered for years to improve vegetation

"The focus of this project was the development and implementation of simple scientific techniques that could be used by rural people, many of whom had no formal education, to collect quantitative data"

and water quality and quantity in degraded catchments, were now paid for their rehabilitation work.

The success of this initiative attracted funding from external agencies and the initiation of several projects of which Terry was project leader, such as the biomass initiative tree nursery programme, South African Nature Foundation community garden project and Independent Development Trust tree education project, and a later WRC project on improving the livestock carrying capacity of grasslands with rainwater harvesting and conservation, including biogas generation from manure.

In 2006, Terry was honoured twice in the national Women in Water Awards scheme, winning in the research category as well as taking third place in the education category, based on her efforts to reduce soil erosion in the remote Okhombe area.

Dr Terry Everson on what is necessary for success in a chosen career:

- Love your work
- Dedication
- Extremely hard work

Throughout, Colin was conducting his research from the Land Use Hydrology offices that the CSIR opened at the university shortly after the Eversons' arrival in Pietermaritzburg, though he now called himself one of the 'silverbacks' that ran the programme with young scientists in tow.

Field-based experiments became a hallmark of his career. A memorable achievement was when he built a lysimeter, a technology used to estimate evaporative loss from large containers commonly filled with soil, water and plants. This time the lysimeter consisted of a 1m³ of undisturbed soil monolith. "The local labourers were convinced that I was mining for gold!"

His involvement in the Kruger National Park Rivers Research Programme saw him tackle the substantial challenge of erecting a tower to measure riparian zone evapotranspiration using Eddy Covariance in the middle of the Sabi River. "At times, I had to swim through the braided streams to reach my site after driving eight hours from Pietermaritzburg," he says of the "crazy" exercise.

Unfortunately, the expensive setup was eventually all washed away to Mozambique in the floods of 2000.

Building micromet towers in remote areas has always been a challenge he enjoyed, but the job was made slightly easier when he was introduced to scintillometry, which allowed him to simply point equipment over a canopy, for measurements over a distance of up to five kilometers. He would later apply large aperture scintillometers to measure evapotranspiration of Knysna's indigenous forest, among other projects.

Colin's research covered a large number of topics, ranging from investigating the effect of the introduction of agroforestry species on the soil moisture regime of traditional cropping systems; developing guidelines for irrigation management in pasture production; to studying evapotranspiration from the Nkazana swamp forest and the Mfabeni Mire in the iSimangaliso Wetland Park; and improving the livestock-carrying capacity with rainwater harvesting and conservation on grasslands (a project with Terry as lead). Their detailed research on the Jatropha curcas, once hailed as a potential wonder plant for its potential for biodiesel production, conclusively showed that the species is not suitable to South African conditions, and must not be cultivated.

He has also led detailed studies at the Two-Streams catchment located in the KwaZulu-Natal Midlands, to investigate the impacts of Acacia mearnsii stands on hydrological processes. As part of the ongoing study, the hydrogeology of the catchment was investigated and characterized to understand the long-term impacts of the plantations on evaporation, streamflow, low flows and groundwater resources.

Looking back on a prolific partnership

Having a good partner makes the hard work lighter, Colin says. “We understand each other’s problems, and know exactly what the other is up to, and why. The two of us together are larger than the single parts.”

The Eversons are now toning down on work and tying up last projects. Yet, they are still spending as much time as possible “out in the open somewhere.” They hiked the Fish River Canyon last year, and the Otter Trail the year before that. “We never sit still,” Terry says. Gonarezhou National Park is on the cards, and they are currently considering slackpacking, in-between running and cycling.

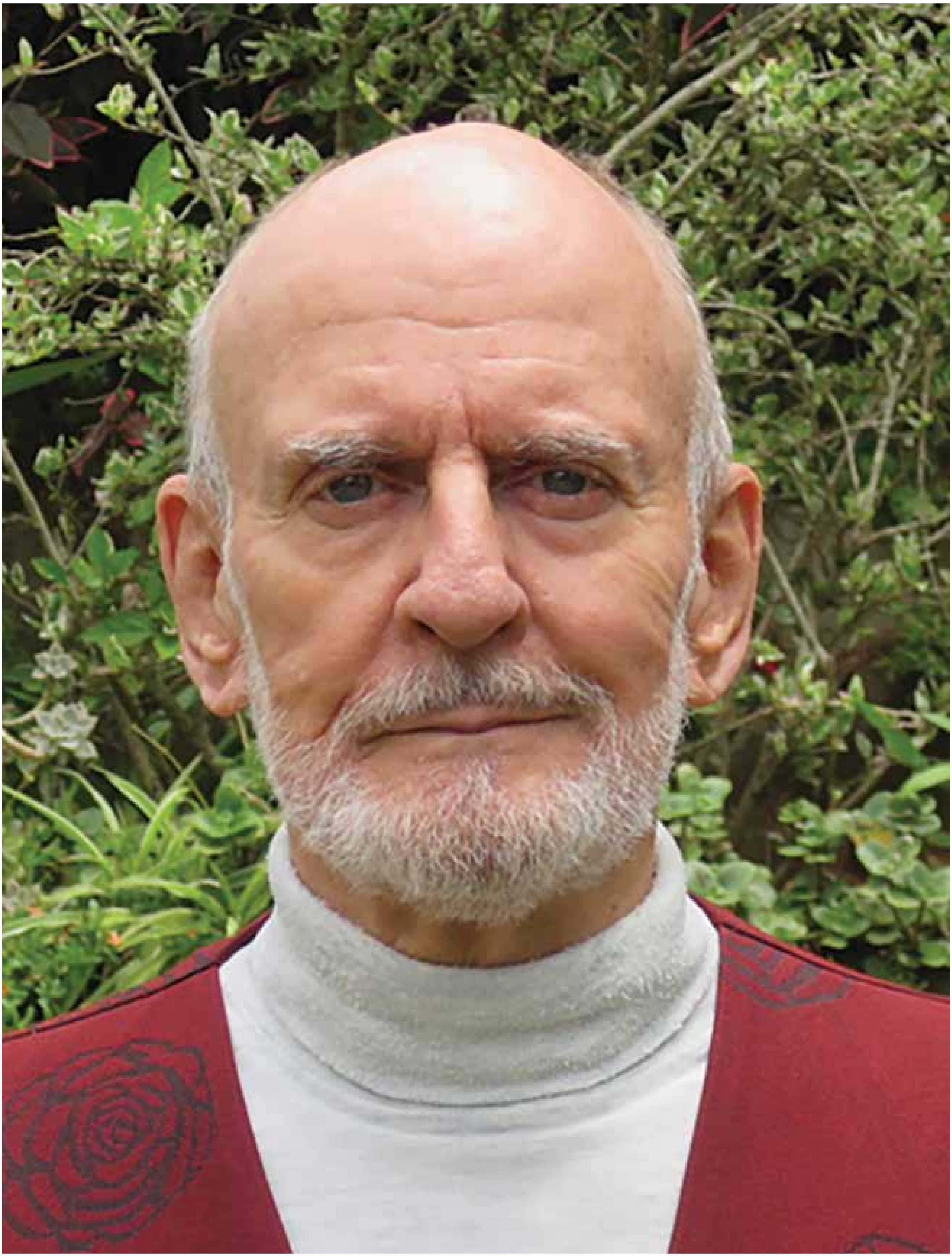
In retrospect, Terry says life has been good for the Eversons. Looking at the legacy they are leaving behind, the same positive feedback has trailed the many projects they worked on as individual scientists, and the prominent team that they’ve become.

Award-winning scientists in their individual capacity, together the Eversons have built a lasting legacy.

Photo credit: Petro Kotzé

Prof Colin Everson on what is essential for success in a chosen career path:

- Hard work, dedication and determination
- For micrometeorology research, a basic knowledge of physics and numeracy
- An ability to write
- Innovation in one's approach to research
- If the career path includes field work one needs to be able to work in uncomfortable environmental conditions for long hours and deal with unusual problems



Prof Geoff Pegram

Photo supplied

GEOFF PEGRAM

A grand master of the art of hydrometeorological engineering

Current position:
Emeritus Professor, Civil Engineer and Senior Research Associate in UKZN's School of Engineering

Research interests:
Stochastic and deterministic hydrology and physical and computational hydraulics, space-time modelling of rainfall from radar and satellite images, real-time flood forecasting using radar and linear meta-models, modelling of rainfall measured by large networks of gauges and large water resources system analysis and reliability

Awards

AWARDS

2021: WRC Legend Award
2016: Recipient of the medal of the South African Society for Atmospheric Sciences
2015: Recipient of the Water Research Commission Knowledge Tree Award
2004, 6, 7 & 8: Research Excellence Award, Faculty of Engineering, UKZN
2001: Mieyegunyah Distinguished Fellow Awardee, Melbourne University
1992: Award for "The best paper published in The Civil Engineer in South Africa in 1991"
1989: Fellow of SA Institution of Civil Engineers
1977: Ernest Oppenheimer Trust University Fellowship

If mathematics is an art, Prof Geoffrey (Geoff) Pegram is a master of hydrometeorological engineering. His work has helped pave the way internationally for multifaceted advancements in the monitoring, understanding and modelling of hydrological and hydraulic processes, radar-rainfall modeling and hydrometeorology. However, he is as revered for the beauty and clarity of his explanations, for dreaming up ambitious new research projects and inspiring generations of students swept up by his enthusiasm for fluid mechanics and hydrology.

His passion for the field has not waned over time. In 2020, with his 80^{th} birthday already behind him, Pegram completed his Doctor of Science, a ranking higher than PhD. His unsupervised DSc thesis is a selection of his collection of selected published papers, summarising his contributions to hydraulic engineering and stochastic hydrometeorology.

In response to the congratulations that followed, Pegram replied with a heartfelt quip that he was "delighted this journey is coming to an end" – but his reputation begs one to believe otherwise.

Pegram has tackled, and helped to solve a range of South Africa's most vexing and complex hydrometeorological engineering problems, and continues to do so well into his official retirement.

He has consistently applied scientific analysis to improve, among others, reservoir storage and reliability, rainfall and flood estimation, the statistical design of large water transfer schemes, flood and drought monitoring and the downscaling of global circulation models, with notorious capacity and enthusiasm. "Whether, it was a 5am start at the university campus to drive a car full of students to Bethlehem for meetings on weather radar with colleagues from the South African Weather Service, or yet another mentally demanding multi-hour maths session on the whiteboard, he always gave maximum attention and effort," says Dr Scott Sinclair of the Institute of Environmental Engineering in Zurich, a long-time collaborator of Prof Pegram, who first met him as a Civil Engineering undergraduate at the University of Natal (now the University of KwaZulu-Natal), the institution that Pegram would be associated with for the bulk of his career.

"Your work has to be practical"

Prof Geoff Pegram with his WRC Knowledge Tree Award.

Photo credit: WRC

Prof Pegram and his wife of 28 years,
Dr (of Humanities UKZN) Joan Pegram.
Photo supplied

"He was an inspirational teacher whose love and enthusiasm for fluid mechanics and hydrology were infectious."

The making of a civil engineer

Pegram completed his degree in Civil Engineering at the UKZN in the early sixties after which, to honour his scholarship from the then Rhodesia Railways, he started his first job as Assistant Engineer in charge of track renewal between Bulawayo and Ndola in Zimbabwe. He was subsequently appointed as Assistant Engineer Camp Services, contracted for the Orange-Fish Tunnel for a few months in 1966.

Fortunately, because of a bequest, he was able to transplant his family to the University of Lancaster in the UK, where he completed his PhD in the record time of two years. His PhD at Lancaster on "Stochastic Reservoir Theory", completed in 1972, awakened a desire for more international experiences and contacts. He subsequently spent several sabbaticals overseas, including at the universities of Colorado State, Haifa (Israel), Newcastle (UK), and Bologna (Spain). He made regular visits to the University of Melbourne as a Visiting Research Fellow, and as Visiting Professor to the universities of Barcelona and Stuttgart. These trips resulted in a series of publications, but also offered him the chance to collaborate with top-class hydrometeorological academics, and opportunities to nurture ideas that he would bring back to enrich his work in South Africa.

On his return to Durban, Pegram completed his Master's in Civil Engineering, writing his thesis on the water resources of the Umgeni River, supporting himself. He was then approached by the then Head of Department, Prof Kenneth Knight, and stepped into his first official post at the UKZN on 1 January 1968, so for more than the next forty years, as lecturer then Professor (at that time the second youngest ever) at Howard College, a responsibility that he cherished. "I have loved teaching and mentoring my students, and opening up their minds as to how they can make a contribution to improving the environment and its vagaries, by using their unique skills," he says. This passion has rippled out in the careers of the students he inspired, many of whom continued to top positions locally and internationally. They have fond memories of being taught by Pegram.

Sinclair remembers his capacity to turn even the topic of Fluids and Hydrology into an "entertaining" class, always well received. "He would typically begin the lecture with a clean chalk board, and by the end it would be crammed full of the hieroglyphics that he assured us were valid equations describing the day's topic."

Prof Pegram at his final lecture at UKZN in 2004, with his two postgraduate students either side of him.

Photo supplied

Professor Emeritus of Environmental Fluid Mechanics at the UKZN's School of Engineering, Derek Stretch, also has fond memories of Pegram's classes. They first met some 40 years ago when Pegram walked into Stretch's second-year undergrad engineering class in Civil Engineering to teach fluid mechanics. "He was an inspirational teacher whose love and enthusiasm for fluid mechanics and hydrology were infectious," Stretch says. The clarity and beauty of his explanations remain an enduring memory from that time and, Stretch says, inspired his own lifelong passion for the subject, having completed his MSc thesis with Pegram, which launched him into Cambridge University where he obtained his Doctorate.

Pegram acted as Head of the Civil Engineering Department from 1987 to 1992, and was appointed as an Emeritus Professor in 2011. The contributions in question are substantial, with highlights that follow the development of water resources management in South Africa and often, beyond the country's borders.

Early work on Markov Chains and reservoir reliability

Pegram stepped into his professional career as South Africa entered its second golden era of dam building. In contrast to the schemes built before the Second World War, the multi-purpose schemes that followed in the sixties and seventies focused on water provision for domestic and other uses as well as the traditional irrigation use.

The young civil engineer originally turned his attention to reservoir storage and reliability, thriving in mathematical modelling from early on. His initial work focused on Markov Chains, a stochastic model (random process) that describes a sequence of possible events in which the probability of each depends only on the state attained in the previous. One of his earliest contributions was to extend the traditional Markov Chain to allow for statistical comparison of multiple variables, which allowed for a flood cascade model that could compare various storage reservoir configurations. It resulted in his first paper, accepted without revision by the *Journal of Hydrology*. "To my sorrow, it never happened again," Pegram says.

"I have loved teaching and mentoring my students, and opening up their minds as to how they can make a contribution to improving the environment and its vagaries, by using their unique skills."

During this time, he also solved the frustrating problem of how frequently a reservoir with a given input flow regime would fail (in the sense of running dry) by analysing the effect of failure as a function of the withdrawal rate.

Design rainfall and flood estimation

Reliable estimates of floods, their peaks and the frequency of such peak flows and volumes are a serious challenge to hydrological practitioners. Poor estimates result in substantial losses to the economy, environment and human and animal life. In 1984, for example, hurricane Domoina wreaked havoc from Mozambique to Swaziland. The severe tropical storm (the first classified as such by the South African Weather Bureau) resulted in 100-year floods, leaving millions of Rands of damages in its wake.

"It is paramount to determine the risk of such damage due to these rare events, in order to design for improved defenses," Pegram says. His work in this area started around the Domoina hurricane damage caused by rainfall over 600 mm in a day, and was initially based on physically realistic conceptual models, with results that contributed to improved design procedures in the face of extreme and rare storm events.

A couple of years after Domoina, in 1988, South Africa would be in the midst of the worst drought in the summer rainfall region than any on record. It prompted government to look at large-scale water transfer schemes in order to take water there where it was most needed – a near redesign of the distribution of the country's surface water. Pegram was approached to assist with adapting and synthesising computer code for multisite reservoir modelling along the Vaal River System, and devising a stochastic multisite monthly rainfall model for many stations. Software developed at that time is still in use by consultants today.

An important milestone in Prof Geoff Pegram's career has been the adapting and synthesising of computer code for multisite reservoir modelling along the Vaal River System.

> “The infilled values need to be as good as possible, because poor infilling is likely to lead to poor decisions.”

At the turn of the millennium Pegram went into a new phase of research. South Africa had had a longstanding research programme on rainfall enhancement, in which the infrastructure expertise and related hardware and software to collect and archive high-quality radar data, analyse the information and conduct comparisons with conventional measurements on catchment scales, were developed.

The high spatial and temporal resolution, and real-time nature of the weather radar data, initiated by SAWS’ installation of the MRL-5 radar near Bethlehem in 1984, have distinct advantages over even dense rain gauge networks when catchment rainfall under convective conditions is estimated for flood hydrology. The information gained from radar data has also provided insight into the structure of rain-producing systems, enabling the more accurate modelling of the phenomenon.

Radar rainfall would become a lifelong interest. His work has addressed the shortcomings of the technology, including radar-rainfall image repair techniques, infilling areas where estimates of rainfall by radar are bedeviled by ground clutter – especially high mountains, anomalous propagation, hail and the bright band on rainfall estimates. His work has also led to the extension of the useful range of radar data for rainfall estimation, which is necessary due to the less-than optimal radar spacing over South Africa.

His ideas on improving the information obtained from radar-rainfields has been used in European Union projects in which he partnered, helping in knowledge transfer for the beneficiation of the flood prevention methodologies.

Under Pegram’s leadership a long-term research programme has been running at the UKZN to estimate spatial rainfall fields from radar data and combining this with information from ground-based observations (rain gauges) and satellites to generate improved estimates of spatial rainfall variations over the whole country. As a result, we are now able to produce estimates of extreme rainfall at chosen locations in regions where no pluviometers (instruments that record at sub-daily intervals) are available.

Work has also contributed to urban planning, showing that the risk of urban flooding in current design practice is routinely underestimated with as much as 30–50%, and offering methods for sensible revision.

Filling in missing rainfall data

An “unpleasant and tedious task”, filling in missing rainfall data is essential for analysis and water resources management and good decision making. “The infilled values need to be as good as possible, because poor infilling is likely to lead to poor decisions.” He has routinely been working on ‘patching’ rainfall data, repairing missing data in the country’s rainfall and streamflow datasets.

His initial work focused on filling the gaps in rainfall records which interfere with the construction of water-balance models. Pegram's work relied on regression methods to find the trends in the data, which was converted to a generally popular programming langue (FORTRAN code). The method was used extensively in South Africa by consultants to the Department of Water Affairs and Forestry to repair rainfall records for generating streamflow sequences via catchment models that Pegram also helped devise.

The hydrometeorological engineer followed that up some years later with a new copula-based method to infill missing daily and monthly rain gauge data. This method allowed for a flexible way of describing nonlinear dependence among consecutive data. He continued to improve his methods over the years, most recently still working on the difficult problem of infilling missing data in a diminishing South African national rain gauge network (now down to less than 1000 from the 4000 gauges in the 1970s), using novel statistical tools such as copulas.

Hydraulic modelling

Pegram entered the realm of hydraulics studies as the foundation of the Lesotho Highlands Water Project was being laid in the late eighties. To transport water from Lesotho to South Africa, a cylindrical tunnel of 5.35 metres diameter, 83 km long and fall of 77 metres had to be bored through rock. At the time, only a few kilometers had been bored, and the hydraulic engineers designing the tunnel needed to know how rough the surface inside the tunnel was likely to be, and how this would relate to hydraulic resistance.

They needed an innovative solution, and looked to Pegram and his research group to find the answer. For these early studies the group devised a micro-laser scanner on a one-metre-long portable rail driven by a stepper motor, to record traces at 0.5 mm intervals, fed by motor-car batteries into the "dripping, dry, dusty, dark environment for several kilometres from the tunnel entrance." Their results were relevant to all engineers involved with the hydraulics of tunnels excavated by boring machines. Studies on hydraulic roughness would later be refined with the use of laser measurement, and applied for the design of the Orange-Fish tunnel and others.

Pegram also conducted research on the design of overflow spillways. Early work included the hydraulics of skimming flows on modelled stepped spillways. For this purpose, he built a three-metre-high model of a stepped spillway overflow from a reservoir in his hydraulics laboratory, with which they determined the hydraulic roughness of the steps, and the relationship between the step size and the water depth on the spillway. This work assisted the then Department of Water Affairs with economic design of the overflow spillways of relevant South African dams, and led to Pegram being asked to review other's work on stepped spillways.

Soil moisture and evapotranspiration for flood and drought monitoring

Monitoring of the spatial distribution of soil moisture and evapotranspiration over a large region in fine detail has great value for coping with two weather extremes: flash floods and droughts. Soil moisture conditions have a major impact on the runoff response of a catchment to heavy rainfall. For flash flood forecasting, for example, the current state of the soil moisture of small catchments with a short response times is a good indicator of risk. Except for flood forecasting, good, up-to-date estimates of soil moisture are valuable to a range of disciplines, including numerical weather prediction and agriculture.

Yet, it is not easily measured. One of the major challenges facing providers of soil moisture products is validation, which is predominantly a result of the limited availability and coverage of in situ observation networks.

Providing a solution to the problem, Pegram adapted the TOPKAPI rainfall-runoff model to South African conditions, first applying it to successfully model the hydrology of the Liebenbergsvlei. The model was since used extensively in WRC projects as PyTOPKAPI, improving on the original designed by an old friend in Italy, Prof Ezio Todini.

The process was taken a step further in the HYLARSMET project (completed in 2013), when satellite data was used to estimate soil moisture with encouraging results. For one, an automated modelling system that produces country-wide estimates of soil moisture state (and actual evapotranspiration as a by-product) in three-hour steps on a 12 km spatial grid over South Africa was developed. These results formed a proof of concept for operational use by the South African Weather Service (SAWS) in their national Flash Flood Guidance system, and informed numerous other fields such as crop modelling and drought monitoring.

A very important liaison was formed between Pegram and Bárdossy, Professor at Stuttgart, with whom he has published for more than 10 years, visiting there for a month per year from then until the COVID pandemic. Andras has reciprocated by visiting Durban in early February and worked together at UKZN after Pegram retired, working in an office nearby, which he describes as a joy.

At the same time (from 2011 to 2013) Pegram and his research group partnered in the two-year European Project, GLOWASIS (Global Water Scarcity Information Service). The project aimed to set up a so-called one-stop-shop portal for water security information. One of the core drivers of the methodologies created to obtain measures of water scarcity was remote-sensing of soil moisture and global hydrological modelling of catchments and, as such, soil water behaviour. Pegram used the opportunity to extend the usefulness of PyTOPKAPI and making the model and source code freely available on the internet, with added up-to-date maps of soil properties over the country.

Pegram says, beside the routine work of updating the model software, the workshops to “get the model out there” was the most important and rewarding activity; especially the concomitant response of the informed members of the hydrological community, who showed their support by “voting with their feet, cars, flights and participating seriously to the efforts we made.” There are now several groups of researchers making use of the PyTOPKAPI model and HYLARSMET outputs, both locally and internationally, Pegram says.

His research into estimating soil moisture daily, in spatial detail, over South Africa was eventually expanded throughout the SADC countries, South of the Equator. These projects entailed massive computing tasks, which demanded the development of new tools for high-speed parallel computing, all of which were made available for free. Later, the work would be used to help assess the vulnerability of South Africa climate shifts, and how the country should adapt to reduce exposure to vulnerability.

Assessing the effect of possible climate change scenarios on local precipitation

In 2010, Pegram took his first steps into the realm of climate change, downscaling precipitation using regional climate models and circulation patterns. His first paper, described as a 'research highlight' in Eos, was to define a method for determining reasonable estimates of rainfall modelled by global circulation models coupled with regional climate models. The paper describes and uses two new procedures designed to give confidence in the interpretation of such rainfall estimates.

Then, in 2012, they devised a method of bias correcting regional climate model precipitation estimates over catchments as well as pixels, which led to new methodologies for interpolating rainfall data in individual time intervals (ranging from a day to a year). Pegram later also devised a method to downscale regional circulation model rainfall to gauge sites in five regions in South Africa, information that is of direct relevance to design and planning scenarios, even under climate change.

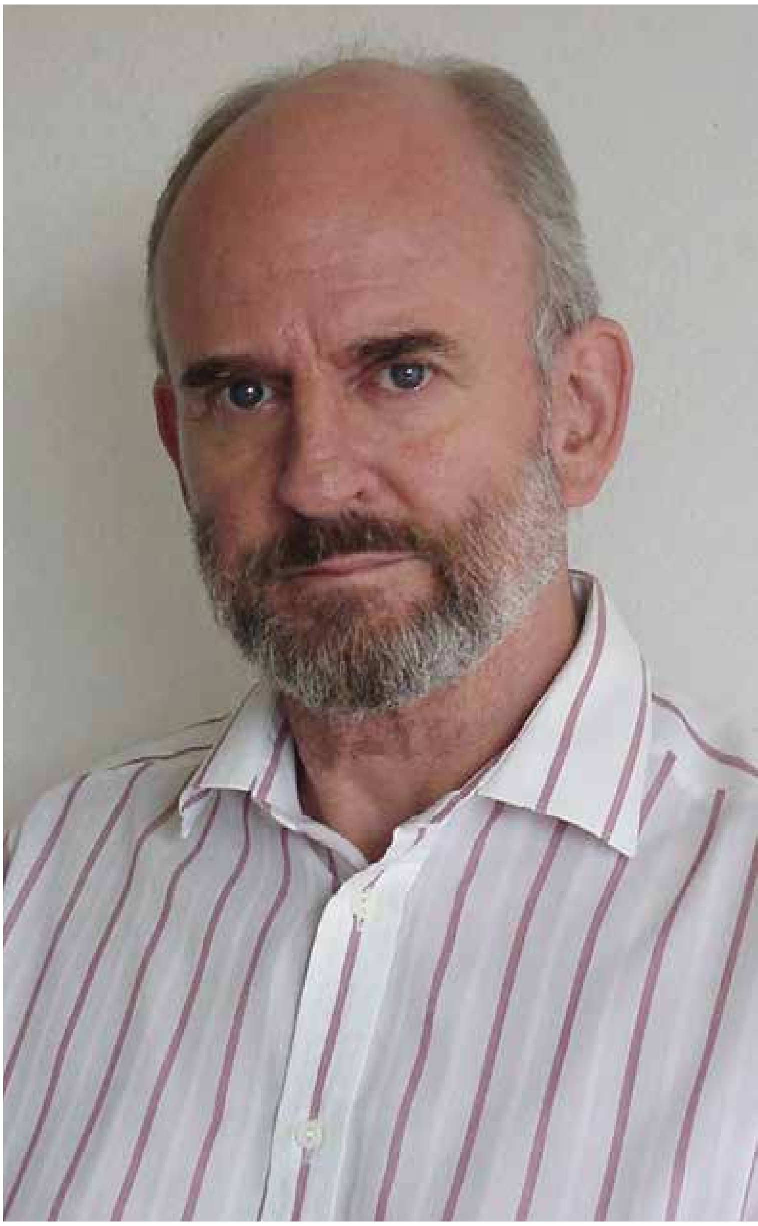
What makes art of engineering

From his early work on Markov Chains and reservoir reliability to the "string-of-beads" rainfall model and beyond, Pegram's research has won renown for its innovation, as well as the wonderfully crafted scientific papers that he conveys his ideas and solutions with. He has, over the years, perfected the art of conceptualising, analysing and synthesising complex ideas in an orderly way to give structure to thought.

The professor himself is scant on details of his own achievements, but says he counts himself fortunate to possess a combination of analytical skills across a broad spectrum of techniques in mathematics, stochastic and spatial statistics. These gifts, he says has been nurtured by his interactions with top-class academics and consultants, and have allowed him to engage with a range of professional practitioners and researchers.

Because today's problems demand multi-disciplinary approaches, Pegram says these capabilities have been embraced by leading researchers in their fields, using his enthusiasm to break down, analyse, articulate and solve complex problems.

Accolades from those that have worked with him are much easier to come by, and he is often referred to as a mentor, legend, inspiration and a true model by colleagues. His former student, Prof Stretch, sum it up concisely. His contributions, he says, "are an indelible legacy for us all to enjoy and build on."



Dr Rian Titus

Photo credit: Petro Kotzé

RIAN TITUS

A hydrogeologist that continues to dig deep to uplift others

Current position:
Founder and director of GWI Consulting

Research interests:
Assessment and characterisation of the impacts of mining activities on the groundwater resources; environmental impact assessment studies (groundwater component); the assessment, development and management of groundwater resources; strategy development with respect to the management of groundwater resources; and training and capacity building initiatives.

Award

AWARDS

2021: WRC Legend Award

Across the country, and beyond the borders, there is a cohort of researchers and experts that have built their careers on the foundation Dr Rian Titus helped create. They sit in management positions at the WRC and national government departments, run their own consultancies, fulfil expert positions in places like the Petroleum Agency of South Africa and Sasol, to name a few. Though their occupations vary, they all took their first fledgling steps at the same place. They all studied hydrogeology at the University of the Western Cape (UWC).

Titus, with the support of colleagues and industry partners, launched and developed the university's first undergraduate and postgraduate programmes in hydrogeology. Subsequently, he became the first black person with a PhD in hydrogeology in South Africa, obtained from the same institution. As consultant, his groundwater and mining-related projects allowed him to apply his expertise across multiple African countries. Now, his next project will combine his experience in theory and in practice to, once again, fill vital training gaps in South Africa's water industry.

When asked about his greatest achievements in the water sector throughout his career, Titus prefers to deflect the question to the achievements of the students that he helped train. The groundwater expert says he is pleasantly surprised to learn where some of his former students ended up after recently getting in touch with a handful of them. Though he left official academia years ago, he has always remained true to his passion for students, and has acted as external examiner in the years since. Though he does not like to shine the spotlight on himself, the influence of his own career on groundwater management and research sector in South Africa has been vital and will, he is proud to say, will long outlive his working life.

From structural geology to hydrogeology

"I wanted to be a structural geologist," Titus says. The scientific discipline concerned with rock deformation experienced a boom in South Africa around the eighties or so, and a young Titus wanted to be part of it. He completed his degree in Geology at the UWC, but his post-grad studies would focus his career on a different aspect of the Earth's physical structure and substances.

After he won a scholarship from the Sir Henry Strackhorst Memorial Trust, a mentor convinced him to focus on groundwater, leading to the student completing his MSc in Hydrogeology at the prestigious University College London in 1994. He completed his thesis on the geochemistry of springs, a topic that introduced him to his first WRC-funded project.

Dr Titus was the first black person to earn a PhD in hydrogeology in South Africa.

Photo credit: Petro Kotzé

On his return to South Africa and the UWC, he was appointed as a lecturer at the Earth Science Department, but with his new qualification in hand, was thrust in the deep end. Fresh from London he was tasked with establishing and developing an undergraduate and post-graduate hydrogeology programme. At the time, only the Institute for Groundwater Studies at the University of the Free State offered such a degree, but there was increasing space for groundwater experts in various expanding industries in South Africa, Titus elaborates. The task was no small order for the newly appointed lecturer. Honours, Master's and doctorate academic and research programmes had to be developed, international research exchange programmes launched and, to top it off, funding to get the academic programmes and research off the ground and maintained, sourced.

He is very careful to point out the large amount of support that was involved. "No man is an island," Titus says. Over and above drawing from his curriculum in London to help with the theoretical side, he relied on a large network of support from both within the UWC and industry. To fund the post-graduate research programmes and build a hydrogeology unit, both consultancy and research projects that targeted governmental and research institutions were developed. In these early years, the WRC played a key role, awarding multi-year research projects to the fledgling unit. Key roleplayers involved in the process included (among others) Drs Kevin Pietersen and George Green of the WRC, staff members of the Department of Water Affairs (including Gawie van Dyk, Allan Woodford, Mike Smart and Eddie van Wyk), staff of the CSIR (including John Weaver and Dr Gideon Tredoux), Des Visser (of Toens and Associates). Except for official staff members, Titus also relied on senior and post-graduate students to mentor and teach younger students. Dr Shafick Adams (currently with the WRC) is one such example. Lecturers from international universities, such as the University of Missouri, also presented lectures and assisted with research projects.

Milicent Solomons, Director at the Department of Forestry, Fisheries and the Environment obtained her Master's at the University of the Western Cape in 2002. Her thesis was titled *A socio-economic impact assessment of the water supply shortage in the rural areas of Namaqualand.* "It is crucial that the impacts of projects and specifically development projects consider and assess the impacts on the affected communities, both on an environmental, social and economic level in order to achieve sustainability," she says. In South Africa, social impact assessments (SIA's) are incorporated into the environmental impact assessment (EIA's) process in terms of NEMA (the National Environmental Management Act). The definition of environment includes people and hence SIA forms an integral part of the EIA process. However, it is unfortunate, Solomons points out, that the social aspects are often neglected in the process and the legislative public participation process is often used as a replacement for a full-blown SIA.

Some of the unit's earliest work involved the assessment and strategy development for sustainable groundwater supply in Namaqualand, where the group eventually conducted a number of studies with support of WRC funding. They also looked at geomechanical modelling as a tool for groundwater exploration of the region's fractured rock aquifers and later, how to transfer and share knowledge gained from the research undertaken there to end-users and local authorities.

In those days the course work and projects entailed large amounts of field work, which provided numerous students the practical experience necessary to complete their degrees. Except for trips throughout the year, the department offices would shut for a month mid-year to only focus on fieldwork. It was a very different scenario from today. Now, students are often exposed to precious little experience in the field, and are part of much larger classes. Still, it did not take away from the workload involved back then. Titus says he still regrets missing some important family celebrations such his son's first birthday. As was the case so often, he was out in the field.

Yet, the hard work paid off. On top of a growing student corps and expanding laboratory, UWC was awarded a UNESCO Professorship in Hydrogeology on the motivation of the late Minister of Water Affairs, Prof Kader Asmal. The position was taken up by Prof Yongxin Xu in 2000.

In 2003, Titus obtained his PhD in Hydrogeology at UWC, writing his thesis on the hydrogeochemical characteristics of the basement aquifers in Namaqualand. He was the first black person in South Africa to do so, followed closely by long-time colleagues Drs Kevin Pietersen and Shafick Adams. After a decade in academia, Titus decided he wanted to gain experience in the hydrogeology industry, and moved over to consulting full time.

Since he left UWC, he is proud to say that his work there has outlived him, and grown even further in his absence. Today, the course has been folded into the Environmental Water and Science Programme of the Earth Science Department. The approximately ten-person strong leadership and academic staff team have succeeded in developing a considerable postgraduate research programme, Titus says, through the implementation of multiple research activities with diversified income streams to support their postgraduate students.

Sean Davids obtained his Master's in Hydrogeology from UWC in 2003. His thesis was on the identification of potential groundwater zones in the Kamiesberg Region of the Northern Cape. He is now employed as Divisional Geologist at the Petroleum Agency SA (PASA). Davids says the field experience and friends he made during his academic years are lifelong. Like him, many have established careers in significant global and national institutions and he says, the UWC Geology Department has continuously produced highly skilled students for the South African workforce. For him, his understanding of fluid flow and field experience provided an extensive base for his career in a petroleum company, and he is grateful to the WRC for allowing him to add significant value to the South African economy.

From academia to industry

His first job outside of academic was as the manager of the Water Geosciences Business Unit at the Council for Geosciences, a position that Titus held from 2003 to 2005, but he admits that administrative positions are not what he loves best. His passion lies with getting out there to do the work. He started his first consultancy, Water Geosciences Consulting, in 2005, before taking up the position as director (groundwater) at SLR Consulting, South Africa. Currently, he is the director of the company that he founded in 2013, GWI Consulting. He also has director positions at Geo Tail SA (Pty) Ltd and MDT Environmental. In addition, he served as the national chairperson of the Groundwater Division of South Africa (GSSA) from 2008 until 2010.

Titus's work as consultant has taken him to various African countries, including Botswana, the Democratic Republic of Congo, Congo Brazzaville, Tanzania, Mozambique and Kenya. He has worked on various aspects related to the assessment and characterisation of the impacts of mining activities, such as mine-water management and water quality assessment on groundwater resources. He has completed numerous projects for large mining companies, including Impala Platinum, Lonmin, Glencore, Anglo Platinum, Tharisa, Eastern Platinum, BHP Billiton, Cominco Resources Limited and Banro Mining in the DRC and Uranium One in Tanzania. These large mining projects have been some of his favourite projects to work on, as it allowed him the opportunity to go deep underground for sampling. Most hydrogeologists have to contend with collecting samples from boreholes.

Titus says he did not want to retire at UWC, he wanted to see how the industry looked first, but the idea was always to return. His next venture will take him there, and allow him to strengthen the relationship between theory and practice.

Combining theory and practice for vital solutions

Titus, again relying on the support of industry colleagues, is in the process of establishing a private niche educational institute called the Water Business College (WBC). "The tertiary system in South Africa cannot accommodate every qualifying scholar," he says and in addition, several scholars that matriculated prior to 2020 are still looking for opportunities to access the tertiary education sector.

The vision of the WBC is to become a Centre of Excellence that contributes to the improvement of water management across the water and related engineering, environmental, socio-economic and legal sectors. The intention is to work alongside, and in support of, related programmes at tertiary institutions in South Africa. They will offer undergraduate and post graduate academic programmes, starting with occupational qualifications for water reticulation practitioners and water infrastructure management.

Once again, Titus is in the deep end though this time, he jumped in himself. It's incredibly hard work to get the institution off the ground, he says but, they simply must get it right. WBC will once again help to launch and improve the careers of many in the water services and water resources industry, and so ensure that his legacy, even if unseen, will live in the lives of those that reached the ladder of success from springboard that he helped put in place.

Dr Sharon Pollard

Photo credit: Petro Kotzé

SHARON POLLARD

Leading the long and uncomfortable road to successful IWRM

Current position:
Executive Director at the Association for Water and Rural Development (AWARD)

Research interests:
Research, implementation and advocacy work around participation in sustainable, integrated water resources management in underprivileged areas in Southern Africa and elsewhere; systemic, social learning approaches to natural resources governance, catchment management planning and implementation especially under climate change; water and issues of equity and socio-environmental justice in poor rural communities; planning for meeting water

Award

AWARDS

2021: WRC Legend Award
2017: SanParks Appreciation Award (presented to AWARD)
2013: WRC Knowledge Tree Award

The Olifants River catchment is a behemoth – both in shape, and challenges. Despite the landmark National Water Act of 1998, the 560 km-long river consistently logs less than 30% of the minimum recommended drought flow. The challenges in South Africa's most stressed catchment are extreme. In 2005, cross-border flows to Mozambique stopped for 78 days. This history was about to repeat itself when severe drought hit in 2016 and yet, the lower Olifants River not only kept flowing but the river's Environmental water requirement (EWR) – or the Reserve – was met throughout.

It was one of the crowning achievements of the RESILIM-Olifants programme, a USAID-funded project active in the basin since 2013. It also validated Dr Sharon Pollard's decades-long commitment to integrated catchment management planning from the ground-up – an approach that focuses on the social domain first, before science. Now, as the Executive Director for AWARD (Association for Water and Rural Development) she is an award-winning specialist in planning to meet water requirements for sustaining ecosystems and, especially in poor rural communities. But initially the young ecologist was derided for her interest in social issues, and she describes the early part of her career as uncomfortable.

It started when she left her home country of Angola for South Africa. When Pollard arrived in the early eighties to launch her ecology degree at the University of Cape Town, apartheid was in full swing.

An uncomfortable introduction to ecology

Pollard says she couldn't adjust to the local social climate. Surrounded by enthusiastic, budding ecologists, she wondered about the people in the systems they were studying. "It was a hard time to be an ecologist if you were socially sensitive," she says, expected to focus on fauna and flora in a country on the brink of civil war. Politics, and finding a space in uncomfortable situations would run as thin threads through the rest of her career.

After her undergraduate studies, she left for Brazil to volunteer for the World Wildlife Fund in the Amazon forest, working on projects focusing on the minimum critical size of ecosystems. Deforestation was already rife, as was conflict with indigenous Amazonian Indians in the face of looming development. It reaffirmed an interest in people and ecosystems in the young scientist; one that was further piqued when she moved on to projects related to the possible damming of the Amazon River. The drive for economic development heavily infringed on people's rights, leading to difficult conversations. However, Pollard said that, rather than threatened, she felt relieved that there was space for this to take place – in comparison to her earlier experience in South Africa.

Yet, changes were on the horizon at the southern tip of Africa, and Pollard returned as news broke of Nelson Mandela's pending release from prison to be part of the changeover to a young democracy. She enrolled at UCT for a Master's in freshwater ecology with fieldwork in the Lowveld on the Kruger National Park Rivers Research Programme (KNPRRP). She found the challenges she first left behind in South Africa, remained. Pollard did not fit into the expected box of a typical ecologist. In the change-over to the new democracy, water was heavily politicised, and she did not want to divorce that reality from her work. "I was often criticised for thinking like a social scientist", she says, instead of a 'real' scientist.

Dr Pollard's concern for people – and their interaction with the environment – is what has been driving her career.

Photo credit: Petro Kotzé

Nevertheless, slowly, thinking started to shift towards managing ecology as part of a broader systems through a socioecological framing and therefore as complex adaptive systems that would years later, in the shape of strategic adaptive management, led to fundamental changes in the management of ecosystems and water in South Africa. People started to look upstream, outside the fences of protected areas for solutions. Finally, Pollard saw something that she could associate with for a future career and she found herself on the cusp of something "amazing".

First steps in a new direction

By this stage, she was based in Mpumalanga, and busy with a PhD on the downstream impact of dam construction. When she joined the Wits Rural Facility (WRF), for the first time, she felt at home in an environment where her ideas were not out of place. It would be a landmark association, setting the trajectory for the rest of Pollard's career.

The WRF was established in 1989 with a grant from the Anglo-DeBeers Chairman's Fund. The facility was a base from which the University of the Witwatersrand (Wits) could bring academic resources to bear on development challenges created by the apartheid homeland system. Pollard became heavily involved in the WRF's Water Information Project (WIP), established in 1993, which entailed a series of village water projects. The work lay the foundation for her future pioneering research and advocacy work around the links between integrated water resources management and water supply, and stakeholder participation in underprivileged areas in South Africa.

The work was difficult and challenging, Pollard says, but she persevered and flourished in the environment. She was surrounded by colleagues who brought different ideas to the table that required integration – from engineering through to social and environmental issues. Progressively, Pollard wanted to apply the work, more than only doing the research. The debilitating drought of 1992 suddenly shined the spotlight on the plight of the rural poor and of the environment. It was the catalyst for the change that she was hoping for.

No longer could water be developed uncontrollably without due consideration to broader issues that Pollard wanted to investigate. First was the need to test – in practice – the landmark policies regarding sustainability and equity. These included how much water there was; who was using it, how and for what purposes; what inequities existed; how sustainable these were; and, if the current use could be rationalised from social, environmental and economic perspectives. Moreover, if one were looking carefully, Pollard says, it also pointed to the need to integrate water supply and use within the context of water resources.

Coming into her own

In response, she co-founded the NGO AWARD in 1998. She describes herself as 'reluctant' to take up a principal position, saying it was never her ambition to lead, but she has become the face and driving force of the organisation. The NGO became the vehicle for her work on integrated catchment management planning and implementation, and from their early days of being concerned primarily with sustainable, participatory water resources management as the basis for services for the rural poor, expanded into policy changes by adopting a more holistic approach to water resources and their development.

Award's work has been, and still is, distinctive from other NGOs in the water sector predominantly because it is based on the central tenets of systems thinking. This approach brings together the social, political and the biophysical as an integrated whole that includes uncertainty, Pollard explains. Instead of the premise that people will behave better when they know more, this entails exploring, with people, their relationship with water from user to custodian. The process acknowledges that there are many factors why people can't change their behavior, so rather asks how they can learn their way into a new relationship with water to become a custodian. It entails work that is deeply uncomfortable, Pollard says, and it goes hand in hand with very difficult conversations.

For example, AWARD work funded by the WRC highlighted the role of water tenure and legal pluralism where some communities had – and were continuing – to manage water resources based on locally derived norms rather than using South Africa's statutory legal system. This situation caused discontentment with a national system that had not taken local systems into account.

It's thus perhaps of little surprise that AWARD has become synonymous with innovative projects and solutions to complex and difficult water-related challenges.

The Save the Sand project is a case in point. Initiated by the government, and the Sabi-Sand Wildtuin in partnership with AWARD, the project aimed to improve the ecological integrity, productivity and water resources of the Sand River Catchment through a socio-ecological approach. In partnership with SANParks, the governance of natural resources, as well as livelihood security were improved by setting up a framework for exploring the inter-relationships between

“You have to be comfortable with uncertainty.”
- Dr Sharon Pollard

the social, economic and biophysical drivers in the catchment using resilience thinking. This recognises that these drivers should be seen as one, interacting and complex socio-ecological system. This thinking also influenced AWARD’s development of national guidelines for the development of Catchment Management Strategies, which were developed at the request of DWAF (now DWS) to guide Catchment Management Agencies (CMA’s) in setting out key IWRM strategies.

Another project led by AWARD, the WRC-funded Shared Rivers Initiative aimed to understand and effect change in the implementation of policies and legislations relevant to the wise use of the Lowveld river systems. It investigated progress towards implementation of the Water Act of 1998 and factors that enabled or constrained achieving the Reserve (or EWRs) in order to provide a grounding from which to design and implement real change.

The study found that none of the seven rivers examined – the Luvuvhu, Letaba, Olifants, Sabie-Sand, Crocodile and Komati – met the Reserve requirements for flow and, with the exception of the Sabie River, this situation had deteriorated since the promulgation of the 1998 Act. Among other outcomes, the project showed how policy intent such as the EWR can be tracked through to outcomes with an integrated approach. It also deepened the discourse on environmental water requirements, compliance and what these mean for society. For this project Pollard became one of the first recipients, and the first woman, to win a WRC Knowledge Tree Award in 2013.

The same year, AWARD’s largest and most ambitious project started when they secured funding from USAID for the RESILIM-O project. The seven-year project allowed the AWARD team to experiment with innovative approaches to resilience-building, for which they again applied systems thinking, together with a social learning approach, for the transboundary, basin-wide programme.

Building a resilient Olifants River Catchment

The goal of the RESILIM-O programme was “to reduce vulnerability to climate change through building improved transboundary water and biodiversity governance and management of the Olifants Basin, through the adoption of science-based strategies that enhance the resilience of its people and ecosystems through systemic and social learning approaches.”

After years of work in integrated water resources management, the project allowed Pollard and colleagues the rare opportunity to put into practice the often nebulous and theoretical concept of resilience-building in a river basin context.

On paper, and in practice, some of the project methodologies are completely different to those normally associated with water management practices in South Africa. Except for the now-commonly accepted Strategic Adaptive Management and the now relatively well-known approach of socio-ecological systems thinking, tools and processes included concepts like systems thinking, social learning and resilience thinking, group model building, Collaborative Resilience Assessments, participatory action research, Activity Network Theory, expansive learning and a complexity-sensitive monitoring and evaluation system known as MERL.

The programme connected activities taking place in different parts of the catchment and at different scales under the thematic areas of water, biodiversity and climate change, and was split into two phases.

The first was dedicated to building a collective understanding between the identified stakeholders, their needs and priorities. In this process all stakeholders had to confront what they thought their own notions of "the truth", and the beliefs of others. For example, beliefs regarding your right to water, or the perceived contribution of 'bad' land management in erosion, instead of our social-political history, has to be deconstructed. "This is often a very painful process," Pollard says, but one that brings people to new insight and understanding.

The findings from phase I fed into the second phase, which comprised over 26 projects that responded to the needs identified. Twelve of these projects were implemented by partners through 22 sub-grants. Challenges were aplenty as they progressed with Pollard suddenly seeing the AWARD staff expand from just a handful to over 50 but, their work showed promise.

Their support to the Olifants-Letaba CMA in the form of systemic governance practices and tools, stakeholder capacity and participation led to significant advances in overdue decentralized governance arrangements. And, they facilitated greater co-operation between South Africa and Mozambique.

These social advances were supported by innovative technologies. They developed the mobile phone app known as FlowTracker. A first for the country, it allows for real-time monitoring of flows against compliance with gazetted standards such as the Reserve and dam levels, and is freely available to stakeholders. Concurrently, the project established monitoring gauges for backup to the national system. This was augmented by an integrated decision-support system known as INWARDs, designed for the needs of Department of Water and Sanitation officials and SANParks, tasked with compliance monitoring, enforcement and the authorisation of water use.

However, in 2017, a major setback occurred. A large part of the RESILIM-O projected implementation rested with the country's CMA process but suddenly, this was unexpectedly and abruptly put on hold. They were flabbergasted, Pollard says. "We had spent spend huge amounts of resources, effort and money on supporting the CMA." With staff feeling despondent, and the future of the project looking uncertain, they realised that they too had adapt, and be flexible in the face of change. At the end of 2018, they had to reinvent themselves, Pollard says, and switched gears to closer collaboration between non-state actors such as SANParks and water user associations.

In the background, a severe drought was intensifying and it looked like the Olifants might come to a standstill again.

Backed by data from the FlowTracker app that showed the severity of the situation, and with support from partners like SANParks and Water Resources Planning (Department of Water and Sanitation) AWARD initiated mitigatory plans to augment flows in the lower Olifants. For this, water use needed to be shifted from the Blyde to the De Hoop Dam, in order for water to be released and to reach the downstream users in the Lowveld, the Kruger Park and Mozambique.

Their efforts were successful and, on 23 September 2016, the first water was released. However, it never reached Kruger.

Once again, with FlowTracker, they could see exactly where the water left the system. A meeting with water users was called where the data was shared with all the attendees. Pollard says they were asked to leave the room to give the farmers and other water users space for a discussion among themselves. After some ruckus, they were invited back in, and assured that subsequent releases would reach that national park. They kept their word.

AWARD took on the responsibility of monitoring the river flows and running the RESILIM-O de Hoop-Blyde release model to recommend further releases until the emergency passed. Such releases were made in 2017, 2018 and again in 2019, resulting in the Olifant River's EWR being met at the Kruger National Park Mamba Weir throughout the drought.

"The project taught us the importance of being flexible and adaptable," Pollard says. "You have to be comfortable with uncertainty." Even more so, change could only be affected by having both the social and technical components in place. If they weren't able to track the river flow, the outcome would not have been possible, but this would also have been the case had the social learning approach not been adopted with stakeholders.

The key, Pollard maintains, is that one does not implement an outcome like the Reserve. Instead, flows of adequate water quality are delivered as a result of the collective implementation of a number of major strategies. These include managing the water balance in the basin, planning for and acting on risks and vulnerabilities imposed by expanding demand or unlawful water use and other drivers, especially climate change, the need to balance development and sustainability and Water Conservation and Demand Management, to name a few. And, importantly, stakeholders have to work together.

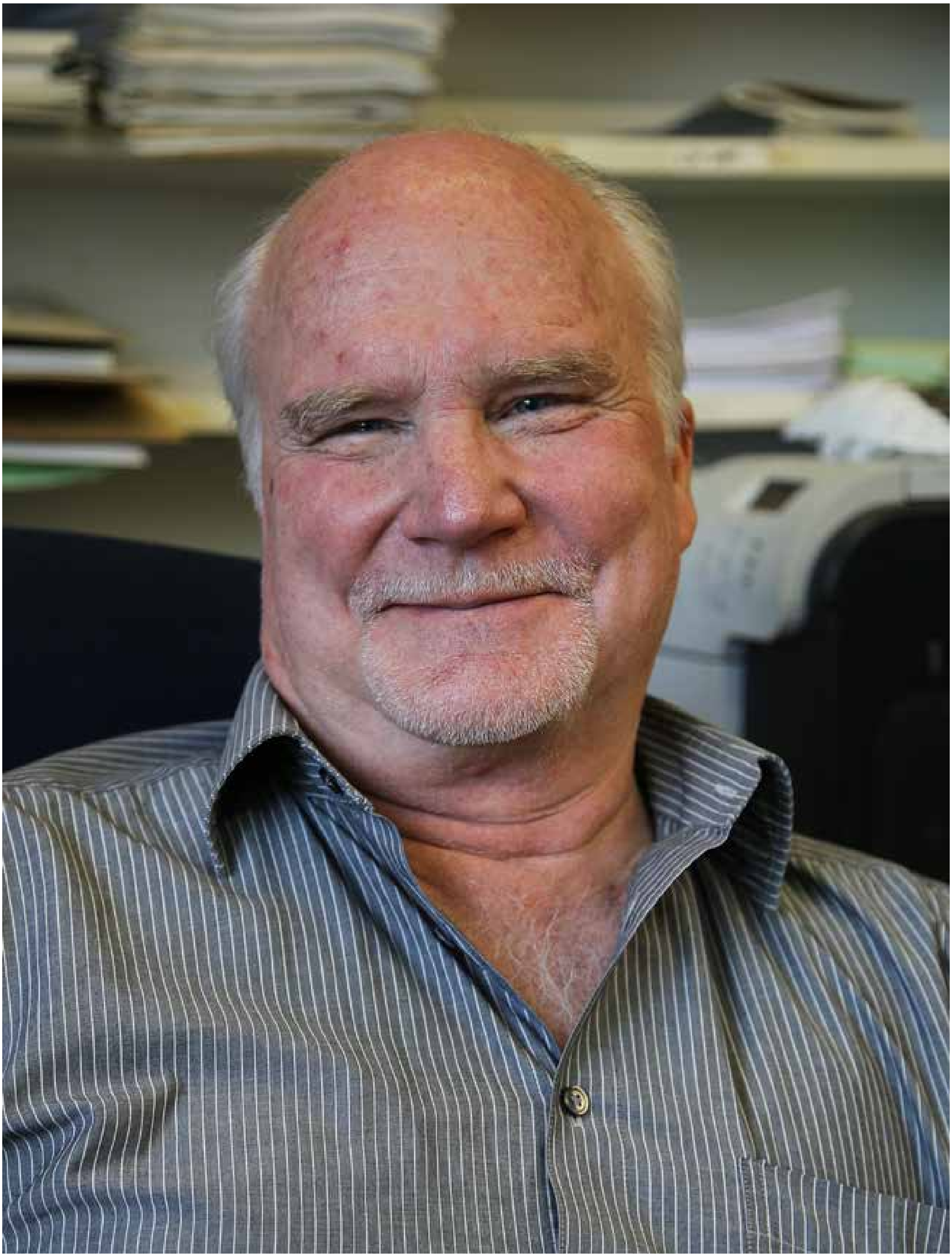
Coming home

From her early days of feeling the outsider, Pollard's unique skills, competence and professionalism have made her a sought-after scientist in the water sector today, both nationally and internationally. Despite being presented with a number of opportunities to move into more lucrative positions, she has chosen to work in those areas where poverty and inequity of access to resources – combined with issues of sustainability – remain a serious concern.

She describes her work as the practice of integrated water resources management, first by learning what people closest to the water are confronting. "We don't tell people what they need," she says. "Instead, we design solutions backwards from what they tell us they need." The work is catalysed by the implementation needs, rather than a research focus, she says. By staying true to what she believed, she has carved out a niche to take a rightful place among top freshwater ecologists in South Africa, but always with an eye on the social aspect that she was once derided for. "It's no longer academic, its implementation, supported by good science."

By staying true to what she believed, Dr Pollard has taken her rightful place among top freshwater ecologists in South Africa.

Photo credit: WRC



Prof Hindrik (Henk) Bouwman

Photo credit: Petro Kotzé

HENK BOUWMAN

A scientist that speaks for those without a voice

Current position:
Professor in the School of Environmental Sciences and Management: Zoology, North-West University

Research interests:
Ecotoxicology applied to various biological systems, mainly earthworms, fish, humans, birds and recently crocodiles; and, bird ecology

Award

AWARDS

2021: WRC Legend Award

Prof Henk Bouwman points to a map stuck behind his office door with an island nothing more than a speck at sea. He almost drowned swimming back from that one, he says. Another time, stormy seas at night nearly propelled him overboard when the fishing boat he was on got lost somewhere between Madagascar and Australia. His office has many stories to tell. Hundreds of books fill shelves in the light-filled space. There are many books on birding, but the Bible lies close to his desk, where Bouwman sits surrounded by packs of folders marked “Mauritius” or “Kruger”, sketches of dragonflies and larvae and a large world map. He has trampled around mangroves along the coast of Tanzania, crisscrossed coral reef islands in the Indian Ocean and once, jetted around the world.

Below a table lies bags of pale and peach coloured dust – simulations of soil from Mars and the moon. He'd like to find out if earthworms can live in it, in case they can be sent to space. Earthworms are after all his first love, he says. They don't scream or bite, pose few ethical dilemmas and eat dirt, he sighs with a wink. "Small things tell big stories," he says. Earthworms have another trait that is important to Bouwman. They can't talk, and they certainly can't defend themselves. So, he has taken it upon himself to speak for them, like he does for many things and people in the same position.

Bouwman is one of Africa's most prominent ecotoxicologists. Throughout his career, he has followed the relentless and enduring trail of persistent organic pollutants (POPs), toxic chemicals persistent in the environment that last for years before breaking down. POPs circulate through a repeated process of evaporation and deposition, permeating their way unseen through the world. Bouwman has tracked them in, among other places, water, the air, soil, eggs, cells, blood and breastmilk. His scope also includes microplastics, metals and pharmaceuticals.

It is his personal calling and conviction to contribute directly to the conservation of biodiversity, human health and the supporting natural ecosystems, and he has done this with astounding efficacy. He was closely involved with the processes that led to the banning or restriction of 23 of the 30 POPs now listed by the Stockholm Convention. Then, as Panel Member for the Scientific and Technical Advisory Committee (TAP) of the Global Environment Facility (GEF), he helped direct millions of dollars in international aid to improve the use of pollutants across the world. As a result, the use of many dangerous pollutants was gradually reduced globally, in turn reducing their threat to people and the environment now, and for generations to come.
"It happened by accident," he says "but everything that preceded it made it possible."

How Bouwman found his voice

Long before his birth, in the fourties already, a substance called dichloro-diphenyl-trichloroethane was developed as the first modern synthetic insecticides. DDT was applied abundantly to combat insect-borne diseases like malaria and typhus and crop destroying pests and to protect homes and businesses. By the sixties, DDT was the primary tool in a global malaria eradication programme, and sprayed liberally on the walls and ceilings inside sheds and houses of many communities.

By the seventies, as global concerns for the price the environment and people pay for the benefits of pesticides gained momentum, a young Bouwman was trying to stay as far away from school and homework as possible. He did not like it. He preferred to be in nature, roaming around the veld of the Middelburg region or reading. He did not expect to get past matric, and contemplated a career in the army or maybe as mechanic. Much to his and his family's surprise, however, he not only passed, but he passed with exemption. Suddenly, a whole new world of opportunities opened.

"I can argue a point and I have imagination."

An ecotoxicologist, Dr Bouwman has dedicated his career to the conservation of biodiversity, human health and the supporting natural ecosystem.

Photo credit: Petro Kotzé

Bouwman went to North-West University (NWU) (then the University of Potchefstroom) for a BSc majoring in Chemistry, Zoology and Microbiology. It suited him perfectly. For the first time, he found a space where he could explore his interests, without the expectation to regurgitate information from textbooks. "I can't do that", he explains, "but I can argue a point and I have imagination". He followed with an Honours degree in Zoology with Biochemistry as extra subject, focusing on dioxin, a highly toxic POP linked to reproductive and developmental problems. Dioxin was famously used in Agent Orange, the herbicide widely applied by the US military during the Vietnam War. Bouwman's study on the effects of dioxin was the first of its kind in South Africa and, ever since, he has been working on the interaction between chemistry and biology. For his Master's, he studied ***A new test medium for toxicological studies with Eisenia fetida*** (earthworms).

By the eighties, pressure was mounting to stop the use of DDT in South Africa. It was already banned for general use in the country in 1974, but it continued to be used in malaria prevention programmes in the northeastern parts of the country (this stopped in 1995). People protected from malaria by DDT could be considered the largest community globally exposed deliberately, for non-working purposes but little was known at the time about the human and environmental pollution from POPs, especially in Africa. Just as Bouwman was looking for a topic for his PhD, the Medical Research Council (MRC) was looking for someone to investigate the implication of DDT for malaria control on the environment. By now, Bouwman fit the description of somebody that could do that, perfectly.

He moved to Durban and, while working as bursar for the MRC's Research Institute for Diseases in a Tropical Environment, completed fieldwork for his thesis on the risks and dynamics of DDT in the human population in rural areas of KwaZulu-Natal. Bouwman decided to look everywhere, "basically at anything that I could analyse," he says. He studied water, birds and fish, and took blood samples from community members. It was the first time that he did his research outside his lab and came face to face with the people possibly affected by POPs. He noticed that first-born children had much higher levels of DDT in their blood than subsequent siblings. Bouwman realised the answer lay in the mother's breastmilk. When he tested it, he found levels of DDT to be “sky high” – still some of the highest concentrations ever measured in breast milk, and in the same breast milk. “It was terrifying,” he says. Unbeknown to the mother, the DDT accumulated in her body, and she disposed of a lot of it when she breastfed her first baby. It worried him tremendously. “Because of circumstances outside of their control the mother had no voice, and the baby had no choice.”

It opened up many important questions on how to protect someone against something deadly, by using something that isn’t good for them either. “This is where I started to feel that I had to make a difference, Bouwman says. “I had to, at least, give them a voice.” In 1990, Bouwman published his PhD thesis on ***Malaria vector control and occurrence, levels and dynamics of DDT in breast milk in certain rural areas of KwaZulu-Natal.*** With it, he had started to ring a bell of warning, but he would have to wait for longer before his message had real and global impact.

To the Stockholm Convention

By now, he was a Senior Medical Researcher at the newly formed Research Institute for Environmental Diseases at the MRC in Pretoria, supervising and participating in various research projects. He then spent the early nineties back at the NWU as Senior Lecturer in the Department of Zoology and, after five years, accepted a position as Division Manager with the Agricultural Research Council (ARC) Pesticide Dynamics Division of the Plant Protection Research Institute.

While Bouwman was steadily taking one step after another to advance his career, unbeknown to him, developments were fermenting in the background that would catapult him straight to his Dunkirk.

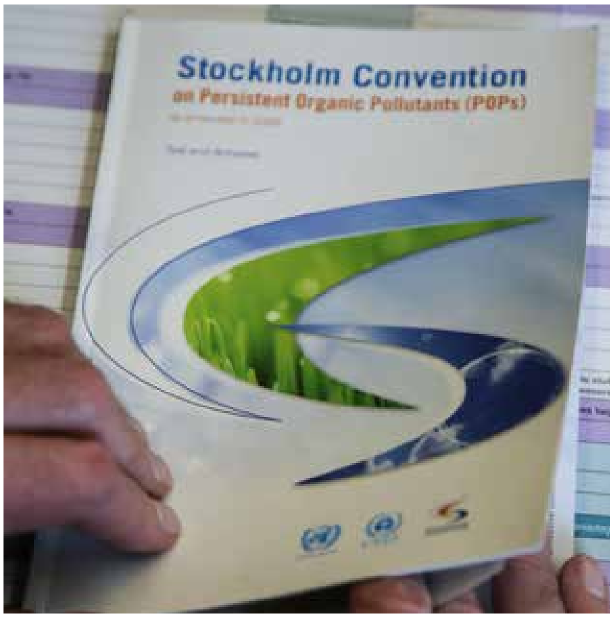
The nineties saw South Africa experience the growing pains of a new democracy. The country underwent many challenges, including being readmitted to the world arena and, in 1994, the country rejoined the United Nations.

At the same time, the United Nations Environment Programme (UNEP) started taking action on the growing awareness that POPs were posing major and increasing threats to human health and the environment. In May 1995 the Governing Council of UNEP requested that an international assessment be undertaken of a list or 12 POPs (the so-called dirty dozen) for the International Forum on Chemical Safety (IFCS) to develop recommendations on international action. The IFCS concluded that available information was enough to prove that international action was necessary to minimise the risks from the dirty dozen. UNEP started preparations to convene an International Negotiating Committee (INC) with a mandate to prepare an internationally legally binding instrument to manage the use of the dirty dozen and identify additional POPs for future international action. The INC met in Montreal in June 1998. Around this time, Bouwman switched his television on, and saw what was going on in the news.

The next day, he phoned a contact at the then-Department of Environmental Affairs, to ask if they knew about the Stockholm Convention developments, and that South Africa’s position would need to be negotiated. In reply, Bouwman was asked to send his CV and, the next day, was called to meet with the newly appointed department Director, who would be representing South Africa. There was a big scientific convention in Bangkok coming – the first of two meetings of the Criteria Expert Group and, would Bouwman represent South Africa?

Dr Bouwman fulfilled various government accredited roles during the negotiations on the Stockholm Convention.

Photo credit: Petro Kotzé



The text of the Stockholm Convention.

"I felt I had to make a difference. I had to give [people and nature] a voice."

Two weeks later, Bouwman was flying to Thailand. "I had no idea what a convention entailed," he says. He didn't even have a tie, never mind a jacket, he remembers. At first, he had no idea what they were talking about. What, for example, was the chapeau that speakers kept on referring too? An animal, perhaps? No delegates sitting close to him knew. It is, Bouwman laughs at the memory, the presentation heading. Only in his mid-thirties, he knew ***boggerol*** and was just unleashed, as was the young democratic South Africa, onto the world stage.

"It was a huge learning curve" but, he quickly found his feet. "My background taught me the confidence to work independently," Bouwman says. He mentions, for one, that he was part of the VIP protection services for ministers during his national service and at age 17, when a number of his seniors abruptly left, he managed from his own office, and his own secretary! Plus, with his work on DDT and other pesticides in human breast milk, adult and baby blood, and links to aquatic biota from remote areas in South Africa he had established a solid scientific basis for the job. He was also familiar with the ethical dilemma of pesticide use.

The following years would be his career highlight. Bouwman participated and negotiated in several South African government accredited roles on the scientific, technical, organisational, effectiveness evaluation, and financial aspects of the negotiations on the Stockholm Convention.

He wrote South Africa's position on the use of DDT, which was accepted by the G77 and China as their positions. "Just like that," he says. At times he represented the whole of the G77 and China in negotiations with the EU and other developed nations, defending their position on behalf of billions of people.

"It was a rollercoaster ride!" The INC's last meeting took place in Johannesburg in 2000, where negotiations had to be completed. "The experience was incredible," he says. It went on into the early hours of the morning with Bouwman there to confirm the final text for approval. With his inputs on the use of DDT, the Stockholm Convention resulted in requirements of utmost care in application, strict reporting, and searching for safer alternatives.

When it was accepted, everybody threw their hands and papers in the air, he remembers. The Convention was adopted the following year in Stockholm, Sweden which means that Bouwman's text is now part of international law. It remains valid and effective today by dramatically reducing the use of DDT for indoor spraying of for malaria control while searching for and implementing safer alternatives.

Post-Stockholm

The initial convention banned or addressed 12 different POPs and entered into force in 2004. From 2005, Bouwman was the South African government nominated member of the POPs Review Committee (POPRC), which consisted of 31 international experts that reviewed applications by countries to add new POPs to the list of those banned of restricted.

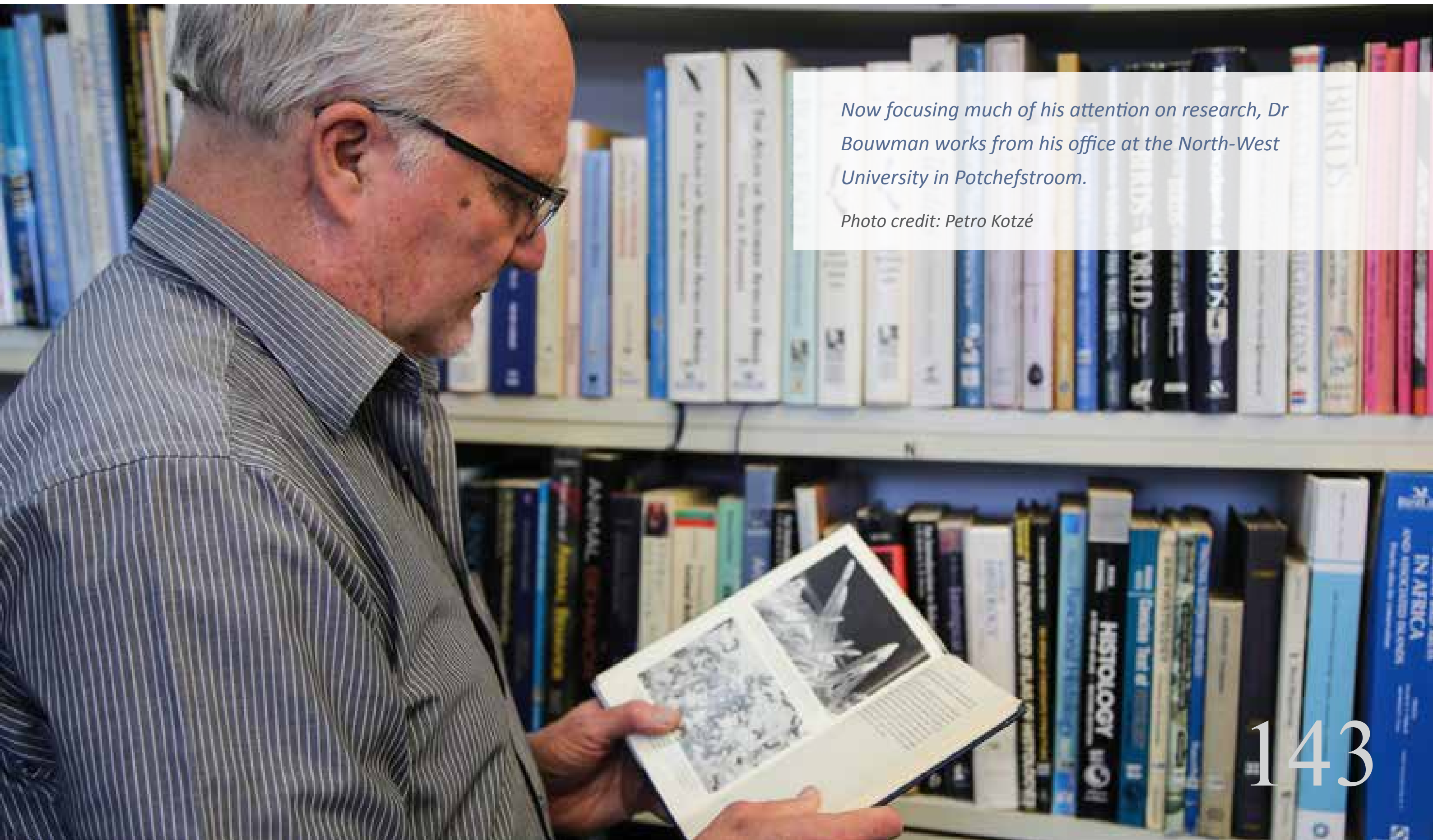
Countries that are party to the Convention can produce and/or use DDT for disease vector control when locally safe, effective and affordable alternatives are not available. Parties are required to notify the Secretariat of such production or use or the intention to use DDT. The Secretariat maintains a DDT Register listing Parties producing and/or using DDT or intending to produce or use of it for the acceptable purposes stipulated under the Convention. Every three years, Parties that produce or use DDT are obliged to report the conditions of such use to the Secretariat using a DDT questionnaire that was adopted by the Conference of the Parties (COP) to the Stockholm Convention. The COP, in consultation with WHO, evaluates the continued need for DDT for disease vector control during its regular meetings. The DDT Expert Group, established by the COP, undertakes an assessment of scientific, technical, environmental and economic information related to DDT and reports its recommendations to the COP for its consideration in the evaluation of continued need for DDT. – DDT overview, Stockholm Convention

He was once again in a position to speak for the voiceless, this time also having to face large industries and sometimes, governments, with vested interests in the POPs that were up for consideration to the banned, NGOs and IGOs on the other side. “There was no model to follow,” he says. “We had to figure it out ourselves, knowing our decisions would impact industries worth billions of dollars.” Fighting for the middle ground was not easy but Bouwman says he is comfortable ruffling feathers. Even when he was a child, he would argument with the church minister on the interpretation the Bible. “I’m not scared to argue in order to understand things,” he explains.

Among others, this is how Perfluorooctane sulfonic acid (PFOS), which was widely used in electronics, firefighting foam, photo imaging, hydraulic fluids and textiles, and the pesticide lindane (once used to treat headlice were banned). Ultimately, he participated in banning and or restricting and additional 11 new compounds over a period of five years.

On conclusion of his years on the POPRC, he was appointed as panel member of the Scientific and Technical Advisory Panel (STAP) of the Global Environment Facility (GEF) responsible for chemicals and ozone depleting substances. Serving as independent expert from 2010 to 2015, he helped decide which proposals from developing countries would receive international funding. During his four-year stint, the Chemicals and Waste component disbursed well over half a billion dollars to developing countries.

During his time, he oversaw and participated in a number of significant STAP reports. For one, he introduced and promoted the issue of marine plastic debris. The influential report that followed led to USD 200 million reserved for marine debris intervention projects in developing countries. Another report on the biodiversity of plastics followed and together, they firmly entrenched plastics pollution on the UN environment agenda. The work was based on his research on the topic on coral reef islands in the Indian Ocean and he remains in the centre of this



Now focusing much of his attention on research, Dr Bouwman works from his office at the North-West University in Potchefstroom.

Photo credit: Petro Kotzé

research in South Africa. A newly designed and dedicated microplastics lab is being constructed, probably the first in Africa.

The period in his life was both good and bad, Bouwman says. On top of a brutal travelling schedule, he still had to maintain his responsibilities as full-time Professor too (he returned to the NWU in 2000). Once, he travelled right across the globe in one stint, leaving South Africa for meetings in Vienna to travel to Hawaii via Calgary. Still, he kept on doing it because the work made a difference. “I had a responsibility towards people and the environment.”

Unfortunately, that type of work did not necessarily translate into success in academic terms. He does not, for example, have the necessary peer-reviewed publications in high impact journals for a high National Research Foundation (NRF) rating. How can a university measure my achievements based on this, he asks, pointing at the deceivingly small booklet that contains the text of the Stockholm Convention. Nevertheless, he is content with what he has achieved. “I have a different ruler that I measure myself against.”

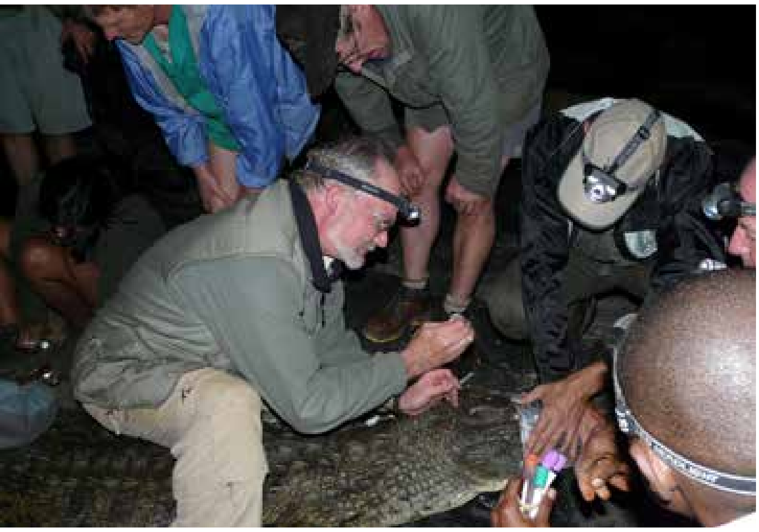
Back to his love of research

“I’m an academic at heart,” Bouwman says, and the recent years of his career has brought him back to his first love of research, though much if it is done with an eye on influencing policy and interventions. Together with Prof Rialet Pieters, he also co-manages the POPT (Persistent Organic Pollutants and Toxicants) research group at the NWU.

Among others, he has led three projects for the Orange-Senqu River Commission (ORASECOM) which involved basin-wide ecotoxicological assessments for South Africa, Botswana, Namibia and Lesotho. The first report, published in 2013, was a catchment wide and complete scoping of pollutant distribution patterns, including metals, POPs and polycyclic aromatic hydrocarbon in sediments, fish and bird eggs. It was the first of its kind in Africa. As part of this study, they also discovered a wild bird egg with the highest concentration in the world of the POP, PFOS.

With funding from the WRC, the group has investigated antiretrovirals in water, including research into the environmental concentrations, effects, and social conditions that influence how these medicines reaches water. Bouwman is also involved with researchers in Uganda on pharmaceuticals and other chemicals of emerging concern in Lake Victoria.

More recent work includes an assessment of impacts of DDT on human health, birds, frogs and snails in Limpopo, passive sampling of airborne organic POPs, POPs and heavy metal pollution in penguin eggs, levels of POPs in terns from the Indian Ocean, interactions of birds and bats with cyanide-containing slurry, child environmental health, effects of pollutants on female reproductive organs of marine snails, effects of pollutants on male freshwater snails, causes and effects of pollutants on crocodiles and fish, and various bird biology and ecology investigations. Projects on microplastics, POPs and metals in bird eggs, corals and plankton, the effects of pharmaceuticals on a variety of animals and bird feather structure, have all come across his desk. Another first, he established adult dragonflies and wasps as indicators of environmental POPs and metal pollution.



Dr Bouwman is grateful for the many adventures that his profession has given him access to, from researching crocodiles in the Kruger National Park to various projects on the impact of POPs on birds and penguin eggs.

Photos supplied

> "We have to give the youth the background to how we got here. We need to give them the tools to fix it, and the confidence to try new things."

Transforming desperation to inspiration

"All of these adventures are such a privilege to be able to do," he says but one must hand the baton to the next generation of researchers. Our generation and the ones before us have messed up many things in the world, but the next generation must remember there is also good news, like how DDT in the environment has decreased, he says. The problem is that bad news is much easier to spread, because it sells better. However, Bouwman says desperation needs to be transformed into inspiration. "We have to give the youth the background to how we got here. We need to give them the tools to fix it, and the confidence to try new things."

Prof Bouwman's lessons for young researchers

- Inspire other people: walk in the front when you have to, push from the back when necessary, walk next to them when they need to shine.
- When you are done, move on to the next thing.
- Don't say you don't know, or you can't. Ask for help only once you have tried everything, and have learned from that first.
- Talk to other people, get other opinions, differ from your professor.

Prof Namrita Lall

Photo supplied

NAMRITA LALL

Unlocking the medicinal power of plants

Current position:
Professor of Medicinal Plant Sciences at the University of Pretoria

Research interests:
Antituberculosis and anticancer natural product leads from medicinal plants, susceptibility studies of other bacteria to medicinal plants, cytotoxicity of plant extracts/compounds, antiacne, antityrosinase (skin pigmentation), antiaging, antiwrinkle, hepatoprotective and immunomodulatory, anticoagulant activity of medicinal plants.

Awards

AWARDS

2021: WRC Legend Award

2020: The Vice Chancellor's Exceptional supervisor award

2019: Top Intellectual Property Creator, by NRF-DST/National Intellectual Property Management Office (NIPMO)

2017: Biotech Fundi Lifetime Contribution Award, by Gauteng Department of Agriculture and Rural Development (GDARD) and the Gauteng Province Innovation Hub

2016: Winner of the Gauteng Accelerator Programme (GAP) innovation competition, (second prize nationally) which identifies emerging technology entrepreneurs for incubation and start-up (Nov 2016).

2014: National Order Presidential Award (Order of Mapungubwe, Bronze)

2011: Distinguished Young Women in Science Award, Department of Science and Technology

2003: University of Pretoria Exceptional Young Researcher Achievement Award

2002: The Outstanding performance certificate for being awarded an UNESCO-L'Oreal Award for her research on tuberculosis (one of the 10 selected candidates internationally in March 2002)

1997: S2A3-Gencor bronze medal by South African Association for the Advancement of Science for the best MSc dissertation at the University and a council award of a gold medal for MSc

1994: Council award of a gold medal for BSc Honours

The phytochemicals produced by aquatic and terrestrial plants for protection against environmental stresses have for centuries been used to treat diseases in people. Until leading academic in the field of phytomedicine, Prof Namrita Lall, turned her attention to the topic, little research had been done to explore this potential of South Africa's indigenous aquatic plants. Thanks to Lall, a leading expert in the extraction and identification of compounds from medicinal plants, we now know that selected local aquatic plants can be used to treat various skin disorders, gum disease and tuberculosis.

Before the India-born researcher turned her attention to aquatic plants, she had already unlocked the potential in numerous other species to treat skin disorders, periodontal diseases, tuberculosis, diabetes and cancer and, in the process, scientifically validated the use of South African plants for medicinal and cosmetic purposes.

An expert in chemical sciences, Lall's work is a nod to both cutting edge research and indigenous knowledge. She works with both industry partners and traditional health practitioners to evaluate the potential of medicinal plants and, once their efficacy is proven, develops it into valuable pharmaceutical and cosmetic products for introduction to the commercial market, to make scientifically validated, indigenous, plant-based cures available to the general public.

In a career spanning over two decades, she has excelled. She has been placed in the Essential Science Indicators list of the top 1% of publication outputs (citations) in the discipline pharmacology and toxicology. Among the plethora of local and international awards bestowed on her is South Africa's highest, the Presidential Order of Mapungubwe, for her outstanding contribution to the field of medical sciences and for "giving hope to many who are plagued with the scourge of tuberculosis." She is also the South African Research Chairs Initiative (SARChI) Research Chair for plant health products from indigenous knowledge systems.

"I was always interested in plant-based medicines as I grew up using Ayurveda products," she explains. Ayurvedic medicine is a holistic approach to healing from India, in which plants are an important form or treatment. Following this interest, she completed her degree in Biology and Physical Sciences in India, before pursuing post-grad degrees in South Africa – a bold decision that would lead to another decade of studies.

The start of an illustrious academic career

She admits that the adjustment to a new country and culture was difficult. However, she says, on consideration of how challenging it is in the world out there, she still decided to continue. The road to success did not become any easier. As her family grew, she had to juggle the increasing responsibilities of being a wife, daughter-in-law, student, a full-time job as lecturer at the Umtata Technical College and mother of one, and later two, children.

In what she described as a "very difficult decision" to the audience at the recent Third Annual Women in Science symposium, she chose to continue her work instead of taking a long break after the birth of her first child. She realised that the longer she was away, the more difficult the transition back into the academic world would be.

In general, Lall says, in her career in Science Technology Engineering and Maths (or, STEM) research, she faced the challenges

Growing up with a passion for the healing power of plants, Prof Namrita Lall has become an expert in the use of indigenous medicinal plants for the benefit of people in South Africa and beyond.

Photo supplied

"I was always interested in plant-based medicines as I grew up using Ayurveda products."

many women traditionally do. It's described as the 'leaking pipeline' – a metaphorical depiction of women dropping off promising career paths in academia due to finding the environment unwelcoming and unsupportive for academic mothers. Research has found that many women tend to choose to leave academia due to parenting and mobility, while men tend to have no such concerns.

Determined, Lall completed her Master's, Cum Laude (gold medal) in 1996, writing her thesis on ***Biotechnology, enzymatic studies in plants in response to stress,*** which won her the S2A3-GENCORE bronze medal for best Master's thesis at the Walter Sisulu University (then the University of Transkei).

She enrolled at the University of Pretoria (UP) for her PhD and landed a position as Senior Research Assistant. The hard work and perseverance through these years would become a milestone in her career. Lall's topic was Medicinal Plant Science ***(Isolation and purification of natural products, susceptibility studies of Mycobacterium tuberculosis, and other bacteria to medicinal plants)*** which, after all these years, brought her in line with her original interest in the healing power of plants. Her PhD, she says, is where she really discovered her research passion. She would continue work on medicinal plants with students and team members for the rest of her career, doing breakthrough work in the process.

> “Take pleasure in new relationships. New relationships that blossom from opportunities such as international travel reignite one’s passion for work and motivates one to continue. Balance is key. Try not to lose the opportunity of sightseeing when attending conferences. Enjoying the places we visit is equally important.”
> – *Prof Namrita Lall*

She completed her PhD in 2001, the same year she was appointed in a permanent position as lecturer in the UP’s Department of Plant and Soil Sciences, and launched her own research group. Almost immediately, her work started attracting attention and funding locally and abroad. Among the many achievements and awards to her name, she was one of ten young women scientists internationally to receive the coveted L’OREAL-UNESCO fellowship for Women in Science in 2002 (in 2009 she would be selected as one of only 10 candidates profiled to showcase a decade of progress in this area).

The year 2007 would be another landmark one. UP launched the Medicinal Plant Sciences programme, a unique study programme offered as a specialised field on a postgraduate level and co-founded by Lall. The main vision of the degree is to study and use indigenous medicinal plants of South Africa for the benefit of its people. The programme investigates diseases in the area of microbial and parasitic infections as well as cancer. Antibacterial, antifungal, antiviral, antiparasitic and antioxidant activities of plant extracts and isolated plant compounds are investigated. However, the aim is not primarily to isolate compounds that will enter the pharmaceutical industry as new lead compounds but, rather to use semi pure fractions or extracts in the medicinal plant industry in its widest sense related to the primary healthcare of people and animals in rural communities.

The same year, Lall was also promoted to Associate Professor. “That’s when I saw that my career goals were coming to light after years of dedication,” she says. She was promoted to Full Professor in 2016 and launched an online course on Phytomedicine and Natural Products in 2019, to provide practical and theoretical skills to South African scientists and researchers already working in the industry.

Exceptional research work

Lall has made a significant contribution to the field of medicinal plant science through the activities of her research group, and several medicinal plants with valuable biological activities have been discovered. Three patents have been granted in the USA, four in the European Union, another three in the African Regional Intellectual Property Organization (ARIPO) states, and two in China, one in South Korea, two in Australia, one in India, one in Malaysia, and one each in Chile and Japan.

Lall says her intention is not just to educate students but to take medicinal plants from the lab all the way to product level. In that process they managed to get quite a few prototypes, and highlights have been those developed for cancer, tuberculosis and for various skin-disorders.

Their first pharmaceutical product, for the treatment of skin-hyperpigmentation, has been commercialised by companies in Europe and South Africa. Lall says it's moments like those that keep her going. "Being able to celebrate the commercialisation of my first prototype was specially motivating and rewarding," she says of being able to sell the fruits of their labour after years of research and trying to bridge the gap between academia and industry. At the time of writing, about 15 or 16 more products were in the pipeline and nine South African bioprospecting permits have been granted by the Department of Environmental Affairs, Forestry and Fisheries for the commercialisation of researched medicinal plant leads. Together with bioprospecting, ethics, intellectual property rights and benefit-sharing are tasks on their list of high priorities.

"Being able to celebrate the commercialisation of my first prototype was specially motivating and rewarding."

Prof Lall has made a significant contribution to the field of medicinal plant science through the activities of her research group.

Photo supplied

However, over and above scientific innovation and commercialisation, Lall says the idea is to generate jobs which can help with the economy of the country as well. "We say academia should produce job creators and not job seekers." Her students have taken this credo and run with it. Five start-up companies, including a Mamelodi community-based company in Pretoria have resulted from the Medical Plant Sciences programme. These students, Lall says, are looking forward to commercialising their own technologies for skin disorder prototypes that their team has developed from medicinal plants for problems like acne, wrinkles and periodontal diseases.

The book, *Aquatic Plants: Pharmaceutical and Cosmetic Applications,* edited by Prof Namrita Lall and published in 2020, provides a concise description of popular aquatic plants found across the globe. Chapters focus on the aquatic species native to specific continents. Written by a global team of experts the publication explains the distribution, ethnobotanical uses, genome sequencing, chemical compounds, and biological activity of these plants and addresses the cultivation and sustainable production of aquatic and wetland plants. The publication is a valuable resource for academics conducting research on aquatic plants and for professionals in the pharmaceutical and cosmetic industries who are involved with the therapeutic applications of these plants and their sustainable usage.

But the beneficiaries of her work are also found outside the university and industry. She has been working on development projects in Pretoria, the Eastern Cape and KwaZulu-Natal to bridge the gap between the scientific community and communities that harbour indigenous knowledge.
Lall is collaborating with traditional health practitioners to develop cosmeceutical and medicinal products. Community members are being trained for cultivating selected plants, with postgraduate students visiting the traditional healers, who then join students in the university laboratories to observe findings.

Finding a second family in academia

"Anything in life is the fruit of persistence, determination and hard work," Lall says of a career trajectory that took commitment and determination to see through. A consistent challenge for her has been the struggle to balance work and family responsibilities, and to maintain a career while also spending enough time with her children.

Nevertheless, Lall says the payback has been ample. Though her family remains close to her heart, her real rewards are when her students thank her for the difference she has made in their lives through years of dedication. Yet, the legacy of her work has rippled across professional and personal boundaries. Her own daughter decided to follow a career in STEM research.
The celebrated professor recounts a very memorable moment for her, when both her daughter and one of her students received South African Women in Science Awards at the same ceremony in 2015. It's thus perhaps of little surprise that Lall's legacy, beyond being a leader in her field, is that she helps remove the barriers for more women's participation in academic and economic life, to also follow in her wake.

WATER USE AND WASTE MANAGEMENT

Prof Thokozani Majozi

Photo credit: Petro Kotzé

THOKOZANI MAJOZI

The ultimate problem solver

Current position:
Dean, Faculty of Engineering and the Built Environment, University of the Witwatersrand

Research interests:
Batch chemical process integration, water optimisation, energy optimisation

Awards

AWARDS

2021: WRC Legend Award

2019: Order of Mapungubwe (Bronze)

2016: NSTF Award for Engineering Capacity Development

2011: NSTF Category B Award for Individual contribution to research over the last 5 to 10 years

2010: Bill Neal-May Gold Medal Award for Outstanding Achievement and International Recognition – South African Institution of Chemical Engineers (SAIChE)

2009: NRF President's Award (Transformation of the Scientific Cohort)

2008: S2A3 British Association Medal

2008: Leading Minds (1908 – 2008) Centenary Award, University of Pretoria

2007: NRF President's Award

Problems make him tick. “A problem that I haven’t solved,” says Prof Thokozani Majozi, “makes me feel alive.” He has dedicated his career to the problem of wastewater in batch chemical processing plants, squeezing every drop of usable water out of the most common method of production globally with mathematical precision.

He is the global expert on the topic. Among the myriad local and international credits and awards that have trailed his career is the coveted Order of Mapungubwe, South Africa’s highest honour. But recognition, Majozi says, is only the condiment. Like Albert Einstein and his other idols, his purpose has always been the pursuit of knowledge. Along the way, this chemical engineer says he was shepherded by serendipity but, each time it struck, the opportunity found fertile ground in a mind of astounding academic prowess, vision, and zeal to move forward.

The story has no specific beginning, he says, but the roots go back to KwaMashu in Kwazulu-Natal, where he was born in 1972.

The early years

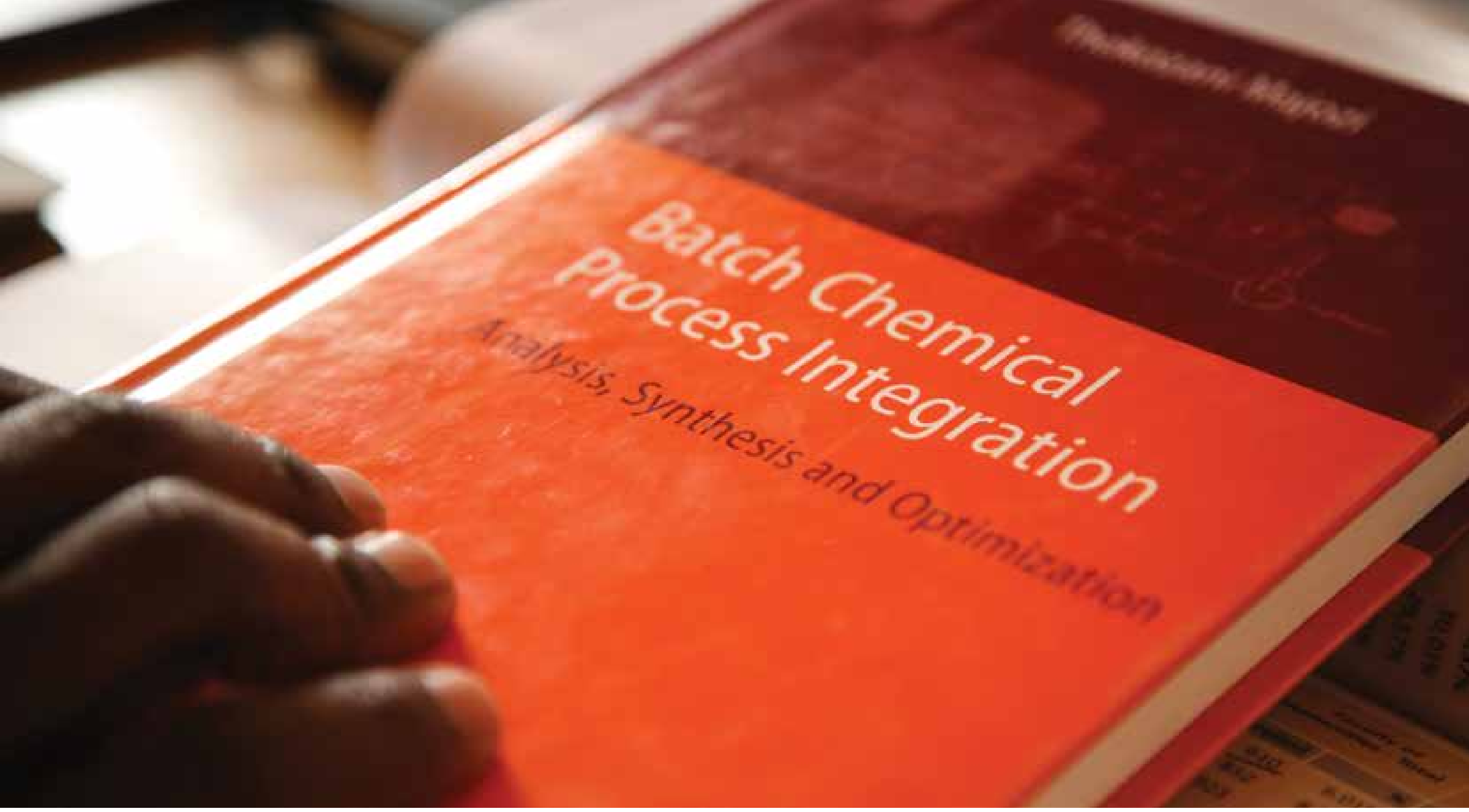
According to Majozi, now the Dean of the Faculty of Engineering and the Built Environment at the University of the Witwatersrand (Wits), he comes from humble beginnings. “My mom was a teacher and my dad a clerk at the post office.” His parents instilled a culture of education and knowledge in both Majozi and his brother, awakening an early love of the academic in him.

The young Majozi wanted to be a doctor, and he certainly had the potential to be one. He was a top achiever at Mqhawe High School and the KwaZulu-Natal province, with a particular affinity for maths and science. In fact, the curriculum couldn’t keep up. Cognisant of his talent, his teachers started supplying the eager student with problems to solve beyond the syllabus to keep him busy. It was a valuable lesson, he says. “The ceiling of the teacher tends to be the ceiling of the student. I was lucky that my teachers had very high ceilings.”

Soon, it was time to think of his career beyond school but his blossoming love of mathematics cast a shadow over his then lifelong desire to wear a white coat and stethoscope. To be a doctor, he didn’t need maths much beyond first-year degree level. Just as he was contemplating his future job, Anglo American visited his school on a recruitment drive, resulting in Majozi’s surprise announcement to his parents that he would become an engineer, a qualification he’d never heard of before until then.

With a bursary from Anglo, he started his journey at the University of KwaZulu-Natal (UKZN, then the University of Natal). He didn’t know what awaited, but like every other black engineering student with his educational background in the then South Africa, he would first have to complete a bridging year to familiarise himself with the nine disciplines on offer. Ultimately, it was a blessing that he now bestows on his own students. I spend months with them to define a clear vision of where they will go, he says. “I tell them not to rush.” Only once they have a clear vision of the destination, Majozi says, they can commit their undivided attention to getting there.

Majozi committed to chemical engineering, becoming the first African student to receive the Dean’s Commendation in his first semester in 1991, awarded to students who achieve outstanding academic results. He appeared on the Dean’s list four consecutive times, finishing his degree in a near-unheard of four years. At 22, he started his working career.



Prof Majozi's main research interest is batch chemical process integration, a field that he's worked in since he started his professional career as a junior process engineer at Unilever in 1994.

Photo credit: Petro Kotzé

"You don't know how many times I would go to the store to check competitor margarine labels to see if they got it."

The problem of margarine

As part of his bursary obligation, Majozi joined Unilever as a junior process engineer in 1994. He owed them at least two years, but Unilever would benefit from the exchange for many years to come. The Dutch owned company had been producing Flora Margarine since 1871 but, just as Majozi stepped in the plant door, the health risk of margarine's high levels of trans fatty acids was coming to light. It was a clear business risk for the company, launching a drive to develop zero-trans fatty acids margarine.

The new recruit was thrown in the deep end. Like pharmaceuticals, agrochemicals and most food products, margarine is manufactured in a batch chemical processing plant. He became intimately involved with trials to adapt the plant to produce margarine with a process of hydrogenation to produce a virtually trans-free product. It had never been done anywhere in the world and, over and above, his university curriculum was lean on batch processes, leaving him feeling inadequately trained to design or synthesise such operations.

> “If you work hard and have a good attitude, doors will open for you.”
> *- Thokozani Majozi*

“You don’t know how many times I would go to the store to check competitor margarine labels to see if they got it,” he says. The soft margarines from Unilever became the global first to attain virtually trans-free label and when this specification sealed the commercial brands, he felt proud. “It was a huge contribution for me,” he says. It was also one that signaled the end of his road with margarines.

Once I’ve solved a problem, Majozi says, it feels like I’ve lost a friend. Since the trans-fatty acid problem was solved, the young engineer felt the excitement of the job wane. In 1996 he accepted a position as senior process engineer: competency improvement specialist at Dow AgroSciences.

Solving problems to saving lives

The product doesn’t matter, Majozi says, it’s about the process. Instead of margarine, his next plant produced pesticides. The product ingredients included arsenic and the plant included buffer tanks that had to be cleaned once too much of it had settled, exposing employees to the Group 1 carcinogen (it causes cancer).

Young and “still full of fire” the new employee decided to change that.
An unsolved problem is something that keeps me alive, Majozi says, but it’s good when that coincides with saving someone’s life. He figured out how to adjust operations to bypass the buffer tanks without losing production output. His suggestion was met with reservation, but a two-month trial run proved him right. Nobody would have to endanger their lives like that in order to work, again. Majozi says it remains a point of celebration for him. “I’m sure that that engineering saved lives.”

His dedication and imagination caught the attention of management, who offered him a bursary to continue his studies. After the brutal paces he were set through for his undergrad, he never thought he would, but found himself going back to the UKZN on the lookout for a research topic. This time, serendipity would catapult him forward towards the destination he would ultimately find acclaim for.

Serendipity in a corridor

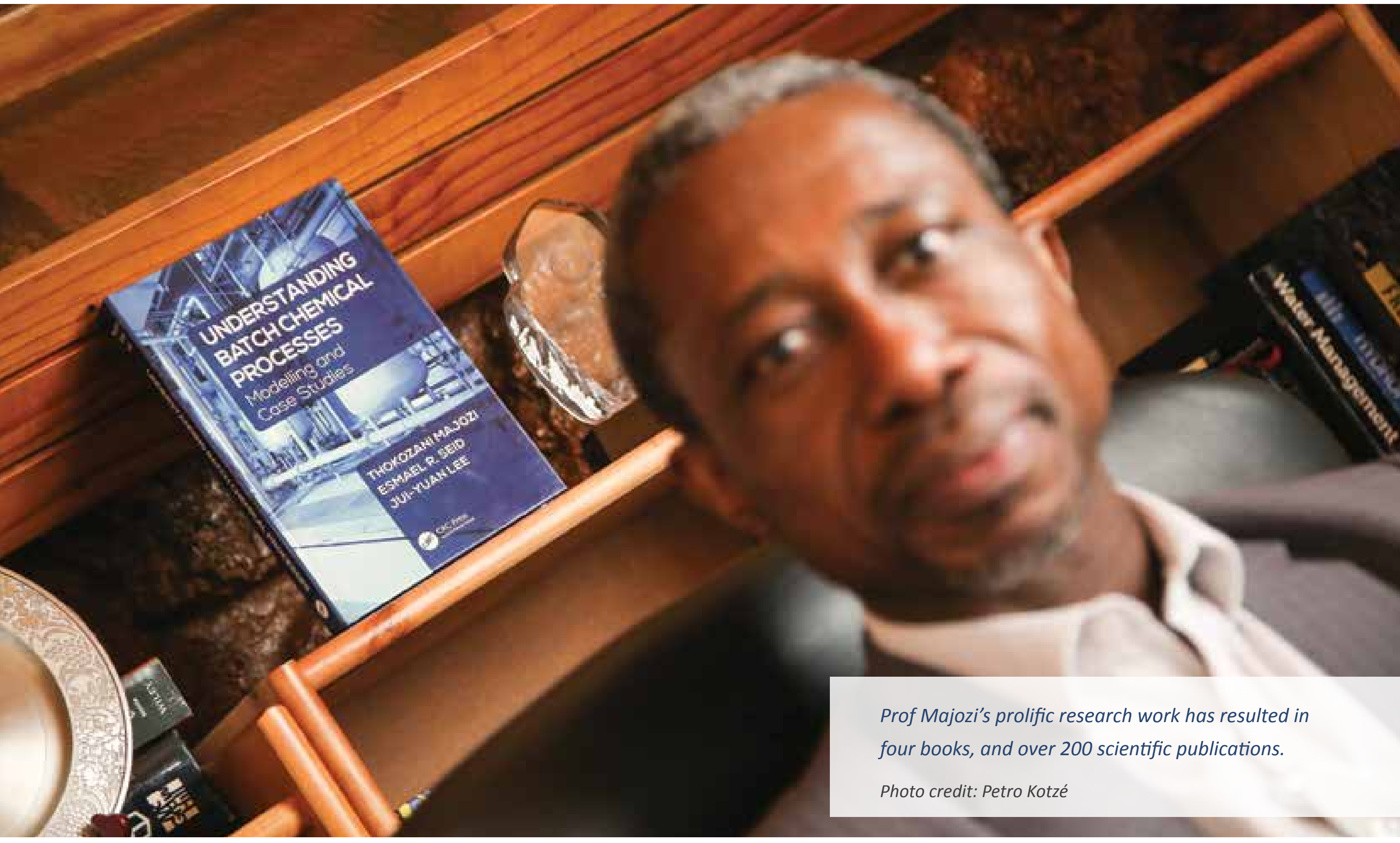
On his way out of the university, Majozi bumped into Prof Chris Buckley, the late head of the university’s WASH R&D Centre (featured elsewhere in this publication). They had never met, but found much in common. The renowned professor was just back from Denmark, where a colleague of Majozi’s mentioned Dow’s serious problems with water, at which point Buckley suggested, “wouldn’t that be a great topic for the future Master’s student?”

If I had left my previous meeting 10 seconds later, we wouldn't have met, Majozi says.

Ultimately, the two formulated the project together, with Buckley acting as Majozi's supervisor. Their initial collaboration led to a graphical technique for near-zero-effluent batch chemical facilities, enabling the reuse of wastewater and the improvement of batch processing globally. "He opened many doors for me," Majozi says in reference to his Master's supervisor. "I've come to realise that if you work very hard and have a good attitude, there is hardly a place on earth where people will not welcome and support you." Buckley would also convince his Master's student to apply for a coveted Commonwealth Scholarship, securing him a spot at the University of Manchester Institute of Science and Technology for his PhD. This time, Majozi was clear on what his research topic was going to be.

How to be remembered in this world

Once, on a freezing morning in England, next to a bus stop, a friend asked him what exactly they were doing there. Majozi answered that, for one, he wanted to be the best at what he did. His friend then asked him how he will know when he's the best, a question nobody had asked him before. After consideration he answered, if literally, there is no conversation that starts and ends on his topic without the mention of his name. The words were prophetic. Majozi would indeed become the recognised expert internationally in water minimisation in batch processing plants.



Prof Majozi's prolific research work has resulted in four books, and over 200 scientific publications.

Photo credit: Petro Kotzé

There are two things to not being forgotten on this planet as a research scientist, Majozi says. First, you have to be the first person either to ask a good question, or to find the right answer. Second, if you can't be the first, be the best. If you can do both, he exclaims, that's even better! He modestly refers to himself as "very good" at mathematical modelling, but he was the first person to apply water minimisation techniques in batch plants. Unsurprisingly, the achievement remains a highlight of his career.

On his return to South Africa from the UK, Majozi joined Sasol Technology as a technology leader for optimisation and integration, eventually turning to academia in 2004. The change-over would be an eye-opener. As an engineer for Sasol, the sky was the limit, especially for your salary, he says. When he left Sasol to join the University of Pretoria (UP) as an Associate Professor, it came with a 40% pay cut. "I underestimated that," he says with a resigned chuckle.

Starting from the bottom, and up again

"I had to establish myself from literally nothing, in a very harsh environment," Majozi remembers of his early days at UP. As part of his strategy for survival, he contacted his old professors. Buckley was overjoyed to hear that Majozi made the move and, in a move unheard of in academia (but perhaps not so much for Buckley himself), he offered to transfer money he had from the WRC to the UP, to help Majozi start his research career.

"If not for that, I don't know how long I would have stayed in academia," Majozi says. "When Chris transferred the money, my life changed immediately." He took his cues from his idols. I learned from Buckley to collaborate with people from all over the world to build a strong research profile. Majozi hit the airspace, establishing his first collaboration of many with colleagues in Hungary, which led to his later appointment as Associate Professor at the University of Pannonia from 2005 and 2009. He tied up with the WRC too, soon raising his own funds. It grew from there, he says, and really never stopped.

"There are two things to not being forgotten on this planet as a research scientist.
First, you have to be the first person either to ask a good question, or to find the right answer.
Second, if you can't be the first, be the best.
If you can do both, he exclaims, that's even better!"

With his students, Prof Majozi helps industry use their available capital optimally to meet their production targets for a range of products.

Photo credit: Petro Kotzé

He was appointed as Full Professor in 2008, and after almost ten years at UP, in 2013 moved to Wits to take up the position of the NRF/DST Chair for Sustainable Process Engineering, becoming Dean in 2021. He also had a stint as an Acting Head of School in the first six months of 2014.

Over time, his research interests have also expanded beyond his initial focus area.

Expanding research focus

Initially, Majozi focused on those areas that he felt were unavoidable to a South African researcher. They were energy, water optimisation and specific to him, batch processing technology. Fifteen years ago, there was no technology for the latter, but the field has since matured, he says, with solutions within easy reach. Majozi has, of course, contributed to that. He has written four books on process integration, on top of more than 200 scientific publications that sprung from his prolific research work. His research has since rippled beyond batch chemical processes to sustainable process engineering that also includes continuous processes, the second type of material processing plants.

In general, his main goal is to help industries use their available capital optimally to meet their production targets for a range of products with different equipment requirements, within prescribed time horizons, he says. His first collaboration with a power producer stands out as a highlight. Initially, he did not think he would be able to apply the technologies he was familiar with in traditional chemical facilities to electricity generation. "My gut feeling was that it was not going to work because it's not my space."

However, it turned into a perfect example of the beauty of mathematical models. "They will seldom give you intuitive solutions. They won't go to where you expect them to go. For a while you doubt your results because they do not dovetail with your thinking, but under scrutiny, they offer a better solution than what you could think of."

Research highlights

Using his novel continuous-time framework as the basis, Majozi developed a novel technique for wastewater minimisation in discrete chemical operations. The technology was used by Johnson & Johnson to reduce their effluent by 20%. He has also successfully demonstrated how this model can be applied to minimise energy use in plants.
He was the first researcher to highlight and model the impact of human intervention in batch chemical processes. In 2005, he developed a continuous process integration technique for systems that involve both heat and mass transfer with the objective of minimising or eliminating effluent (liquid waste) in chemical industries. His contributions in this area involve a graphical targeting and design technique for systems that can be captured in two dimensions and a mathematical technique for simultaneous targeting and design of cooling water systems with more complicated constraints as usually encountered in practice. The results of this work were implemented by African Explosives Limited in Modderfontein, resulting in a 49% reduction in effluent generation and savings of almost R1 million per year. With his students, he is collaborating with Sasol Technology on an Optimal Steam System Design Project aimed at debottlenecking the steam boilers at their facilities.
(Source: The African Academy of Sciences)

The initial solution Majozi proposed to optimise the large power plant was, he felt, out of this world but, the engineers confirmed that it could be done. The facility was big – a 3.6 gigabyte power plant (one gigawatt is enough power for more than 100 000 houses in a big suburb). After implementation of the technology, the plant shaved 20% off their water use, recovering about R5 million within three months of implementation.

> "Of the many highlights of his career, the first and foremost is producing students that have impact in our society at all levels. "This enrichment of lives is what has kept me in academia."

Career highlights

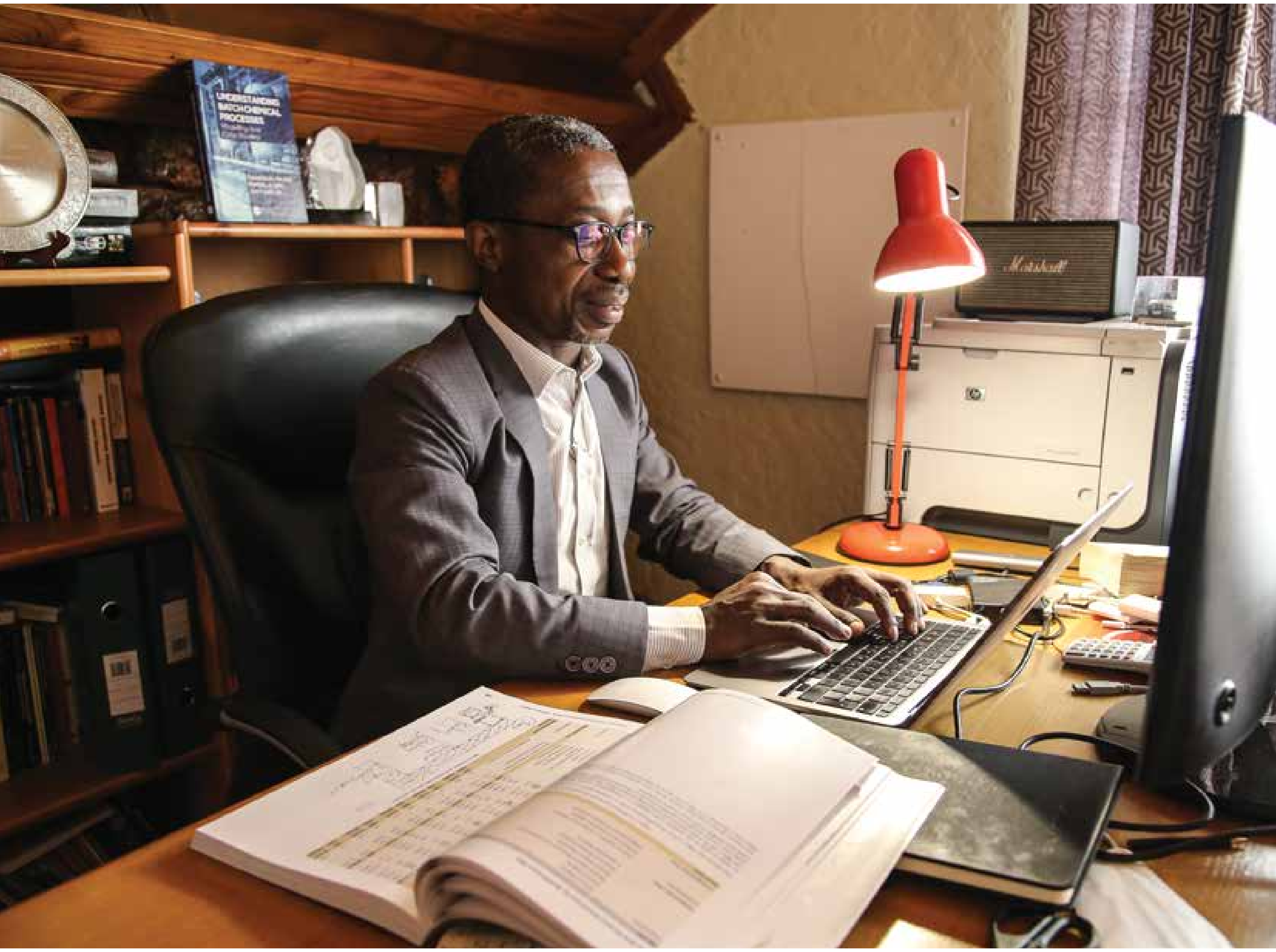
Lecturing is how a student can experience my excitement about research, Majozi explains. "A student either likes you or they don't – it only takes one lecture for them to decide. When they see the energy in you, and you challenge them, the good students will fall in love with you."

That is a characteristic of all good professors in the world, he says. "Good professors will work with very good students, because good students can see a good professor and, a good professor can see a very good student."

The good students are the ones that challenge you in class, he says. You know them by the type of questions they ask, not the answers they give. A good student knows where to probe. The best have asked me questions no-one else had, and I went with them, he says. "That's how I grew my research group."

The second highlight of his career is expanding the frontiers of knowledge in the batch processing space. "I know I've done this, and I'm very happy with it." The third highlight is the introduction of systematic ways to save water and energy in batch plants.

Still, for Majozi, his inspiration has come from the "explosion" of the problem. "Whenever you sink to the depth of any problem, you discover more all the time. It's seldom that things fall into place all of a sudden but as you probe deeper a new place, and a new way, emerges."



"Good students can see a good professor and, a good professor can see a very good student."

Photo credit: Petro Kotzé

Prof Chris Buckley

Photo credit: Tony Carnie

CHRIS BUCKLEY

A pioneer that endeavoured for dignity through sanitation

Position at time of passing:
Co-Director of the WASH R&D Centre (formerly the PRG), University of KwaZulu-Natal

Research interests:
Urban and industrial water and effluent management; sanitation and faecal sludge management

Awards

AWARDS

2021: WISA Honorary Membership Award

2021: WRC Legend Award

2017: UKZN Highest grant holder

2015: WRC Knowledge Tree Awards: Human Capital Development in the Water and Science Sector

“You can’t build a career around someone else’s passion – you have to have a passion for the subject yourself.”

A change maker, a trailblazer, and a legend in his own lifetime – this is how Prof Chris Buckley, co-Director of the Water, Sanitation & Hygiene Research & Development (WASH R&D) Centre was described in 2021 on receipt of the WRC’s first ever Legend Award.

The honour came on the back of a lifetime’s dedication to water conservation, wastewater treatment and promoting the potential value of unwanted human ‘waste’. A chemical engineer by training, the University of KwaZulu-Natal’s celebrated maverick professor won international acclaim for his work, in particular, in the sanitation field, and helped propel the unappealing topic of faeces management onto global platforms.

Buckley was renowned for his sharp mind, vision, unabating work ethic and passion, but his mission was greatly aided by the sheer force of his personality. “I couldn’t separate what is the professional career, and the rest – it’s all entangled,” says Deputy Director, Water, Sanitation and Hygiene for the Bill & Melinda Gates Foundation, Doulaye Kone. Few colleagues can share a story about Buckley without mention of a beer, bunny-chow, a visit to his home or to the Amsterdam pub in Durban; a conviviality topped with a dash of non-conformity.
For years, his business card carried the official title of “shit manager”. Yet, this joviality and good nature was underpinned by a fierce passion and love for his work. “You can’t build a career around someone else’s passion – you have to have a passion for the subject yourself,” Buckley said in the interview for this book.

By his own admission, his profession was chosen by a series of small decisions rather than passion. “I had as much passion for being an auditor (his alternative choice of career) as I did for being a chemical engineer”, he explained. “The opportunity to be a chemical engineer wasn’t a planned career, but a choice made when presented to me.”

Prof Chris Buckley’s advice for young researchers on building a career in their desired profession:

- You can’t build a career around someone else’s passion – you have to have a passion for the subject yourself
- Your career is chosen by a series of small decisions
- Just keep going without chopping and changing too much – there are always lessons to be learned from any situation, good or bad
- Surround yourself with positive, passionate and proactive people. Negative thinking people will bring you down

As it was, opportunities initially came Buckley’s way in the mid-sixties, when the spotlight in South Africa was just starting to shine on the critical importance of water for development, and the detrimental effects of industrial effluents and waste on the environment. Right on par, Buckley was about to complete his Master’s degree

A young Chris Buckley sampling treated water from a textile plant in 1983.

Photo credit: WRC archives

Prof Buckley and other members of the PRG discussing their work with Bill Gates on his visit to Durban in 2009.

Photo credit: UKZN

in Engineering on the filtration of sewage sludge, to be followed by a PhD thesis on the filtration of compressible sludges. The latter was never completed. "There were just so many other far more interesting things to do," he said.

A nascent Pollution Research Group sees the light

As Buckley was taking the first steps of his illustrious career, the foundation for wastewater research in South Africa was being laid. Dr Gerrie Stander had just established the Water Research Commission (WRC) in 1971 with the intention of funding research on water resources in South Africa.

At the same time, the Pollution Research Group (PRG) was born from the merger of two research groups at the University of Natal (now the University of KwaZulu-Natal). While the one group focused on chemical engineering principles for tackling environmental problems associated with the chemical industry, the other focused on closed loop recycling of water, chemicals and energy in the textile industry. Shortly after its establishment the PRG received its first funding for research from the WRC, a relationship that has been maintained throughout the group's existence.

First attached to a similar research group established by the African Explosives and Chemical Industries, Buckley joined the PRG in 1972, then a tiny group of just three or four people. He took over the leadership reigns in 1985 and was appointed as the full-time head in 1987. The group has delivered groundbreaking work, and under Buckley's leadership, expanded its research scope beyond chemical engineering to become a transdisciplinary hub for research, including agricultural economics, crop and soil sciences, microbiology, chemistry, mechanical and civil engineering and development studies. At the base of many new 'movements' in the water and sanitation sector, you will find traces of the PRG.

The research group was among the first in South Africa to research membranes for industrial applications at a time when this technology was not considered viable outside the lab. Their work with textile industries in KwaZulu-Natal led to considerable reduction in water use and pollution output, with huge financial benefits to the industry. Guides which have emerged from their research include closed-loop treatment or recycle systems for textiles; and, planning, design and implementation of wastewater plants in the industry making use of membrane technologies.

Waste minimisation and cleaner production

Other early highlights include the establishment of Waste Minimisation (WasteMin) clubs in the 1990s to improve local industries' environmental performance by promoting cleaner production. The clubs allowed for open sharing of information and ideas among club members, financial benefits to the companies through improved water, energy, chemical and effluent management, and a reduction in their environmental impact. This work built on an earlier research project which resulted in the publication of a two-part guide promoting cleaner production in the textile sector.

Initially, two pilot clubs were established in KwaZulu-Natal, one in the metal finishing sector and a second, a cross-sectoral club in the Hammarsdale region. The success of the first two clubs spawned more than 30 other WasteMin clubs nationally. The approach was also adopted in the Department of Water Affairs/Department of Environmental Affairs National Water Management Strategy. Guides on how to establish and manage Waste Minimisation Clubs, as well as training material, were developed. The initiative led to more, and bigger projects in cleaner production, a general term that describes a preventative approach to industrial activity.

WASH R&D Centre standout project:

In 2021, the WASH R&D Centre, in collaboration with other internationally recognised partners in the faecal sludge management field (IHE Delft, EAWAG, AIT), published a book on *Methods for Faecal Sludge Analysis.* The book was published through the International Water Association and the project was funded by the Bill & Melinda Gates Foundation. Because there are currently no standard methods for the analysis of faecal sludge, standard methods from other fields are being modified for the analysis, sampling and data interpretation for faecal sludge. This resulted in large discrepancies between the different methods used, and the data generated in different regions and organisations. Faecal sludge is a very heterogeneous material and requires standards and methods specifically tailored to address variations depending on the local context and geographic location. The book is the first attempt to address these inconsistencies. It is the first step towards standardisation of methods for faecal sludge analysis. The published methods include different steps in the characterisation and quantification of faecal sludge from onsite sanitation technologies, including analytical measurements, sampling techniques and health and safety procedures.

The PRG later participated in the Danish International Development Agency (Danida) Cleaner Production project, which included 350 small-scale and 50 commercial farmers in the cotton growing sector, multiple manufacturers and related organisations and later expanded further to include downstream operators such as designers and retailers. It led to the establishment of the National Cleaner Production Centre (based at the CSIR) and a Cleaner Production Guide for Regulators.

"Metal finishing and textile companies made significant savings from participating in this project," Buckley explained, "and it resulted in the formation of the Metal Finishing Association." Today, the association represents a significant proportion of the metal finishing industry in the country. Membership includes electroplaters, powder coaters, anodisers and suppliers to the trade.

The PRG has also promoted the establishment of waste minimisation and cleaner production in other industries, such as metal processing, mining, petrochemicals, sugar, beverages and power plants. Clients have included Eskom, Sasol, Tongaat Hulett and Iscor.

Sanitation-related research

Two decades ago, the collection and management of human urine and faeces was not an issue that many academics really wanted to get involved in – but that was not the PRG's approach. "I guess our work takes a special sort of enthusiasm and quite a bit of cajoling, but now we are the go-to people for data in this area, along with testing and development of new sanitation solutions," Buckley noted.

The PRG's focus on sanitation and toilet design dates back to the mid-nineties, when Buckley's group and the eThekwini Municipality began to work together with funding from the WRC on an anaerobic baffle reactor to digest human waste at the Umbilo Wastewater Treatment Works. Later, the PRG and eThekwini also collaborated on the design, maintenance and understanding of the processes taking place in ventilated pit latrines (VIPs) and urine diversion toilets.

Over the past decade, the PRG has increasingly focused on addressing sanitation service delivery challenges, particularly through supporting testing of innovative sanitation technologies and the development of techniques for the characterisation of various excreta streams. The range of sanitation-related research now ranges from biotransformation mechanisms in VIPs and urine diversion toilets, community ablution blocks, anaerobic baffled reactors, to modelling conventional wastewater treatment works processes.

The highlights are many. In the mid-nineties, Buckley and a student travelled through Africa for the INTERWATER project, which aimed to promote the Internet as source of information on water and sanitation. This involved the installation of Internet and dial-up modems in each of the organisations visited, and many adventures in the PRG Land Rover – a vehicle that took a lot of skill and courage to drive.

In 2007, The PRG was tasked by the Bremen Overseas Research & Development Association (BORDA), a German non-profit organisation, to direct its scientific activities on decentralised sanitation systems worldwide. This approach to sanitation offers an affordable solution without the need for electrical or chemical inputs, minimising the capital and operation costs associated with high-tech conventional wastewater treatment plants. Furthermore, it is located near the community, eliminating the need for extended sewer lines and pump stations.

WASH R&D Centre standout project: In the past five years, the WASH R&D Centre has been actively involved in the development of ISO standards for non-sewered sanitation technologies (ISO30500:2018) and large facilities for treatment of faecal sludge (ISO31800:2020). Upon their publication, the WASH R&D Centre was tasked by the WRC with the developing of policy awareness and technical training materials which were tailor-made for specific stakeholder groups within South Africa – policy- and decision-makers, water utilities, and the private sector. This training has been carried out in partnership with the South African Bureau of Standards and the training materials have been translated in a number of languages for use in other African countries.

The partnership, together with eThekwini Water and Sanitation, lead to the construction of a modularised decentralised wastewater treatment system (DEWATS) in Newlands-Mashu, Durban, to evaluate the viability of the plant for on-site waterborne sanitation and the usefulness of the treated water for agriculture. "Seeing our work being implemented, applied and taken up, is tremendously inspirational", Buckley said. The vision for the Newlands-Mashu DEWATS plant is to provide wastewater treatment to areas with relatively high population density, located beyond the sewer network of the city, such as informal settlements, development and transport nodes, and schools and clinics and producing nutrient-rich greywater for agriculture in the process. At the time of writing, plans were in place to install the system in a housing development in Durban, linked to low-flush urine diversion pedestals.

Reinventing the toilet

In 2011, the group's work was propelled onto an international stage, when they landed a US$400 000 grant through the Bill & Melinda Gates Foundation global "Re-Invent the Toilet Challenge". The aim of this challenge was to explore the design and implementation of an innovative toilet system that would significantly reduce water use and lead to the safe disposal and recovery of valuable material from excreta. The collaboration with the foundation has been ongoing, with further grants awarded to provide support to other sanitation technology developers through laboratory analysis of waste streams, and the testing of innovative sanitation systems in the field. From 2017, nearly 20 prototype toilet systems, or components of systems, have been tested on this platform in Durban.

Apart from the impact of the project on the PRG, the group itself has made an overwhelming impact on the project. "The PRG has been the Re-Invent the Toilet Challenge lab, and their impact and contribution can't be counted," says Kone. "It's gone way beyond our initial expectations." Kone adds that there's not one participant in the project doing any significant work, that has not travelled to the PRG in Durban at least once.

"For us", Kone explains, "it's been one of the best partnerships in the world, guiding us through the journey of sanitation. Thanks to the fundamental science, the capability of the human interaction, and the high emotional IQ that Chris brought to this job, we have a very different, fundamental understanding of what needs to be done,

Prof Buckley with a framed photo of the 1970 crop of final-year chemical engineering students. He had been based in the same building until the time of his passing.

Photo credit: Tony Carnie

much better than we knew before. Because of that we can now really think of what the future solution can look like and for us, this lab, with Chris's contribution is a great gift."

Still finding inspiring solutions

In Buckley's own words, his research involved meeting "realistic bite-size targets" – this kept knowledge rolling forward and served as constant inspiration to continue achieving in his field. He was also inspired by multiple successes of the PRG.

Under his leadership, the PRG has grown from strength to strength. They gradually expanded to almost 35 salaried staff, with Susan Mercer appointed as the co-head in 2019. Mercer has been part of the PRG, either on a full- or part-time basis, since 1993, when she joined the group as project leader. The group supports an increasing number of postgraduate students, with many of its members, researchers and alumni now sought-after experts on waste, testing and innovative sanitation solutions. "The fact that past PRG members have moved on to achieve amazing success in academia, research management, consulting, manufacturing and government," was one of his greatest achievements, Buckley noted.

After nearly 50 years in this research space, the PRG transitioned to the Water, Sanitation & Hygiene Research & Development Centre (WASH R&D Centre) in 2020, in order to become a more formalised entity within UKZN, and for the name to reflect the range of research areas and transdisciplinary nature of the Centre.

Buckley was proud of the fact that the PRG has operated on a contract research basis since its inception, and that this means there

“It is important to scan the horizon and strategically place yourself.”

continues to be space for contract research in the country, as long as you keep looking ahead for needs that need to be addressed. This is very different to academic research where you are a specialist in a particular field. “It is important to scan the horizon and strategically place yourself,” he noted. He counted loyalty – both being loyal to funders and collaborators and to have people who are loyal to you – as one of his personal highlights. His near-50-year involvement with the eThekwini Municipality was proof in point. “I was funded by the Durban Municipality for my undergrad and postgrad studies – without their faith in me, I would not be where I am today, giving back to the municipality through research support.” Another is the continued funding from the WRC and the contracts won by the group through competitive bidding. “It shows that we continue to have a space in the field,” Buckley added.

However, for those who have worked with him, Buckley personified exactly that which he revered. “We will look back at this space and know where it all started,” says (now former) WRC CEO, Dhesigen Naidoo. “In a global community of practice that epitomises universal access to services, expanding the frontiers of dignity, business development and technological change to

Preparing faecal samples for freeze-drying in the PRG laboratory.

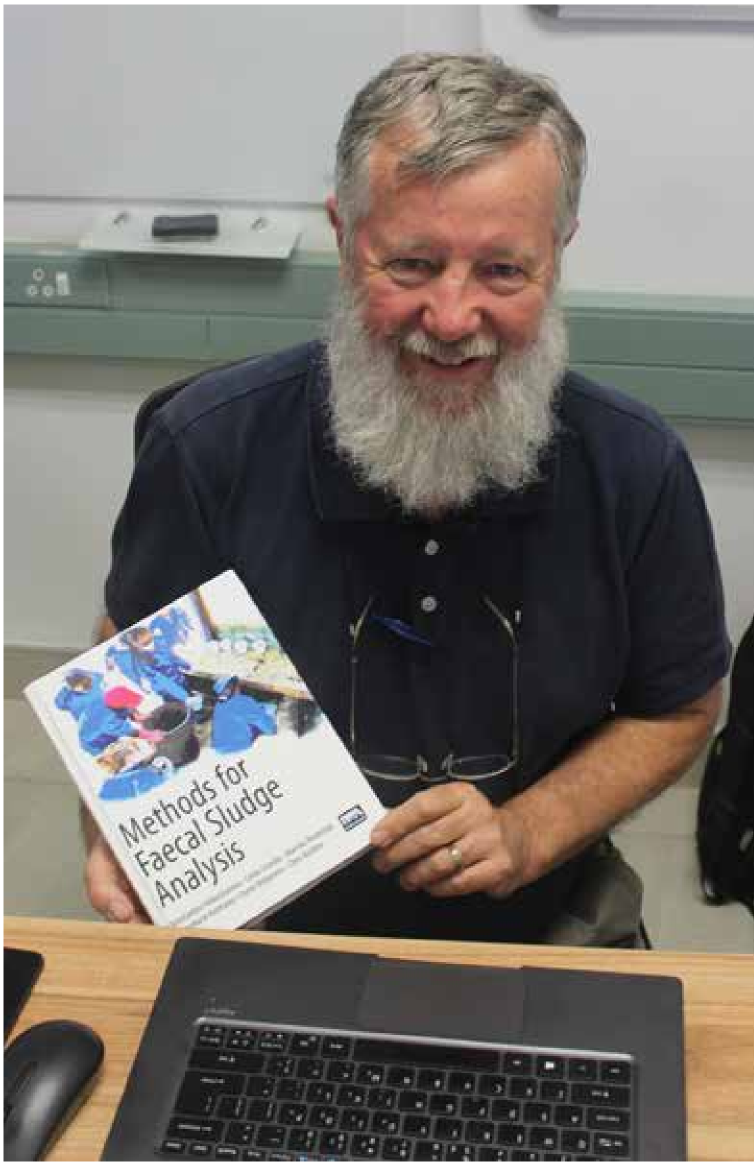
Photo credit: Tony Carnie

revolutionise the society we live in, build the higher quality of life, meet the sustainable development goals and move towards a low carbon economy, we get to meet great people. Now we realise the extended potential that they themselves have. It will come back to the heroes that started it all when no-one else could put it together. In this field Buckley is the epitome of that."

Prof Chris Buckley passed away in 2021.

Prof Buckley on what is necessary for success in a chosen career path

- A very strong technical grounding in your chosen discipline such that the fundamentals can be applied. If you grasp the fundamentals, you can find the strategic thinking in other things. My academic career started prior to the computer era, so understanding the fundamentals was emphasised when undertaking detailed calculations of project implementation as it gave a wider view of the problem rather than getting bogged down in detailed computer coding
- Partnerships and collaborations
- A passion for your subject and a thirst for knowledge (a wide reading interest)



Prof Buckley posing with one of the centre's many achievements, the internationally acclaimed publication, Methods for Faecal Sludge Analysis.

Photo credit: Tony Carnie

Prof Ndeke Musee

Photo credit: Petro Kotzé

NDEKE MUSEE

For solutions to new problems,
we need new viewpoints

Current position:
Professor, Department of Chemical Engineering, University of Pretoria, Lead for the Emerging Contaminants Ecological Risk Assessment (ECERA) Research Group at the University of Pretoria

Research interests:
Interactions of chemical contaminants and the environment including nano-scale pollutants

Award

AWARDS

2021: WRC Legend Award

Many people have no qualms with talking about their achievements. Prof Ndeke Musee is not one of them. Rather he lets his work talk for itself. An environmental scientist specialising in risk assessment of historical and emerging contaminants in the ecosystem Musee has gone from humble beginnings in Kenya to become one of the most respected scientists in his field.

He is among the leaders of nanotechnology environmental risk assessment nationally and internationally, and his work has influenced various international policies at institutions such as the Organisation for Economic Co-operation and Development, and the Basel Convention. Despite these achievements, Musee is the first to admit that the initial steps in his science career were not necessarily taken for the love of the subject, but rather in pursuit of a hot meal and a way to support himself and his family.

"To contribute to society includes being able to sustain yourself first. Before I became a scientist, or an academic, I was and still remain a human being. You cannot therefore develop anybody else before you have not developed yourself," he maintains.

It was a long and winding road that led him to the University of Pretoria (UP) where he leads the Emerging Contaminants Ecological and Risk Assessment Research Group (ECERA). Initially, Musee wanted to become and electrical engineer or a pilot, but did not have the necessary funds to do so. "I ended up becoming a teacher, earning a Bachelor of Education Degree specialising in mathematics and physics from the Egerton University, in Kenya."

Musee saw this as simply the launchpad to develop himself further, regardless of any challenges that stood in his way. At the time, working from "out in the bundus" he sent over 100 hand-written applications to institutions around the world to obtain the necessary funding for a Master's Degree. "It took me four-and-a-half years to get the funding," he says, but he persevered.

His determination was rewarded with a bursary from the German Academic Exchange Service (DAAD), and he went on to complete his Master's in Physics at the University of Botswana in 2000. He subsequently accepted an admission for a PhD at the University of Stellenbosch's Department of Process Engineering with research focus on waste minimisation in the wine industry. After completing his PhD in 2004, Musee took up a position as Postdoctoral Research Fellow at the same university. In 2007, he was appointed as

According to Prof Musee, a scientist cannot be considered successful unless his scientific output leads to better societal outcomes.
Photo credit: Petro Kotzé

“When you are developing your career, don’t look at it as your personal journey to glorification. The best glory is to create a legacy that is not about you as a person, but about a society that is able to achieve its optimal performance and live together in harmony.”

Senior Scientist at the CSIR, and in 2012 as Principal Scientist and Research Group leader. Three years later, he accepted an Associate Professor position at UP followed by an appointment as full Professor in 2021. Musee says he enjoys the practical nature of his work. “Environmental science is the shortest route to take science to practice, either through policy, or by triggering a need for change of technologies or practices.” As an example, he mentions his work on triclosan and triclocarban, two chemicals commonly used in home and beauty, and personal care products.

He published an article on the environmental risk assessment of triclosan and triclocarban in 2018, in which he wrote that trends in the widespread use of personal care products containing the chemicals have led to their presence in high concentrations and elevated risks in freshwater systems. The lack of data on their presence in developing countries was identified as a major issue, and the paper quantified the predicted environmental concentrations in wastewater, freshwater, and soils, estimating likely risks.

On publication of his paper on triclosan and triclocarban, Musee was contacted by Risk Sciences International (RSI), Ottawa, on behalf of Health Canada and Environment and Climate Change Canada to serve as an external peer reviewer of the Draft Screening Assessment Document for Urea (triclocarban).

A belief in quality, over quantity, research

Known for his uncompromising approach to high-quality research outputs, Musee strives for research that seeks to advance the state of information in his field of specialisation. His approach is like a hyena’s jaw, he says, once he latches on, he will not let go until a solution is found. The results show in the impact of the work he produces, though he says, in the current measure of publication metrics for academics in his field, there is only a handful.

For Musee, work that has an impact exemplifies the role of the scientist in society. “It is to be able to use systematic, verifiable, auditable methods to come

> “We know that chemicals improve the quality of life, but also, we need to know what chemicals out of the vast options available we should use to ensure we live in harmony with the ecosystem as we improve the lives of people.”

up with solutions that can either inform technology, policy or changes in practice.”

Another example is ECERA’s work on the impact of the use of hand-sanitisers, which has skyrocketed during the ongoing COVID-19 pandemic. The research group is working on two projects. First, a WRC-funded project entails investigating ecosystem responses to the large-scale use of SARS-CoV-2 disinfectants. A second, co-funded by Umgeni Water, entails modelling the environmental burden of chemicals from disinfectants and sanitizers during COVID-19 into ecological systems.

It’s an example of how science becomes part of society’s toolbox of solutions, Musee says. He designs his projects to produce information to help shape policies. “We know that chemicals improve the quality of life, but also, we need to know what chemicals out of the vast options available we should use to ensure we live in harmony with the ecosystem as we improve the lives of people.”

Another example is the group’s work on the fate and transformation of antiretrovirals (ARVs) and their risks in the environment. “We have more than 52 moieties – active pharmaceutical ingredients for treating ARVs, but until now we’ve had less than 15 studies looking at their toxic effects on aquatic organisms.” The matter is currently a topic of research at ECERA, with the aim of informing best practice at wastewater treatment plants in order to protect environmental health.

Science and success

Musee prefers not to talk about his achievements. For him the scientist does not achieve much on his own. Rather he is dependent on the support of his colleagues, from co-scientists to administrators, and students. His success also depends on opportunities granted to him at various times of his career, he believes.

“When you are developing your career, don’t look at it as your personal journey to glorification. The best glory is to create a legacy that is not about you as a person, but about a society that is able to achieve its optimal performance and live together in harmony.”

The success of a scientist includes the acceptance and uptake of one’s scientific output for better societal outcomes, maintains Musee. “That’s why the partnership between industry, government, civil society and academics is indispensable and immutable. "How much can I do alone? If I produce good science, and the government is not taking it up, how will I enforce it? Similarly, if industry is not an active participant, the ideas cannot find wide incorporation in products and services to society."

Musee works to instill this philosophy in his students. "I attempt to shape the way they look at issues of water, the environment and their future professional careers in a broader context of the society where they're going to work, whether it's industry, government, civil society, e.g., as scientist or engineer."

In this new future during- and post-COVID-19, everybody should be a leader in their domain of life station as we seek to establish a new, alternative paradigm of sustainable development in which we live in harmony with the ecosystem, he maintains. "As leaders, we should have a clear vision of what it will take to make a better future for society, beyond our own wants backed by demonstrable positive outcome(s)."

It's not about us, maintains Musee. The pathway we choose will either be to the benefit or detriment of our children. Thus, it's up to each and every one of us to ask which direction hereon given the current challenges at national, regional or globally that beckons our collective action(s).

Dr Melusi Thwala, Environmental Water Quality Senior Scientist at the CSIR, has experienced this first-hand as one of Musee's PhD students. Musee seeks to mentor, and not just supervise his students, and is a strong believer in herd growth and development, he says. "He always expects the best from his team and pushes each member to their optimum performance for a task." According to Thwala, after

Prof Ndeke Musee is among the leaders of nanotechnology environmental risk assessment nationally and internationally.

Photo credit: Petro Kotzé

working with Musee for over a decade he can say without a doubt that an ethical and transparent approach are amongst his strongest characteristics – that can be outdone only by his sense of humour.

He will leave it up to the people that he has interacted with to decide what they want to remember him for, or not, Musee says, lest he runs the danger of enforcing one-dimensional legacy. "I therefore leave it as an open cheque..."

Prof Maggie Momba

Photo supplied

MAGGIE MOMBA

A trailblazer in water quality and wastewater management

Current position:
Professor at the Department of Environmental, Water and Earth Sciences, Tshwane University of Technology and the South African Research Chairs Initiative (SARChI) Chair in Water Quality and Wastewater Management

Research interests:
Water microbiology, water and wastewater treatment (using nanotechnology), bioremediation and biotechnology

Awards

AWARDS

2021: WRC Legend Award

2019: Leadership excellence award by the Global Water Pathogen Project during the 20th symposium on HRWM, Vienna/Austria

2012, 2016 & 2017: TUT Vice-Chancellor's Female Researcher of the Year

2012: TUT Innovator of the Year

2008, 2009, 2010: TUT Niche Area of the Year

2008: TUT Woman of the Year (research category)

2005: Vice Chancellor's Senior Researcher Medal, University of Fort Hare

2005: Woman in Water Award, Department of Water Affairs and Forestry

2004: Outstanding Community Supporter Awards organised by the 2nd International Conference on Safe Water

From the moment Prof Maggie Momba decided she wanted to become an expert in water and wastewater management, nothing could stop her. "From my birth in the Democratic Republic of Congo (DRC) to my current position as SARChI Research Chair in Water Quality and Wastewater Management, I have defied all the adversities that have come my way as a woman in an academic world," she says. Over and above establishing herself as an internationally recognised researcher, she has dedicated her career to help others to follow on the road she has built.

"Being a researcher is much more than what you see on paper or a business card," Momba maintains. "Beyond the qualification, it's your contribution to the community and country that matters. Your life is not eternal. You are also here to help other people to move forward and contribute with you to the betterment of the country." In this way others can continue your work long after you are gone.

The work that she is referring to is the integral task of improving drinking water quality and wastewater management, specifically in South Africa's rural communities. Among others, she has undertaken groundbreaking work in the field of biofilms – the medium that grows inside water storage cannisters and cultivates disease-causing microorganisms. Her expertise also includes research on antibiotic resistant bacteria and genes in water, nanotechnology and bioremediation.

Her legacy lies not only in the groundbreaking contributions she has made to South African water science, but also in the many students she has taught and uplifted. Throughout her career, she has developed postgraduate programmes and specialist laboratories that take in large amounts of particularly black students and women for training in specialist focus areas, such as waterborne pathogens. Many of her former students have gone on to have successful careers. Importantly, Momba points out that their successes extend to the families and communities that they come from and support.

This aspect of her career has been encapsulated in her appointment as the South African Research Chairs Initiative (SARChI) Chair for Water Quality and Wastewater Management in 2013. The main goal of the initiative is to strengthen and improve research and innovation capacity of public universities for producing high-quality postgraduate students and research and innovation outputs. Her impressive track record has come on the back of hard work, determination and a conviction that she was destined to be someone that will make a difference.

A young scientist determined to be someone

Following a degree in education from the Pedagogic Institute of Gombe in the DRC, Momba obtained her BSc degree in Biology from the University of Kisangani, winning scholarships from both institutions. She completed her Master's degree in Biology in 1985 on the microbial ecology of fishes and its impact on the environment, thereafter landing a researcher post at the Zairian Institute for Conservation of Nature (now the Congolese Institute for Conservation of Nature). Momba was doing well. Her career was on track and she had started a family. However, a USAID-funded scholarship to participate in a four-month training programme at Clark Atlanta University in the United States in 1991, would change everything.

The programme was on the Management of Natural Resources and Protection of the Environment, and focused on drinking water and wastewater treatment. The students visited drinking water and wastewater

"You have to attend conferences. You have to read. You have to see the problems in your country and environment. Once you have the problems, you must find solutions but, it's not only a matter of publishing a paper. The aim is to improve the lives of the people. To find the right solutions to problems, scientists must work hand-in-hand with communities."

Prof Momba's advice to young researchers on finding success in your research career

treatment plants across Georgia, Alabama, Florida and Tennessee.

"This is where I developed an interest in water quality and wastewater management," she says. Yet, developing her expertise in this field meant she had to further her education up to a doctorate level, in an area of specialty not on offer in the DRC. Instead, she would have to go to the politically tumultuous South Africa. "My family didn't like it," she says but, she wanted to "be someone." She left home for South Africa to accomplish her dream of becoming an expert in water quality and wastewater management.

In 1993, then 35-year-old Momba enrolled at the University of Pretoria's Department of Microbiology and Plant Pathology. She arrived on campus knowing little of what lay ahead and, in her strongly accentuated English, explained to her future supervisor that she wanted to do her Master's degree. Without any money, she stood strong on the belief that God would provide.

Something about the determined visitor resonated with Prof Eugene Cloete (now Vice Rector: Research, Innovation and Postgraduate studies at Stellenbosch University). After seeing her academic report, he filled in her forms for her and took it to the Dean himself. On his return, he paid for her registration, a nudge that sent her on her way. Despite the promising start her road to success was not without its challenges. Where Momba stayed close to campus at the time, black South Africans were not allowed past curfew, but the police grew accustomed to the visitor from the DRC. She was scared, she says, and over and above that, she spoke little English. She studied the language with the help of her primary school son, and her Bible.

Still, Momba says she never considered giving up. “I left my family. I left everything I had. So, I had to achieve my purpose.” Her Master’s focused on wastewater management with an emphasis on phosphate removal in activated sludge and its relationship to biomass. “This work taught me how microorganisms are used to control the phenomenon of eutrophication and protect the aquatic environment from pollution”, she explains. She continued with her PhD, conducting research on the impact of disinfection processes on biofilm formation in potable water distribution systems. The topic would come to define much of her career and find application worldwide. Her work in this field remains one of her biggest achievements, according to Momba.

Despite her academic achievements, “quarrels, hatred and jealousy” trailed Momba throughout her early career. Regardless, she completed both her MSc and PhD in five years to become, in 1998, the first black woman in South Africa to hold a PhD in Microbiology specialising in Wastewater Management and Potable Water Management. “I was so excited,” she says.

Today, she looks back on a career that has taken her across all the continents of the world on the strength of her expertise. “There can be no happiness without pain, she believes. “Opposition always takes place wherever success prevails.”

Building her first research group and laboratory

In 1997, the microbiologist accepted a lecturer position at the University of Fort Hare’s Faculty of Science. Momba says that part of her motivation to move to the male-dominated department was to prove to other women that they can also make it to the highest level of formal education.

From the start, she had her sights set on her own research group, an aim for which she was allocated R6 000 in 1998. The budget was small, and the laboratory equipment lacking, but Momba could enroll her first three BSc students to conduct their research, continuing work on water quality in rural areas, specifically on how to prevent infection and diseases from water kept in containers. Early research topics included the evaluation of a combined chlorine-monochloramine disinfection process to inhibit bacterial and biofilm regrowth, and the effects of various different pipe materials.

Stand-out technology: The biosand zeolite silver-impregnated clay granular (BSZ-SICG) filter

Biofilms that develop on the surface inside water containers are rife breeding ground for microorganisms that deteriorate drinking water quality. The BSZ-SICG filter inhibits the formation of biofilm. The technology is made from cheap, local materials, including gravel, sand and clay and 25-litre buckets. It’s easy to make, little technical expertise is necessary for its operation and maintenance. Prototypes tested in households in the Makwane village were found to reduce the incidence of diarrhoea by 96%. The technology has since been filed under Provisional Patent Specification: 2016/02883.

Momba kept at it, continuously writing wining research proposals to attract more local and international funding for her Fort Hare Water Research Group and, to build the university’s first molecular diagnostic laboratory.

Product highlight: GenoTrack – a computer implemented genome tracking method and system

GenoTrack is a web-mapping tool that geospatially links bacterial genomes from water and food to medical facilities like clinics. The technology was developed in response to the lack of strategies currently available to contain and track antibiotic-resistant bacteria (ARB) and antibiotic-resistant genes that emanate from healthcare settings, and enter the environment. This motivated Momba to design a project that focused on a multidimensional approach to characterise and track ARBs in South Africa's terrestrial and aquatic environments.

GenoTrack integrates three main computational analysis pipelines for geospatial mapping of genomes, phylogenomic analysis, and genome alignment. The tool will help scientists and policymakers formulate appropriate strategies to combat transmission of pathogenic ARBs, Momba says. Additionally, geospatial mapping of ARB genomes will permit the identification of national and international hotspots of antibiotic resistance and actions for epidemiological containment. The GenoTrack webtool may also provide baseline information necessary to link the environmental spread of anti-microbial resistance to routes of transmission across different environments. The technology is filed under Provisional Patent Specification: 2020/04797

The group looked at the efficiency of polydex as an alternative disinfectant for the treatment of drinking water in rural communities, and investigated how protozoa can remove faecal indicator and pathogenic microorganisms in the activated sludge system. Their work looked beyond the laboratory results. To ensure that rural small water treatment plants are operated correctly, the group produced guidelines to ensure sustainable disinfection from the point of consumption. Then, they offered on-site mobile training of operators.

Throughout this time, Momba ascended up the ranks, appointed first as Associate Professor in 2003 and then as Professor in 2006. As she progressed, she took others up with her. By the time she left to take up a position at the Tshwane University of Technology (TUT), she had established one of the largest black postgraduate programmes at Fort Hare.

Moving onwards, and upwards

In March 2006, Momba became TUT's first woman research professor. Though she had to, again, build her own specialist laboratory, she was now an expert, with over a decade of experience under her belt. She built her lab with specialty equipment for molecular diagnostics and microbiology, and focused her team's research on the niche of water and wastewater management for the sustainability of water resources in South African under-developed areas.

More specifically, Momba's research unit focuses on novel agricultural uses of wastewater; the effect of land use practices on water resources and ways of predicting and mitigating them; the impact of water resources on the health of the rural communities and strategies to protect the resources and human health; understanding the origin, survival and effect

of microorganisms associated with drinking water; and, strategies to rapidly diagnose and control waterborne infections.

There has been numerous stand-out projects and results in the group's ongoing drive to solve problems, develop products and simulate entrepreneurship with the ultimate goal of improving water quality and wastewater management.

Highlights include illustrating the impact of increased flow and human activities on pathogenic microorganisms loads in riverbed sediment. The research team's findings indicated the need to include routine microbial sediment quality monitoring, Momba says, in order to accurately determine the potential health risk to the human population posed by water resources. She also developed a prototype-based solar radiation-ozonation coupled system to treat wastewater using metal doped titanium dioxide, and discovered a mine water microbiome with the potential to remediate the polluted water.

Project highlight: Integrated Water and Sanitation Safety Tool for the Management of Water Resource and Protection of Public Health

The project purpose is to help rural communities overcome the challenges they face to implement safe water and sanitation plans. The aim is to develop, implement and evaluate a single, integrated risk assessment and management framework to link global scientific innovations with local knowledge in order to identify and overcome barriers that have prevented communities to achieve safe and sustainable water and sanitation management. The six Master's students (including one from the University of Venda) and one PhD student involved in the project are all from disadvantaged rural communities in South Africa.

“You have to be motivated, you have to have a strong personality and you have to be committed. No one can stop you to achieve your destiny if you have courage, determination and God on your side.”

My vision before my retirement is to see my research unit continue being recognised as one of the top research groups locally and internationally in terms of water quality and wastewater management, notes Momba. “I’m not doing it for myself, I’m doing it for the health of the people, and to change the situation in the world.”

“Water is life,” Momba adds. There is a crucial need for scientifically sound answers to the problems of water resources pollution, which can have a negative impact on the economic growth of the country and public health. To address these challenges, capacity building is the key. “I have made a strategic decision to create an enabling environment for research in water, to invest in capacity development and expertise that is needed nationally and internationally.”

Young researchers can also achieve success in the areas that they feel passionate about, Momba adds. “To do that, you have to be motivated, you have to have a strong personality and you have to be committed. No one can stop you to achieve your destiny if you have courage, determination and God on your side.”

Snr Prof Leslie Petrik

Photo credit: Petro Kotzé

LESLIE PETRIK

The nano-chemist with the green heart

Current position:
Group Leader of the Environmental and Nanosciences group at the University of the Western Cape (UWC), Department of Chemistry

Research interests:
Nano-materials for applications in environmental remediation, water and industrial issues including waste reuse. Water chemistry and environmental remediation, including treatment of industrial effluents such as brine and acid mine drainage, removal of organics and inorganics from water, water disinfection, detection and quantification of organic pollutants, as well as decomposition of persistent organic pollutants in wastewater using advanced oxidation processes.

Awards

AWARDS AND HONOURS:

2021: WRC Legend Award

2017/18: National Science and Technology Forum NSTF-South32 Water Research Commission Award for an outstanding contribution to science, engineering, technology and innovation

2016: The Businesswomen of the Year Award in the Science and Technology Category

2015: The WRC Knowledge Tree Research Awards category: Transformation and Redress

2013: The UWC Vice Chancellor's annual distinguished researcher award, in the Natural and Medical Sciences category

2012: The Distinguished Women Scientist Award by the Department of Science and Technology

2010: The dti THRIP Technology Award: Quality and Quantity of Students

Nano-chemist, Snr Prof Leslie Petrik, has spent the best part of her career trying to undo the work of some of her peers. "I've often said there should be a criminal court for chemists," she says. "They have unleashed a plethora of highly complex chemical compounds on people and the environment."

Instead, Petrik, who leads the Environmental and Nanoscience (ENS) group at the University of the Western Cape (UWC), likes to put pollutants back where they came from, rather than disposing of them somewhere else when they've served their purpose. "I look for cradle-to-cradle, instead of cradle-to-grave solutions," she explains. "The loop should be closed." She excels at it, and has become an internationally renowned, award-winning scientist in the areas of environmental remediation, water treatment and beneficiation of industrial wastes.

The first steps towards a research career

Continuing with contract work after officially retiring in 2020, Petrik's own career has almost come full circle, after taking plenty of twists and turns along the way. It started with a bang.

"When I was nine or so my dad gave me a chemistry set," she notes. The tween mixed everything together in a little vial and put it on top of her pelmet. After two months or so, "bah!" Petrik throws her hands in the air. "One heck of an explosion!" That was experiment number one. While the rest of her family pursued more artistic interests, she preferred the outdoors, investigating shallow seashores and collecting shells.

Years later, her first job officially introduced her to the world of research. Petrik landed a position at the South African Institute for Medical Research working on blood grouping and enzymes. From there she moved to the lung function unit at the Witwatersrand University anesthetics department. "I had to push my trolley around and try to persuade these old darlings to blow into my lung function machine to see if they were ok for their operations."

Petrik completed her microbiology diploma at the Technikon Witwatersrand in Johannesburg, followed by a stint in food health and safety and then, a laboratory position working on blood anticoagulants. A gap of eight years followed, filled with two kids, a foray into crafting, and a relocation to Cape Town.

By the late eighties, she was ready to go back to research. She worked as a scientific officer in the Catalysis Research Unit at the University of Cape Town (UCT) Department of Chemical Engineering for the next twelve years. Mostly, she mentored post-grad students and assisted in industrial contract research.

Petrik flips through the pages of the book full of UCT memories that she brought to the interview. Many photos of sophisticated analytical equipment and catalytic reactors flash past. She chuckles. "How often I had to get on the bench and do the plumbing on some of these things…". There are many slightly faded photos of students, all of whom she remembers by name. International researchers flash past. "There's Prof Koos Jansen from Delft University (that Petrik later visited for research); there's chemical engineer and astronaut Albert Sacco with a space-themed tie."

"That's the model of one of the zeolite structures that we made," Petrik says. The microporous minerals are commonly used as absorbents and catalysts, and can be regenerated. "You can use it over and over in hydrocarbon processing," Petrik explains, "so it's a green process as

Seeing the potential in students and having the ability to actually help them realise it, says Prof Petrik, is something that is tremendously rewarding.

Photo credit: Petro Kotzé

"She can spot talent and is able to develop the research skills of any willing student."

you're not needing to use harsh acids."
The Catalysis group did much research on hydrocarbon chemistry, investigating which hydrocarbons can be turned into products with the help of zeolites.

From the Chemical Department Petrik moved to the Geological Sciences department at UCT, and worked for a period under Prof Martin Fey. One day, Petrik experienced a "Eureka" moment, fiddling around in the lab after a day of fly ash dump surveys. The ash is produced when coal is burned from power generation, and is the single largest form of waste being generated in South Africa. Every year about 36 million tons end up at designated disposal sites (dumps).

"Wouldn't the fly ash neutralise the acid mine drainage?," she asked Fey. His eyes popped, she says, and he immediately ran to the lab. The consequent realisation that they could treat acid mine drainage (AMD) with the extremely alkaline fly ash was groundbreaking not only for industry, but also for Petrik. She had just been introduced to water chemistry, and her career was about to really take flight.

On the road to independence

In 1998, Petrik moved to the University of the Western Cape (UWC) as a research manager at the Inorganic Porous Media Group in the Department of Chemistry. The group, under the leadership of Prof Vladimir Linkov, later became the South African Institute for Advanced Materials Chemistry.

In 2003, the WRC stepped in to fund the novel idea of using fly ash to clean acid mine drainage and remove the contaminants in the mine-water, which was the first of Petrik's many WRC-funded projects. Neutralisation of AMD with fly ash takes advantage of the available calcium oxide in the fly ash, thus lowering the concentration of metals and sulfate in the AMD by precipitation.

It's a cradle-to-cradle process, she says. The AMD is treated with the inorganic ash that stays behind after burning coal, and the remaining solids are put back into the void that the coal came from, so that the process of AMD is stopped. The project resulted in two patents. One for the treatment of AMD with ash, and a second to turn the waste coal fly ash into zeolites.

The year also saw Petrik awarded her Master's in Chemistry. Though she had not completed her Honours degree, she was allowed to register for the course on the basis of prior acquired knowledge. "I think I deserved it!" she says, flipping through the years captured in the pages of her memory book, around 13 that preceded the qualification.

After years of supporting others, Petrik could now start following her own research interests. In 2006, she established the independent postgraduate Environmental and NanoSciences (ENS) research group. They explore a broad suite of material science topics including nano-materials for applications in environmental remediation, water and industrial issues including waste reuse. They often collaborate with industry partners such as Eskom, TESP, Sasol, Coaltech, and Anglocoal. The group has delivered pioneering work.

> "The aim is to gain a deeper understanding of the design, fabrication and performance of nanostructures in order to engineer active nanometal alloys and structures. Our studies aim to provide valuable knowledge for the intelligent design and application of future materials."
> *– Prof Leslie Petrik, interviewed by the The Nanotechnology Public Engagement Programme (NPEP)*

Breakthrough technologies include how low-cost nanostructured adsorbents can be prepared from waste fly ash, and applied to remove toxic metals and other pollutants from water, how organic pollutants and problem bacteria in water can be completely decomposed and destroyed in a simple, one-step process using an electrohydraulic discharge system, and how fly ash can be used to treat and purify acid mine drainage from coal and gold mining. Pilot plants at several scales have been designed, built and commissioned with ongoing demonstration studies.

Throughout, Petrik excelled. In 2008, at age 54, she obtained her PhD. "I've had the greatest fun since," she says. Subsequently, she has published four patents, ten book chapters and more than 180 scientific papers in internationally accredited journals. She has obtained numerous research grants and collaborated with several international research organisations and universities in the USA, UK, Russia, Romania, Finland, Poland, Turkey, Oman and France. She is also a reviewer for several international journals and National Research Foundation grants and ratings.

Treatment of acid mine drainage with coal fly ash in a jet loop reactor pilot plant

A 1500 L batch jet loop reactor pilot plant was designed, constructed, and evaluated for performance in the treatment of AMD using coal fly ash. Results showed that concentration of major contaminants (sulfate, Al, Fe, Ca, Mg), and minor contaminants in the treated AMD can be significantly lowered (between one and four orders of magnitude) compared to the raw AMD. It was shown that the one-step treatment process recovered at least 66.6% (728.56 kg) of treated water depending on the degree of dewatering required for slurry pumping. The treated water met the target water quality range limit for agricultural irrigation in South Africa. The analysis of the solid residue shows its suitability for backfilling of mine voids or for making geopolymer such that AMD treatment with fly ash results in a zero discharge process. The treatment process offers a cradle-to-cradle solution to acid mine drainage and coal fly ash. – *From article published in Minerals Engineering (December 2020) by ENS students, under the leadership of Prof Petrik*

(Top) Students Andisiwe Bangisa and Emmanuel Ameh sampling stormwater in Fish; (bottom) conducting fieldwork in False Bay.

Numerous awards have followed in her wake. In 2012 she won The Distinguished Women Scientist Award from the Department of Science and Technology. The next year, she received the UWC Vice Chancellor's annual distinguished researcher award in the category Natural and Medical Sciences, awarded to researchers who bring honour to the university through their cutting-edge work.

“Our studies aim to provide valuable knowledge for the intelligent design and application of future materials.”

“Work like this is achieved due to teamwork. Each and every one of my students and technicians has contributed to the success of our research, and the accolades I am getting are truly theirs as well.”
– Snr Prof Leslie Petrik, as interviewed by UWC on NanoScience for the environment

Petrik was appointed to the rank of Professor in 2014. The following year, she received the WRC Knowledge Tree Research Award in the category Transformation and Redress. In 2016 she was awarded the Businesswomen of the Year Award in the Science and Technology Category. In 2018, the year she was appointed as Senior Professor, she was honoured with the National Science and Technology Forum South32 WRC Award for an outstanding contribution to science, engineering, technology (SET) and innovation.

Lab technician, Ilse Wells, has been working with Petrik for 12 years. “Her success comes from engaging with various people, from different institutions, across many disciplines,” she says. “And, she works tirelessly to reach her goals.”

If anything, Petrik says her drive has increased over the years. I’ve become more passionate about the work that we’ve done because I started seeing the importance of it, she says. “I didn’t aim for success.” Instead, she thinks you need to engage and do the best with what you find at hand. “Life is pretty tough and you’re not going to get opportunities around every corner.” Petrik’s career path is proof. She’s had to navigate big personalities and professional envy along the way. And, somewhere in her house there is a pile of rejection letters that she kept – she sent out more than 90 applications before she landed her first position at the UWC.

She mentions the WRC as a key partner in her journey. “Even if you have dreams as a scientist you can’t realise it without funding.” A lot of the things that we have achieved is because the WRC has been a very good partner. You might have the potential but unless you have the opportunity you can’t achieve your goals.”

The ability to help someone else to also realise their potential, has been a fine thread throughout her career too.

Paying it forward

“Just look at that smile,” Petrik says repeatedly, paging through the second book she brought. “And that one!” The book was given to her by her students on her retirement, and is made up of photos and thank you notes. One describes her like a mother, another points out the wrath of her red pen (she still marks printed theses by hand). One writes of how he was a baker without money to fund his studies when Petrik helped him. The note is alongside a photo of his PhD graduation. Next to all the smiling student faces in the photos,

Since 2003, Prof Petrik has supervised to completion 30 PhD and 60 MSc UWC students, and mentored 24 Postdoctoral Fellows. Memory books capture the precious messages from her mentees.

Photo credit: Petro Kotzé

is a smiling Petrik. “They tackle a hell of a journey going on a Master’s and a PhD,” she says, “so when they get that cap, we all celebrate.”

She is renowned for her dedication to helping students live their potential. Zenzele Ndlovu is in the final year of her PhD, and has worked under Petrik’s supervision for her in-service training, B-Tech and Master’s degree. Petrik then encouraged her to enroll for her PhD in 2017. “Prof Petrik taught me how to become self-driven, to develop quality research and work towards making the world a better place,” she says. “She can spot talent and is able to develop the research skills of any willing student.” More importantly than good grades, Zenzele says Petrik showed her that building resilience and working hard was key to achieving academic excellence.

Many have benefited from Petrik’s guidance. Since 2003, she has supervised to completion 30 PhD and 60 MSc UWC students, and mentored 24 Postdoctoral Fellows. Over the 15-year period that the ENS group has existed, more than 90 postgraduate students (MSc, PhD, NDT, MTech, DTech) have been supported financially by ENS grants and funds raised by Petrik.

Over and above, many young intern students from the Cape Peninsula University of Technology (CPUT) have received their practical training on diverse projects at the ENS and have completed their NDT Chem Eng qualifications and proceeded to graduate with their Btech and MTech degrees. Petrik has also provided opportunities for many postgraduate students to present their research at international conferences and spend time at international laboratories.

Seeing the potential in the students and having the ability to actually help them realise it is tremendously rewarding, she says, and part or why she likes working in this field. It's just fantastic to know these students are all over the world taking water research or waste research forward, she says.

Once Petrik leaves the professional field and the work of the ENS winds down, the next cadre of nano-scientists will continue to be in the making. She played a lead role in the establishment of the National Nanoscience Postgraduate Teaching and Training Platform (NNPTTP) presenting a Master's degree in nanoscience in the three study fields of nanobiomedical science, nanochemistry and nanophysics, supported by the Department of Science and Innovation (DSI).

However, she's not done yet by a mile. The challenge of solving a problem in a creative manner and then engaging with society is the interesting part, and continues for her. Plus, she says, "I'm still having too much fun!"

Coming full circle

More recently, the ENS started looking at the impact of marine sewage outfalls on the seawater quality and possible desalination around Cape Town, and the treatment of persistent organic pollutants in wastewater that negatively affect ecosystem and people. It's a topic that gets Petrik riled up.

Prof Petrik with WRC research manager, Dr Nonhlanhla Kalebaila.

Photo credit: Lani van Vuuren

Prof Petrik has received numerous awards and honours throughout her career.

Photo credit: Petro Kotzé

If she can help implement proper barriers that ensure reclaimed water is safe, Petrik says she will feel like she's done something worthwhile.

"If not halted the continuous discharge of effluents containing those hazardous chemicals via the marine sewage outfall will result in an increase in levels of those chemicals in marine waters…., which will have a negative impact on the viability of the associated Marine Protected Area. Treatment of the sewage before its release into the marine environment should be mandatory to protect and maintain marine biodiversity and human health."
– From Presence and risk assessment of herbicides in the marine environment of Camps Bay (2020) by ENS students under the leadership of Prof Petrik

It's easy to ignore it, but waste will engulf our world if we don't start dealing with it, she says. We cannot simply keep unleashing it onto the environment. We need to be able to not pass on a chemical legacy to the next generation. These chemicals actually have generational affects, she says, affecting our children and grandchildren. Petrik aims to help fight this battle at a molecular level. "There are catalysts that one can use to break down these harmful compounds; tiny clusters of metals can be tailored to the job that we want them to do."

If she can help implement proper barriers that ensure reclaimed water is safe, Petrik says she will feel like she's done something worthwhile. In a sense, I've come full circle, she says, thinking back to that first chemical explosion and her fascination with the sea. "That's what I would like to be remembered for, for making our water safe."

Prof Bhekie Mamba

Photo credit: Petro Kotzé

BHEKIE MAMBA

An innovator destined to teach

Current position:
Executive Dean, College of Science Engineering and Technology (CSET) UNISA,
Former Founding Director of the Nanotechnology and Water Sustainability Research,
now the Institute for Nanotechnology and Water Sustainability (iNanoWS)

Research interests:
Development of advanced nano and membrane technologies for
water treatment with emphasis on organic micro pollutants

Awards

AWARDS

2021: WRC Legend Award

2019: Appointed as one of the top 2% scientists in the world (as compiled by Stanford University)

2019: Selected as 'One Thousand Talent of Foreign Experts', Tiangong University, Government of Tianjin

2019: UNISA Innovation Award for Patent Application Incentive: A Process for Treating Acid Mine Drainage (with Prof KK Kebede)

2017: National Science and Technology Foundation (NSTF) – South 32 Water Research Commission Award

"The sky's the limit," says Prof Bhekie Mamba of a career in academia. It has provided him the opportunity to imagine boundless ideas of how to help solve humanity's problems, he says, and the space to develop innovative technologies to make it a reality.

> He is renowned for his work on the removal of organic micro pollutants in water.

Mamba has done this remarkably well, over a meteoric career path in which he has emerged as a leader commonly referred to as both visionary and astounding. His chosen field of expertise is nanotechnology-based systems for the sustainable provision of safe and clean water, and he is responsible for significant scientific and technological contributions and achievements in the field. More specifically, he is renowned for his work on the removal of organic micro pollutants in water. Mamba was listed among the top 2% of the most cited scientists in various disciplines globally in 2019 and was the first recipient of the National Science and Technology Foundation (NSTF)- South 32 Water Research Commission Award.

His achievements have come in the face of large adversity. Twice, he has had to build up research groups from scratch, each time developing them into globally celebrated scientific institutions. Yet, for him, his legacy lies elsewhere. More than being remembered for the scientific excellence of the work he delivered, Mamba wants to be first remembered as a great mentor, and then, secondly, as a researcher that was also a good human being. This mission is his divine destiny, says Mamba. Numerous times over the years, it has come knocking to show him the way.

The first steps of a career are laid

It started in Swaziland. Mamba excelled academically from a young age and could consequently have his pick among career choices. He was one of Swaziland's top matriculating students and received an "A" in Principles of Accounting, one of the High School subjects that he loved dearly. However, he settled on Science, a much more difficult but prestigious topic, since so few students made the cut for acceptance to study at the then University of Swaziland.

Destiny sometimes knocked in strange places. He was persuaded to specialise in Chemistry instead of Physics when he bumped into the first year Chemistry lecturer, Dr Charles Kumsah, one Saturday in the Kentucky Fried Chicken outlet. He chuckles at the memory. The dice was cast, he says. "There was no Physics lecturer to offer a counter argument!" Since he also completed a Diploma in Education concurrent with his degree, the final examinations time-table at the University of Swaziland resulted in him having to write 17, three-hour exams over 12 days. In order to proceed to the next year all modules had to be passed, otherwise all modules had to be repeated again. The immense pressure taught him resilience, persistence and organisational skills that would stand him well in his coming career.

Mamba graduated in 1990, expecting to continue his studies abroad. However, as South Africa was just emerging from political isolation, scholarships were suddenly funnelled there, leaving University of

Swaziland graduates like Mamba to search for opportunities closer to home. He settled on a Master's in Organic Chemistry at the University of Witwatersrand, and subsequently graduated with a PhD in Organometallic Chemistry at the same university in 1999. As part of his bursary agreement, he started working at Polifin, now known as Sasol Polymers.

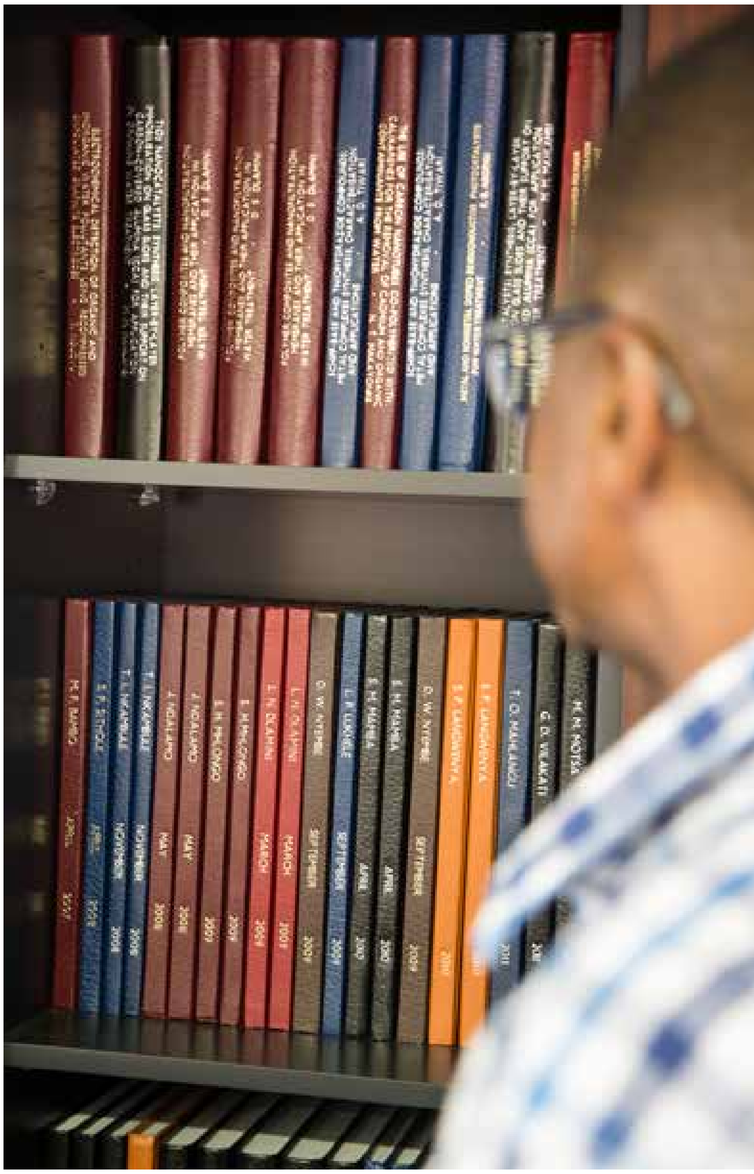
However, he found the world of applied technologies mundane and isolated, with little room for innovation. Mamba says it took destiny six months to come knocking again, arriving as he was getting dressed for his graduation ceremony, in the form of a phone call from the Technikon Witwatersrand (now the University of Johannesburg). It was an offer for a Chemistry lecturer position. He knew academia was where he should be so, regardless of the looming pay cut, handed in his resignation straight after graduation. The first Monday he stepped into the class, he felt at peace. "This is where I wanted to be, surrounded by students," he realised.

The start of a research group

In those days, technikons in South Africa were post-secondary institutes of technology (typical Polytechniks as commonly known elsewhere) and focused on career-oriented vocational training. They were not known as hubs of scientific research and typically did not contain the laboratories and equipment necessary to be such.

Mamba, however, wanted to do research. Contemplating his next move one December afternoon from his office, he received a call from a friend (who used to be a lecturer at Wits), now working at the WRC. He told Mamba that for funding, he had to solve problems affecting mankind and the country as a whole. In South Africa, this included water contamination, and in particular,

Mamba was listed among the top 2% of the most cited scientists in various disciplines globally in 2019.



One of Prof Mamba's greatest achievements is the mentorship role he has played for so many students.

Photo credit: Petro Kotzé

the substantial challenge of effective technologies to detect and remove organic compounds from water supplies.

Organic pollutants include trihaloethylenes, endocrine disrupting compounds (EDCs) and pharmaceuticals and their residues, which can be potentially toxic. Conventional water treatment technology such, as activated carbon, was being used with some success but was not always effective in the removal of minute quantities (parts per billion).

Mamba retired to the staff room for a cup of tea to think. Unusual for him, he picked up a magazine which, to his surprise, had just published an article on polymers (so-called nanosponges) for removing organic contaminants as a preliminary investigation. "It's incredible but I just stumbled onto it,"he explains. He immediately realised the potential of the technology to treat drinking water in South Africa. The article had planted a seed that would grow into some of Mamba's most renowned work.

Nanosponges bind organic molecules in aqueous media, but release the same contaminants in organic media, which make them ideal not only for the removal or organic compounds, but for chromatography, separation science, and for potential sensor applications. Mamba wrote his first research proposal for the WRC on the topic, subsequently winning a project funding grant of R110 000. When the letter of award landed on the Technikon's Director of Research's desk, he had no idea what was going on. Mamba was tasked to start a research unit from scratch.

Still an unknown lecturer, Mamba managed to attract two students studying for their National Diploma and called on technical support from his Master's and PhD co-supervisor at Wits, who made the university's labs available to him. Mamba submitted his first WRC report in 2000, detailing his findings and the facilities he could build up with the funding. When a next call for proposals came for the WRC, he won "serious money" and could now, for one, start building a lab. However, he needed more equipment.

In those days, technikons lacked the prestige of universities, and Mamba knew he was unlikely to attract Master's students in South Africa for his project – a requisite of WRC funding. He looked to his undergraduate alma mater, University of Swaziland, for the solution. At the university's next annual graduation ceremony, Mamba was waiting at the end of the stage, handing out pamphlets advertising his project to each graduate. Two came to South Africa, while a third, a South African student also joined. They did not have a name yet, but the enrollment of MSc students in 2004 marked the start of Mamba's research group.

The group focused on the synthesis of nanomaterials and nanoporous polymers for the removal of organic and inorganic contaminants from water. They specifically focused their solutions to be relevant to developing nations. The so-called 'nanosponges' Mamba developed could remove pollutants at nanograms/litre with high efficiency (>80%). In addition, they are reusable, which reduces treatment cost. Their novel solutions to difficult problems soon started attracting attention in South Africa, and beyond.

Yet, what Mamba remembers most fondly during that period in his career, is the satisfaction he felt when he could first secure funding to send some of his students, now part of the official Water Research Group, to international conferences. The first three students presented papers in Serbia and Montenegro in December 2004. By 2005, their papers started appearing in international journals as their work on nanotechnology for the removal of the global problem of organic pollutants attracted international attention.

Soon, as Mamba built up his experience and laboratories, he could supervise his own PhD students (instead of referring them to Wits). The Water Research Group became one of the only research groups to research organic pollutants in water, and the only one that investigated nanotechnologies for water decontamination. The group also started looking at the improvement of water treatment plants and other technologies with the addition of nanotechnologies, and later membranes. The multidisciplinary nature of the work would in time attract a broad range of scientists beyond chemists, including physicists and engineers. "We just grew and grew," Mamba says.

In the meantime, the Technikon Witwatersrand had merged with the Rand Afrikaans University as part of then-Minister of Education Kader Asmal's restructuring of higher education in South Africa. On their merger in 2005, they formed a new institution called the University of Johannesburg (UJ), which offered both academic and technology degrees. Mamba was appointed as Head of the Department of Applied Chemistry at UJ, becoming Associate Professor in 2007 and Professor in 2009.

By that time (in 2008), the now called Water and Health Research Group boasted 27 post-graduate researchers, including postgraduate students from Swaziland and Zimbabwe and postdoctoral fellows from India. They became known as international experts, were invited to more conferences, and were able to attract substantial funding. From 2007 to 2014 the group received funding to the tune of R2.5 million per year.

Innovation in the shape of a Silver Impregnated Porous Pot

Now being used in Mpumalanga and Limpopo, Prof Bhekie Mamba, in collaboration with Prof Maggy Momba from Tshwane University of Technology (TUT), first described the manufacturing of the Silver Impregnated Porous Pot (SIPP) filter in 2008 (it was later developed as part of another WRC-funded project). This nanotechnology-based clay pot includes silver in the firing process of the clay and filters contaminated water. The technology benefits marginalised communities in South Africa and treats wastewater to produce safe drinking water at a household level. The SIPP device is cheap, reusable and can readily be made from locally available materials.

In 2010, Mamba was awarded the status of Chartered Chemist (CChem) and Chartered Scientist (CSci) by the British Royal Society of Chemistry and the British Science Council, respectively, the same year he received a C-rating from the National Research Foundation (NRF). The next year, he was the recipient of the Distinguished Vice Chancellors Research award and in 2012, was awarded the NRF Research Chair in Nanotechnology for Water. In 2013, he was appointed as the Dean of the Faculty of Science at UJ, the same year he was elected as a fellow of the African Scientific Institute. The honorary association includes some of the most intellectually active individuals in the world, who have made outstanding contributions in scientific research.

In 2014, his research group became the Institute of Water and Nano Technology, of which he assumed directorship. By that time he had published over 120 papers in peer-reviewed journals, presented his research group results at conferences locally and internationally, and successfully supervised 40 Master's and PhD students. Mamba was at the apex of a distinguished career and started entertaining the idea of a well-deserved retirement at the back of his mind.

But his divine destiny was about to come knocking again. In October 2013, Mamba was publicly suspended. "Academics can be ruthless," he says. Mamba was vindicated three months later when he was found not guilty in the disciplinary case brought against him by the university, and his suspension was lifted. Yet, he felt the damage was done and that it was time to explore other horizons.

The renowned academic suddenly faced an uncertain future. Then, the University of South Africa (UNISA) entered the picture. Following discussions about the vision UNISA had about their research agenda in Science and Engineering, Mamba provided them with his CV and a proposal for a five-year period. "They told me I could come in and do whatever it takes to take UNISA to the top in the field of nanotechnology and water research", Mamba says. The offer came with a budget of millions to start a research unit from scratch. Mamba accepted.

Starting from scratch at Unisa

In September 2014, Mamba established the Nanotechnology and Water Sustainability (NanoWS) Research Unit at the College of Science, Engineering and Technology (CSET) at UNISA, together with two other founding academics (Prof Thabo Nkambule and Prof Titus Msagati) both of whom came along with Mamba from UJ, and assumed directorship of the group.

The unit soon enjoyed international recognition for their cutting-edge research, investing millions of Rands in state-of-the-art equipment and instrumentation, for nanomaterials synthesis and characterisation, water quality monitoring and purification technologies. Within three years, the UNISA Senate had recommended the institutionalisation of the NanoWS research unit. This was approved by the UNISA Council in 2020, and the unit consequently changed its name to the Institute for Nanotechnology and Water Sustainability (iNanoWS).

The institute is at the forefront of integrating nanotechnologies with existing water treatment practices with the goal of optimising the efficiency of conventional water treatment technologies. Beyond the application and science of nanostructured membranes for use in water treatment and desalination, the research plan includes the development of novel nanomaterials as absorbents, catalysts and sensors for water purification and understanding the fate of these engineered nanoparticles in the environment.

In 2017, Mamba was promoted to Executive Dean of the CSET. On acceptance of the position, he committed to position the College as a world class institution in the scholarship of science, engineering and technology. He delivered that, and much more.

Under his tenure, the Science Campus's modern facilities and laboratory equipment has positioned UNISA as one of the most advanced institutions not only in the country and the African continent, but globally as well. They now attract students and

Photo credit: Petro Kotzé

"They told me I could come in and do whatever it takes to take UNISA to the top in the field of nanotechnology and water research."

researchers from all over the world and take a centre stage in accelerating Africa's development.

Mamba had done it again. Within a few years, he built a research unit from scratch, into a world-renowned institute while, at the same time, winning increased recognition for his leadership traits through his fast promotion up the ranks.

There have been personal highlights. One is the recognition from the WRC, when he received the inaugural NSTF-WRC Award in 2017, which recognises excellence, leadership and impact in the field of sustainable water management, knowledge generation and solutions. Another was when he was elected by the Water Institute of Southern Africa (WISA) as a Senior Fellow of WISA in 2021, in recognition of his contribution in water research and the water sector throughout his decorated career span.

However, Mamba says his biggest achievement has been the development of human capacity. Over the span of his career, he has supervised to completion over 100 Master's and doctoral students, many of whom are employed or running businesses locally or internationally. Many have also followed Mamba's footsteps to enter a career in academia, and he says he finds it immensely satisfying to work alongside colleagues and professors that were once his students. The larger net of his teaching influence is vast.

In addition, Mamba has been an external examiner of MSc dissertations and PhD theses from various universities, including Wits, Tshwane University of Technology, University of the Free State, Royal Institute of Science and Technology (Sweden) (Main External Examiner), Delft University of Technology (Netherlands), Nanyang Technological University (Singapore), Rhodes University, University of Western Cape, University of Botswana and University of Stellenbosch.

Everything that has happened might look like coincidences, he says, but all of the small and large incidents that have shaped the path of his career have pointed him towards his destiny. Regardless of the local and international accolades, honours and awards, this destiny was ultimately to be able to invest his time, energy and capacity in teaching the next generation of scientists to also reach their full potential.

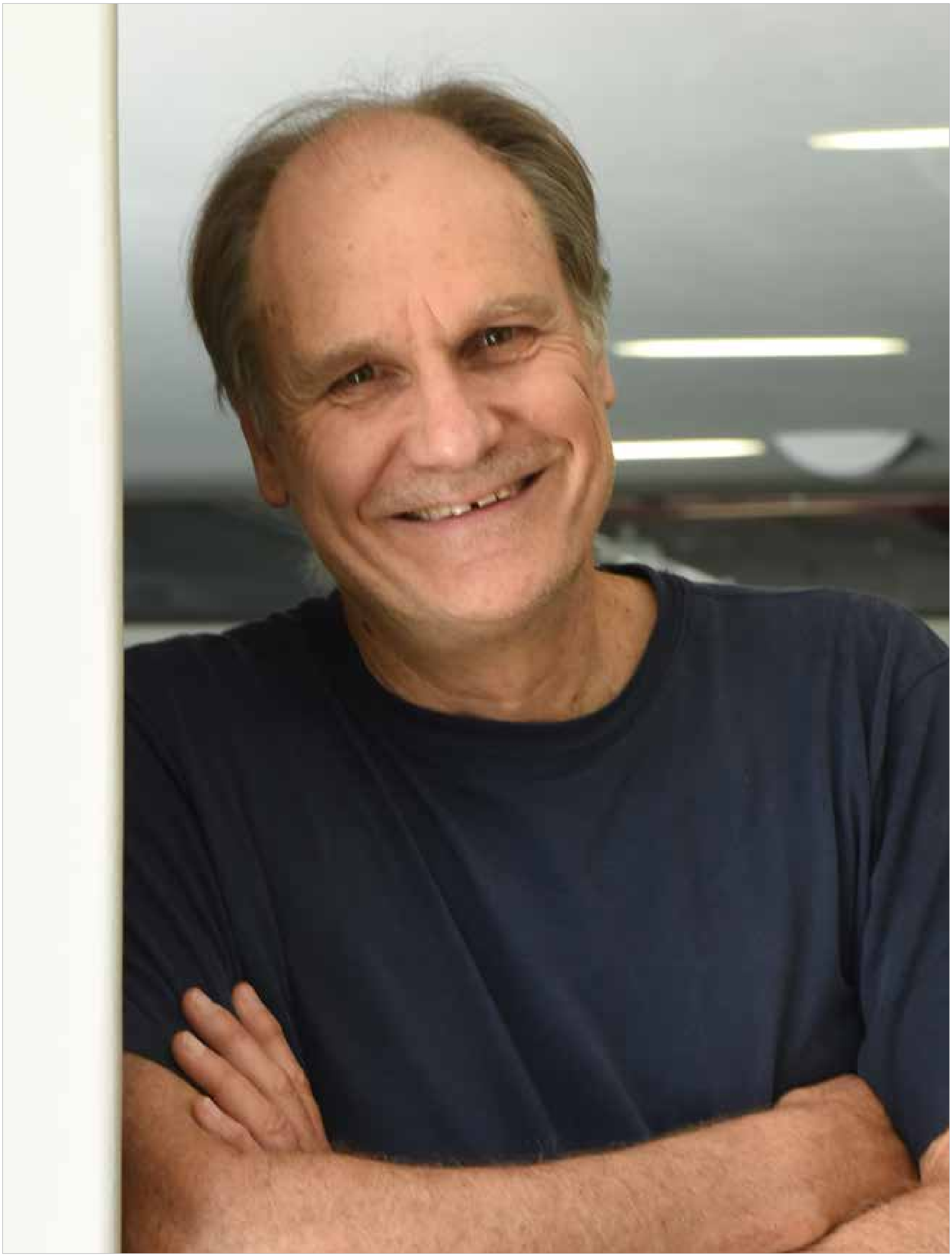
Prof Mamba founded the Nanotechnology and Water Sustainability (NanoWS) Research Unit, and built it up to become the Institute of Nanotechnology and Water Sustainability (iNanoWS) within a few years.

Photo credit: Petro Kotzé

CSET innovations

Some of the innovations patented under Prof Bhekie Mamba's helm at the CSET include technologies in the areas of photonics, optoelectronics and renewable energies. Specific patents include the concepts of collecting thermal energy from the sun, storing it in water in standard household geysers, and converting a portion of this energy to electricity. Research indicates that conversion efficiencies to electricity of up to 60% can be obtained by adding specific electronics technology to thermal-electric cells. This concept is unique in South Africa and can generate a new paradigm of supplying electricity to households in the country. Local and international patents have also been filed on a new generation of photonic sensors that can be integrated on microchips and uniquely sense a number of environmental parameters and bio-materials, including viruses in the atmosphere. Another includes a new type of water desalination unit using specially constructed membranes that can be used in a household to purify water from any mineral or organic contents. In 2019, Mamba (with Prof K.K. Kebede) was awarded the UNISA Innovation Award for a technology for the treatment of Acid Mine Drainage. In 2020, the NanoWS unit was awarded a European patent for a technology that can clean up crude oil and petrol spills in water while making both the oil and the water usable again.


SVALBARD
(Norway)
Novaya Zemlya
Kara Sea
Barents Sea
Baffin Bay
Davis Strait
Hudson Bay
Denmark Strait
ICELAND
Norwegian Sea
North Sea
Newfoundland
NORTH
ATLANTIC
OCEAN
Black Sea
Mediterranean Sea
Red Sea
Gulf of Aden
Gulf of
Guinea
SOUTH
ATLANTIC
OCEAN



Prof George Ekama

Photo credit: UCT

GEORGE EKAMA

World captain of unchartered (waste) waters

Current position:
Emeritus Professor of Water Quality Engineering

Research interests:
Water chemistry and water conditioning – modelling of integrated chemical, biological and physical treatment of water and wastewaters; acid mine drainage treatment; anaerobic and dual digestion of sewage sludges; activated sludge kinetics; sludge settleability and secondary settling tank design; filamentous bulking in activated sludge systems; sewage sludge management; and, solid waste and leachate treatment.

Awards

AWARDS

2021: WRC Legend Award

2017: University of Palermo Prize for sustained cooperation with UCT on Membrane and Moving Bed Bioreactor System

2014: Recognised in China as one of 35 major contributors to the activated sludge process over 100 years of research from 1914 to 2014

2013: South Africa's Presidential Order of Mapungubwe, Silver

2012: IWA project innovation award (as part of international research team)

2004: WISA/WRC/CSIR Stander Memorial lecturer

1998: WISA Piet Vosloo Memorial prize for development of mathematical models for biological wastewater treatment plant design

1993: WISA Umgeni Award (with co-authors Mark Wentzel and Gerrit van Rooyen Marais)

1992: WISA Umgeni Award for most significant paper in water in South Africa

A giant in the history of wastewater treatment research, Prof George Ekama is as well known for his integrity, empathy and generosity of spirit, as for his renowned research outputs. Ekama himself is modest about his achievements, and prefers to highlight teamwork, dedication and perseverance. His colleagues, however, are more direct. “He is an undisputable and absolute leader in the field,” says Dr Chris Brouckaert, senior research fellow at the University of KwaZulu-Natal’s Water Sanitation and Hygiene Research and Development Centre.

“There is no question that George is a legend; not only in South Africa, everywhere,” he adds. “People like George established the South African water research sector as at the absolute leading edge at a time [in the nineties] when our reputation was the best. He is among the originators of innovations that are now widespread around the world, says Brouckaert, who has been collaborating with the renowned professor for years.

Now retired, Ekama dedicated his career to help solve South Africa’s water crisis. He focused on municipal and industrial wastewater treatment, and his work has blossomed through the decades to include biological nitrogen and phosphorus removal, activated sludge system modelling, biological sulphate reduction, anaerobic digestion, plant wide modelling of whole wastewater treatment plants and alternatives to desalination for augmenting urban water supply. He has been a National Research Foundation (NRF) A1-rated scientist since 2006 and is listed among the most cited academics in the world. Locally, he has been rewarded with the country’s highest accolade, the Presidential Order of Mapungubwe, for his innovative solutions to enhance and improve wastewater treatment, and so helping the country find solutions to water scarcity.

He has been described as the man who switches lights on. Thanks to a combination of specific skills, traits, opportunities and deep-seated passion for his profession, he has brought relief to some of the most concerning problems faced in water treatment globally.

According to Ekama, he chose civil engineering because that was one of the easiest courses to get a bursary for but, he has it in his blood. He learned the basics right in the family garage with his father, a mechanical engineer who liked to ‘tinker’ with the family car. His grandfather, uncle and brother were all engineers too and though Ekama himself apparently did not excel at school, this was the sixties, and the apartheid government needed engineers for their major infrastructure projects. Airports, roads, dams and harbours needed to be built and bursaries were available aplenty.

A fateful meeting that sparked a renowned research relationship

Ekama crossed the country to study at the University of Cape Town (UCT). “Like going to San Francisco,” he said of the move to the Mother City. “Everyone was a hippy” and, adds a colleague who has seen photos of the teenager at the time, with a wink, so was Ekama!

He stepped into his career at a time when environmental engineering saw explosive growth in line with nationally identified needs. For one, the country was experiencing serious water quality problems. High loads of phosphates and nitrogen from wastewater led to enormous difficulties with eutrophication, with algal blooms rife in dams, rivers and lakes.

I did not plan to be successful; that I have become so is a surprise to me also – it grew out of going to work every day, paying attention to detail, meeting deadlines, doing one's best and serving others."

Prof George Ekama, interview published by the Academy of Science of South Africa (ASSAf), Legends of South African Science, 2017

Though the Water Act of 1956 required a high standard of wastewater treatment, the workhorse at the time was the trickling filter, which was unable to remove the nutrients except by chemical means. Chemical removal of phosphorus was not an option in South Africa because it would exacerbate the growing salinity problem from acid mine drainage. Plus, South Africa was using design criteria from the United States for activated sludge wastewater treatment, which was inappropriate to local conditions. Finding a biological way to remove nitrogen and phosphorus was paramount in protecting South Africa's surface water supply, and removal methods with the activated sludge process became a national priority.

One of the research leaders in municipal water and wastewater treatment at the time was Prof Gerrit van Rooyen Marais, the Chair of Water Resources and Public Health Engineering at the University of Cape Town's (UCT's) Department of Civil Engineering. Marais ran the Water Research Group (WRG), which develops mathematical models for simulating the chemical, physical and biological processes of wastewater treatment systems, and running experimental systems to validate these models. The group was one of the first to be supported by the Water Research Commission, which initiated a national research drive into biological nitrogen and phosphorous removal from wastewaters in 1974.

Around that time, Ekama had grown bored of his first job. After achieving an Honours Degree in 1972, he started working at the container quay in the Cape Town harbour, but decided he better enroll for some evening classes "to keep his neurons from dying out". Back at the Department of Civil Engineering, he met Prof Marais, a meeting that sparked a research relationship with eventual international ramifications. Ekama resigned from his job at the harbour as soon as possible to join Marais's laboratory at the Professor's invitation to do a Master's degree and, for his PhD and throughout his early career, Ekama worked with Marais to develop models of biological processes for removing nitrogen and phosphorus from wastewater.

"One of the things he likes to tell his students is to keep the main thing, the main thing," says Dr David Ikumi, who took over directorship of the WRG on Ekama's retirement. Researchers can struggle to stay focused when interesting things pop up during the research, but Ekama would remind them to be patient and remain very, very focused on what they are doing, he says. This intense focus paid off.

> “Inspired locally, recognised internationally.”
> *– Prof Ekama’s well-known research credo*

The pioneering process the research group developed, the UCT activated sludge process with integrated biological nutrient removal was a world first, and has been the state of the art in sewage treatment internationally. The process removes carbon, nitrogen and phosphorus by biological means at a low cost and with less waste sludge production, without adding to the salinity. The research group’s work fed into an international modelling effort that resulted in the international standard models known as Activated Sludge Model numbers 1 and 2.

“They were the top in the world for wastewater treatment,” Ikumi says. “The UCT team was like a dream team, and Ekama was one of those at the forefront of it.” He remained a soft-funded staff member of the university, but when Marais retired in 1992, Ekama stepped up to the plate as Director of the small research group.

Working systematically, and with intent

The field of mathematical simulation of chemical processes that we work in, is not for everyone, Brouckaert says. I’ve heard it described as a mindset of consulting the model in our heads before we deal with reality. It’s amazingly detailed, systematic and accurate and allows for a wide-ranging understanding of the chemical reaction processes. George has that mindset, he says. “He is perfectly suited to the fields he chose.”

> “The challenge is not technology – it is changing people’s mindsets and how they engage with water and their waste. At the moment, waterborne sanitation and water-supply systems have been designed purely for the comfort of the user. Any change from the current system is likely to cause some form of discomfort. All of us need to become more aware of our environmental impact and learn to embrace greater complexity and some discomfort to minimise it. However, the benefit would be a cleaner and more sustainable society for all to enjoy.”
> *Prof George Ekama, interview published by the Academy of Science of South Africa (ASSAf), Legends of South African Science, 2017.*

Ekama is renowned for the long-term, detailed experimentation work that he sets up. In mathematical modelling you can easily make up numbers to replicate that system, Ikumi says, but Ekama made sure the model predictions would be realistic. “We spend a lot of time on high-level experimental work to calibrate the models – setting up systems in the lab that would showcase what you'd like to find in the mathematical equations in the models. Ekama ensured that he had a really deep conceptual understanding of the issue to be solved, and that there was a very high explicit link between what you're trying to put together as a virtual replica of a system," he explains.

Adds Brouchaert: "What makes George's achievements incredible is that he did it without the formal training. George is a civil engineer but we work in a chemical engineering field, and yet, even without the formal training he is one of the best chemical reaction engineers that I've ever come across. It is purely through experience," Brouckaert says.

Ekama is also known to work with intent. "He only spends his time on things that he deems most meaningful, and he makes sure that he puts substantial effort into it," Ikumi says.

Having been part of a national effort that developed the biological nitrogen and phosphorus removal activated sludge system he joined the national effort on dealing with the salinity problem: how to reduce sulphate in acid mine drainage, but by biological means. This, again, opened his work on biological sulphate reduction using sewage sludge as the energy source, which led him back to municipal wastewater treatment arising from seawater toilet flushing, an intriguing new problem that Ekama worked on with colleagues in Hong Kong.

Ekama remained at the forefront of developments in wastewater treatment, primarily through a strong research group. Through the decades, the WRG has made significant contributions to research outcomes in the wastewater sanitation industry nationally and internationally.

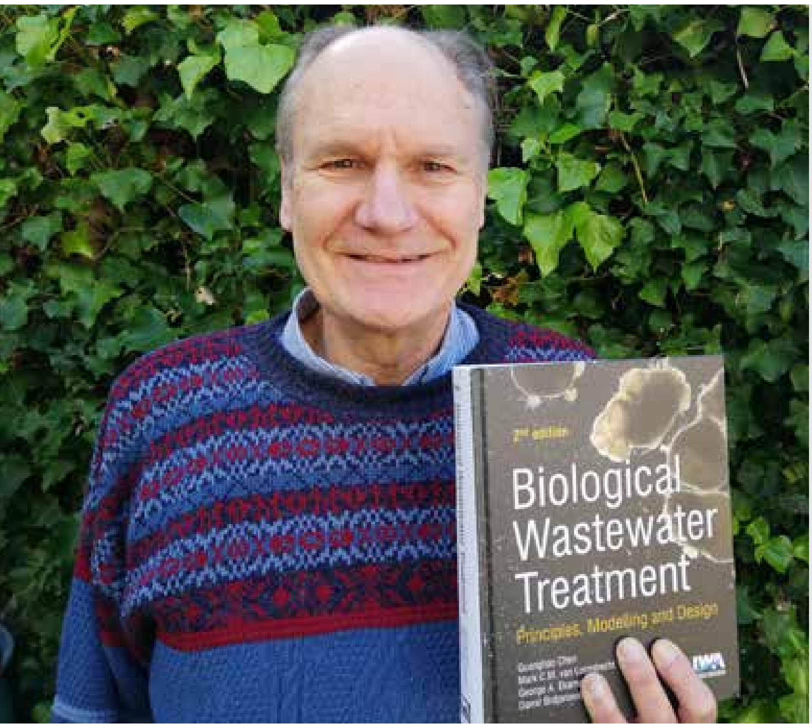
Ekama has always stressed the importance of collaboration in research. "Because the research conducted is done as a group, of which I am Director, it is difficult to separate my contribution from the group's achievements as a whole and to an extent, the measure of the group's research achievement is also a measure of my research achievement and vice versa," he once wrote.

Now retired, Prof George Ekama was happiest in the lab, solving some of the world's most complicated wastewater problems.

Photo credit: WRC archives

Passing skills and knowledge on to future generations

Ekama taught since he started at UCT in the seventies. He sees himself as a steward for the skills and knowledge he has amassed throughout his career, and he believes one of his most important duties has been to pass this on to future generations.



... the book was published during an incredibly challenging time in Ekama's career.

Prof George Ekama with the seminal book which he co-authored, Biological Wastewater Treatment – Principles, Modelling and Design, which has since been translated into several languages.

Ikumi saw how passionately Ekama did this when he first attended one of his Wastewater Management classes as an undergraduate student. He later learned that his lecturer actually developed the ideas behind the course content. "It was a rare thing to be taught by the person who [literally] wrote the book," he says. Ekama's passion inspired Ikumi's own career. He remembers walking into his lecturer's office to discuss a Master's, upon which the professor asked him if he liked wastewater research. When he confirmed that he did, Ekama beamed: "So do I!"

Ekama would become instrumental to Ikumi's own career, acting as his Master's and PhD supervisor and motivating him to apply for a position at UCT. It was typical Ekama, who is well-known for the care and interest he takes in his students. Only when Ikumi himself started teaching, did he realise the extent of his supervisor's skill.

"I realised that actually, it's very, very difficult," he says of his introduction to teaching. "[Ekama] spent a lot of effort assisting the students to overcome challenges towards grasping required knowledge or skills to be developed in the learning process. He taught me that a good teacher does not just want to teach, they want someone to understand."

He actively sparked some sort of curiosity in students to explore this material beyond the classroom. In reaction, his students delivered excellent work. Eleven of the 15 times the Water Institute of Southern Africa GG Cillié prize for the best publication or thesis in anaerobic digestion has been awarded, it has been awarded to PhD graduates supervised by Ekama.

A significant part of his UCT post-graduate course material fed into the seminal book on wastewater treatment. Published in 2008 by the International Water Association (IWA), Ekama co-published and co-authored ***Biological wastewater treatment - Principles, modelling and design.*** It became a best-selling work of reference, and it has been translated into Korean, Spanish, Arabic, Chinese and Russian. It also forms the basis of an internet-based postgraduate course on wastewater treatment administered by the Unesco-IHE Institute for Water Education in the Netherlands for students in developing countries who do not have access to high quality Master's Degree programmes in wastewater treatment.

Remarkably, the book was published during an incredibly challenging time in Ekama's career.

The 'absent' professor

In 2006 the WRG suffered tremendous losses. Stalwart Dick Loewenthal retired, a research officer resigned, former PhD student Sven Söteman left to start his own consultancy, PhD student Ashley Muller was killed in a car accident at the Rondebosch Common a month before submission and, long-standing research officer Prof Mark Wentzel was permanently medically boarded. The group shrank to one, with Ekama also being Head of the Department of Civil Engineering at the time. Little time for research remained and, he said, he was renamed the 'absent professor' by his wife Janet and daughter Kate.

Ikumi just started his career at UCT, and still remembers Ekama as a tremendously dedicated teacher during this time. He did wonder how on earth he kept the pace up. He recalls meeting a sweaty Ekama dressed in running shorts in the mornings. He used to jog to UCT from his Claremont home, shower at the campus, teach classes for the day and complete administrative duties as head of department before diving into teaching evening classes and still enjoying passionate discussions with his students. Seeing as he didn't arrive in a car, he then had to run back home.

In 2008, Ekama stepped down as head of the department and was able to concentrate more on research again. In 2010, his laboratory at UCT was demolished to make way for a new building, which further freed up his time as he no longer had to deal with the administration and fundraising for his own lab. Instead, he used colleagues' labs in Padua, Delft and Hong Kong, where he spent some productive research leave periods.

In 2020, Ekama co-edited the second edition of ***Biological wastewater treatment - Principles, modelling and design*** with international colleagues. It has already been translated into a number of languages, with the Japanese edition in progress at the time of writing.

A legacy that lives on in research

George is a giant in wastewater treatment all over the world, says Ikumi: "Whenever anybody asks me about my research, I tell them that I have been fortunate to stand on the shoulders of giants." Ikumi is not alone. After much thought, they recently defined the vision of the WRG. It is "to develop highly skilled engineers and scientists for industry research and academia, while engaging in innovative and impactful research, with an emphasis on environmental and socio-economic sustainability." Since the group has been so intimately shaped by Ekama, it is also a statement of his legacy.

At the time of writing, the university was in the process of launching the George Ekama Scholarship in support of research excellence. Throughout his career, Ekama worked with intent to ensure the necessary work will be done, to lasting effect. Even now that he is retired, this professor is still sparking inspiration, and switching on the lights of research innovation and solutions.

Prof Faizal Bux

Photo credit: Petro Kotzé

FAIZAL BUX

Leading wastewater research from the front

Current position:
Director of the Institute for Water and Wastewater Technology (IWWT),
SARChI Chair in Wastewater Treatment

Research interests:
Wastewater treatment technology,
algal biotechnology and environmental health

Awards

AWARDS AND APPOINTMENTS:

2021: WRC Legend Award

2021: Appointed Senior Fellow of the Water Institute of Southern Africa (WISA)

2020/21: NSTF-WRC award

2018: National Research Foundation Award: Champion of Research Capacity Development and Transformation at South African Higher Education Institutions

2018,2019: Vice Chancellors Research Award

2018: Appointed Fellow of International Water Association

2017: WRC Knowledge Tree Award for Transformation and Redress

2016: Appointed Fellow of Royal Society of Chemistry and Member of Assaf

1997: Technikon Natal medal for outstanding contribution to the field of research

Prof Faizal Bux works in a square and austere-looking building tucked away on the Steve Biko campus of the Durban University of Technology (DUT). Universities across the globe have tried to lure him away, but he has chosen to build his career here..

Unbeknown the passers-by, the stark 450 m² building contains 14 laboratories with high-end instrumentation including gas chromatographs, an elemental analyser, ion chromatograph, flow cytometer, atomic absorption spectrometer and Sanger sequencer, two cold-rooms, a walk-in incubator, offices, seminar- and boardrooms topped with a 100 m² greenhouse and four, 3 000 litre raceway ponds to experiment with algae. It is, of course, the celebrated Institute for Water and Wastewater Technology (IWWT), a Centre of Excellence in its core research areas of wastewater treatment technology, algal biotechnology and environmental health.

From its founding days in the nineties, Bux has steadily built up the institute to run the internationally renowned flagship programme it does today, picking up numerous local and international awards and honours along the way. The IWWT was one of 13 National Research Fund (NRF) recognised developed Research Niche Areas in the country from the early 2000s (until 2011). In 2012, Bux successfully secured one of the two NRF South African Research Chair Initiative (SARChI) chairs in wastewater treatment.

However, he says he never planned any of it – not becoming a full Professor, creating the IWWT or publishing so many papers (he is ranked the most published researcher at DUT). Instead, it’s all the result of hard work and a passion for his field of study. “I just really love what I do,” he says, foot tapping throughout, giving the impression that he is two seconds away from getting

Prof Bux, Director of the Institute for Water and Wastewater Technology (IWWT) with the 2019/20 NSFT-WRC Award.

Photo supplied by IWWT

“He looks at the challenges the world, and especially developing countries are facing, and affects the solutions that we need.”

right back to it. His work ethic, capacity and dedication are renowned, and he credits his busy mind for the few holidays he prefers to take. “He doesn’t delay things, and never procrastinates,” says Oluyemi Awolusi from Nigeria, a PhD student who started in 2011 and is now Research Associate at the IWWT.

Yet, Bux carefully selects the projects that he applies himself to, mindful to not over-extend himself to the point where he cannot deliver the absolute best results.

His work in the broader fields of pollution abatement, wastewater treatment optimisation and beneficiation are defined by key characteristics. First, he chooses projects that will make a difference. Water is a global and national imperative, he says and, as his knowledge has increased over the years, so has the passion for his work. “What I do is very much applied”, he explains, to have an impact on the water sector and society.” For this reason, the research group work closely with water utilities and municipalities.

This aptitude for practical research is matched by his publication outputs. Bux has contributed to 195 journal articles, edited 8 books, 22 book chapters and more than 160 conference presentations, with his citations standing at well in excess of 9 000. However, though substantial, the body of knowledge he will leave behind will be only part or his legacy. The value of his work goes beyond writing papers and conducting good quality science in the lab, to scaling up technologies quickly. For Bux, provision of water is not solely about research but about the actual delivery happens at municipal level. “At the end of the day it’s not only about high-quality science and new technology development, it’s also about delivery of water and sanitation to the people.”

In order to do this, he conducts work that is applied locally, but benchmarked both locally and globally in terms of publications, planning and collaboration – a second key characteristic of his work. The approach has played a pivotal role in the IWWT achieving its objectives, and the team are currently participating in a large number of bilateral and multilateral projects. His students are part of the approach. “He looks at the challenges the world, and especially developing countries are facing, and affects the solutions that we need,” explains Dr Krishna Kumar Jaiswal. The post-doc research fellow at the IWWT, one of more than over 50 Master’s and Doctoral students and 34 Postdoctoral fellows supervised by Bux says the Professor is giving him the expertise that he needs to help solve water problems not only in South Africa, but also those in his home-country of India, and in the rest of the world.

The outcomes of these approaches are stamped on the groundbreaking work they are conducting at the IWWT – of which there are ample examples across their specialties of wastewater treatment technologies, algal biotechnology and environmental health.

In the five years leading up to 2019, they had published in excess of 126 journal articles and 83 conference presentations locally and internationally. Some of their highlights include the following.

IWWT innovation in the field of wastewater treatment

One of the key outcomes of wastewater treatment is the removal of nitrogen, which can be deleterious to the environment. Conventional nitrogen removal is accomplished by nitrification and denitrification (the process by which combined nitrogen is reduced to gaseous end products) as individual processes. The anaerobic ammonium oxidation (ANAMMOX) is an emerging biological process for wastewater treatment where nitrite is used as an electron acceptor for the conversion of ammonium to nitrogen gas by the activity of a group of bacteria known as "ANAMMOX" which are strictly anaerobic in nature. This has great potential in the current world's scenario of energy crisis as it requires further optimization to emerge as an efficient and stable process to replace the existing technologies.

They IWWT has also embarked on research to investigate the prevalence and fate of antibiotics and possible derivatives in sewage treatments and the receiving environment.

Trailblazing research

An important part of research at IWWT involves the development of algae-based technologies for the recovery of resources from, and remediation of domestic, industrial and agro-industrial waste streams. Micro-algae have the ability to remove nutrients from wastewater with the simultaneous production of valuable biomass. In a nod to the circular economy approach, the use of wastewater as a nutrient and water source offers a dual-role purpose of remediation and generation of algal biomass, which can be used for value-added processes and products.

One project on algae biofuels, a multi-million collaboration that includes the eThekwini Municipality, is looking into using final effluent for microalgal propagation and biodiesel production. The project epitomises Bux's approach to scale-up technologies as quickly as possible, and to benchmark globally. The main funder is the Japan International Cooperation Agency, and the technology to harvest and extract oil was created by Japanese partners in a parallel development. The study is currently being conducted by the IWWT at a 300 000-litre demonstration-scale raceway pond at Kingsburgh wastewater treatment plant in Durban. Another project entails the study of microalgae-based treatment processes to remove pharmaceutical components from wastewater, currently focusing on the potential remediation of antiretroviral (ARV) drugs. Yet another is investigating the use of microalgae to fulfill the dietary requirements of farmed tilapia.

The IWWT has also made valuable contributions to wastewater-based epidemiology for COVID-19 surveillance, hotspot detection and trend analysis, methods which have shown immense potential globally as a powerful tool

Prof Bux with his students and research team in one of the IWWT laboratories.

Photo supplied by IWWT

Prof Bux delivering a lecture to students and staff.

Photo supplied by IWWT

to pre-empt community outbreaks at district levels. The institute set up national protocols using the latest molecular techniques and is monitoring wastewater treatment plants on a weekly basis. They are using an advanced molecular method (droplet digital PCR) for viral quantification, sharing the data with the provincial departments of health, the National Institute for Communicable Diseases (NICD) and other relevant authorities.

However, all of this might never have happened. Bux's career was nearly nipped in the bud even before it started, when he was expelled from school at 17.

Learning to be independent

Bux grew up not far away from the DUT campus. "All my life I had lived in an urban setting," he says, though he has also always loved nature, and his country. "I'm very patriotic of South Africa." After participating in a boycott of the apartheid government in 1981, Bux was one of a group of students in and around Durban expelled from school.

He describes the experience, shortly before finishing matric and on his way to achieving good final marks as "a bombshell."

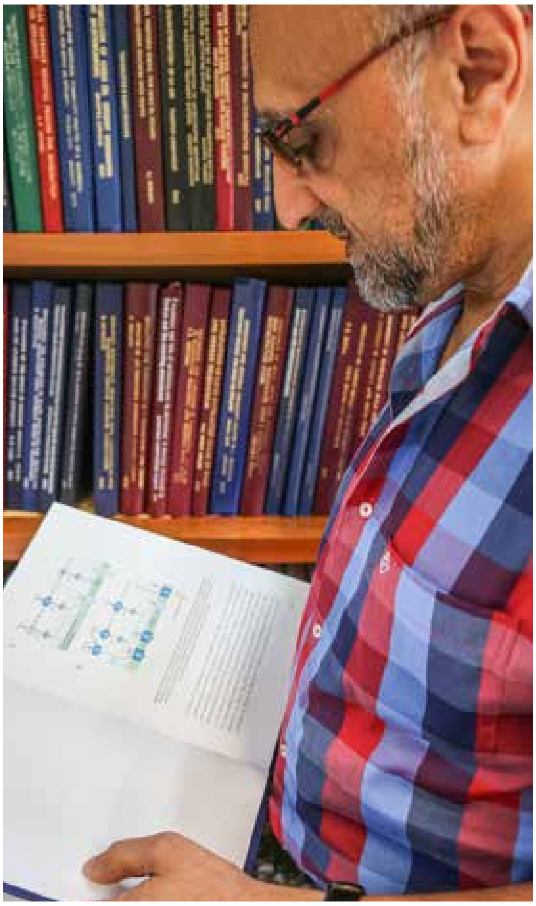
He was later permitted to write matric as a private candidate, but was not allowed to return to school, or receive any assistance from teachers. "I think getting expelled really taught me to be an independent learner." He attended the then University of Durban-Westville where he completed his BSc and BSc (Hons) degrees and started his career in 1988 as a Lab Assistant in the Department of Microbiology.

He had his first taste of life as a researcher in 1990 when he worked as co-project leader on a WRC-funded project focusing on heavy metal bioremediation. Bux took an instant liking to it. "It was really aligned to my interests in nature and science, trying to use micro-organisms to remediate effluent laden with heavy metals." Bux says at that stage he was just going with the flow, but really loved what he was doing and, moreover, once he published his first paper, was inspired to do it again.

He joined the Technikon Natal, where he initiated the Centre for Water and Wastewater Technology with now senior executive from Rand Water, Prof Hamanth Kasan, in 1994. Bux was appointed as researcher, with a primary mandate to initiate research in the field of environmental biotechnology specialising in water research. He took on the challenge for "really small money" but a view on the bigger picture. "I don't plan," he says, "God is the best of planners." Regardless of limited infrastructure and equipment, he managed to attract funding from the Foundation for Research and Development (now the NRF) and the WRC, which was used to purchase basic equipment and to initiate projects in consultation with water sector partners.

In 1998, the Centre for Water Research became the Centre for Water and Wastewater Technology. Bux took over directorship in 1999, three years before the Technikon Natal and the ML Sultan Technikon merged to form the Durban Institute of Technology (2002), which later became the Durban University of Natal. In 2003, the same year he obtained his doctoral qualification, he was appointed Associate Professor.

In those early years they functioned from a one-floor facility. The "jigsaw puzzle" saw them fit students into the lab where they mixed chemicals and Bux set up an office. "We still did good quality science under those circumstances," he remembers. "Good quality science" is an understatement. Within a few years, the centre was approved as an RNA funded Research Niche Area by the NRF – considered a significant milestone. In 2007, Bux received an award from the NRF for being the longest standing RNA within the Institutional Research Development Programme.



Prof Bux is the most highly cited researcher at DUT.

Photo credit: Petro Kotzé

The centre was granted institute status in 2011, becoming the IWWT and in 2019, the new four-storey building was officially launched at the Steve Biko campus. "Over the last 30 years, my career has progressed to lead a formidable team of researchers and establishing the IWWT at DUT."

Bux describes his career journey as fruitful, but not without hurdles. "Many times, I have worked hard and expected the deserved results, but was left disappointed." This happened in 2012, when he successfully applied for funding for the university SARChI chair, but finally the position was given to someone else.

“Don’t let your career get to your head. All you need is to be a good and honest person, and to not do harm to others.”

Raceway ponds to experiment with algae atop the IWWT building at UKZN Steve Biko campus in Durban.

Photos supplied by IWWT

Bux was initially sorely disappointed by the decision. However, he says it taught him the importance of perseverance. “Don’t let your career get to your head. All you need is to be a good and honest person, and to not do harm to others,” he says.

The ability to not get despondent in the face of setbacks, and to get up again and move on, are elements that he identifies as key to succeeding in an academic career. And, not long after the chair position was announced, he secured millions in funding from the JICA for the project on the production of biofuels using algal biomass. Perhaps, he says, this might not have happened had his focus been elsewhere. He was subsequently awarded the chair position in 2018.

Looking back from the apex

In his office, Bux reaches for the prestigious NSTF-WRC award, among the plethora to choose from, when asked to highlight one. Regarded as the Oscars of the scientific community, he received the award in 2020 for his research on using wastewater as a resource. He sees the award as a reflection of the high-quality outputs from his research team, and maintains that it further entrenches the credibility of the IWWT as a leading player in the water sector. The same year, Bux was also a finalist for the Lifetime Award, placing him among leading and globally-respected experts.

He has now reached the pinnacle of a rich and rewarding career. For him, this means doing work that is making a difference to society and the water sector, and building a body of work that is respected globally as shown in the high citations of his work. Bux is immensely proud to have a large number of students that he has trained who are now holding senior positions in the water sector in South Africa and far beyond. More importantly, he is delighted at being able to do what he loves every single day.

Prof Alison Lewis

Photo credit: UCT

ALISON LEWIS

For bold solutions,
dare to be brave and dare to do good

Current position:
Dean of the Faculty of Engineering and the Built Environment, University of Cape Town (UCT), member of UCT Senior Leadership Team, Director for the Crystallisation and Precipitation Research Unit

Research interests:
Industrial precipitation and crystallisation, recovery of value from effluent streams, water treatment through crystallisation, Eutectic Freeze Crystallisation, product and particle analysis, process analysis and control for optimised product quality, crystallisation process development, aqueous chemistry modelling of speciation, thermodynamic equilibria, hydrodynamic and population balance modelling of precipitation system

Awards

AWARDS

2021: WRC Legend Award

2019: National Science and Technology Forum (NSTF) Engineering Research Capacity Development Award

2016: Africa Water Leadership Award

2015: Distinguished Woman Scientist Award, Department of Science and Technology; WRC Knowledge Tree Award

2012: Distinguished Woman in Physical and Engineering Science award, Department of Science and Technology; South African Women in Science Award

2010: NRF President's 'Champion of Research Capacity Development at South African Higher Education Institutions' Award

1998, 1999 and 2000: UCT Merit Award

When Prof Alison Lewis first floated the idea of eutectic freeze crystallisation, a research curiosity studied in the Netherlands, for application in South Africa, people thought it was ludicrous. Basically, it entails freezing mining wastewater to separate water from salts. Years later, the technology is on the brink of commercialisation.

> "Be bold, and mighty forces will come to your aid."

Lewis has often gone against the grain of what is expected, only to emerge successful. In 2011, she presented a TEDx talk. TEDx is an internationally renowned platform where experts share 'ideas worth spreading'. One particular quote describes Lewis's outlook on life in a nutshell: "Be bold, and mighty forces will come to your aid."

Bold choices have marked her acclaimed career. She is a specialist in crystallisation and precipitation, which she applies to solve the disquieting problems of industrial effluent streams. Not only has she pioneered application of such technologies in water treatment in South Africa but through her research unit at the University of Cape Town, advanced fundamental knowledge in the field internationally.

She also puts her success down to what her husband (a psychiatrist) calls her oppositional defiance. When choosing a degree, a career advisor told her that the two most difficult options were actuarial science and chemical engineering and, that the latter was definitely 'not for girls'. With "zero idea" of what it entailed; her future career was thus settled.

Prof Lewis on her approach to a successful career

First, you need to be focused. Choose a specialty to focus on and then, second, become an expert at it. Lewis says that this approach has worked well for her. She often tells her students that if they are using what's in their 'toolboxes' to implement a project, they are spending their knowledge. Conversely, if they are filling up their toolboxes, they are developing knowledge. Research is about filling up the toolbox and for this, being an expert is absolutely critical. "You have to know what you're talking about at a deep, deep level."

Education and social responsibility

The career advisor was correct. Lewis remembers her graduate studies as extremely tough, but regardless of feeling out of depth, incredibly rewarding too. It also gave her the opportunity to express a deep sense of social responsibility that would guide her career choices in future. She was ardently involved in the student politics of the early-eighties, and took a year off in-between studies to focus on activism full-time. She graduated in 1985, and followed her degree up with a Master's on "Modelling techniques for biological systems" before taking up her first position as process engineer at the South African Nylon Spinners. She quickly realised it wasn't for her.

Searching for options for PhDs that would push her career in a new direction, she attended a course on low-cost sanitation, presented by renowned engineer and water

Prof Lewis surrounded by her students in the lab.

Photo credit: UCT

and sanitation expert, Prof Gerrit Marais. She initially thought the topic sounded terrible, but instead, left greatly inspired by what Marais had to say. Upon meeting him she was convinced that she had to consider a topic related to water. "It touched a nerve," she says. She realised that her contribution to the improvement of society could be to apply her technical expertise to the many challenges related to water.

Lewis subsequently chose a PhD on the "Mathematical simulation of dynamic behaviour of secondary settling tanks" marrying her loves of mathematical modeling, water and social responsibility through wastewater treatment. She accepted a position as Post-Doc Fellow at the UCT's Civil Engineering Department's Water Research Group in 1994, becoming a senior lecturer in the Chemical Engineering Department the following year.

Busy with all the obligations that came with the job, she reluctantly accepted an invitation to attend a course in Johannesburg on industrial crystallisation. It would be another game changer. Unbeknown to her, her career was about to really take off. Once again, she would dive boldly into the deep end.

Introductions to crystallisation

The course was presented by Prof Gerda van Rosmalen of the Technical University of Delft in the Netherlands. Van Rosmalen would spend twenty years as Professor of Industrial Crystallisation and Clean Technology at the University, with distinguished positions that included being a Board Member of the Working Party on Industrial Crystallisation of the European Federation of Chemical Engineers. She had the room full of industrial experts spellbound, Lewis remembers, and displayed a brilliant depth of knowledge, and the ability to apply it in the real work, two characteristics that Lewis has aspired to since.

The lecture not only introduced Lewis to an important mentor in her future career, but also the topic for much of her future research. Since then, she says, all of her publications reported on research in water, but with a strong "crystallisation flavour."

At the time, the industrial applications of crystallisation and precipitation already had a long history – precipitation has been studied scientifically since the 1930s. However, understanding of the operation was still very limited. Under the guidance of van Rosmalen, Lewis initiated industrial

"Out of total naivety, I started working on the most difficult problems."

crystallisation research in the Department of Chemical Engineering in 2000, to advance existing fundamental knowledge in the fields of crystallisation and precipitation, especially related to the South African and International mineral processing and extractive metallurgy industries.

Her early introductions to the topic were challenging. Initially, she had little idea how complex the process was, and how much work it would take to untangle it. "Out of total naivety, I started working on the most difficult problems," Lewis says. One of her first was nickel crystallisation at Impala Platinum, a "dirty, complicated solution with just about everything in it." The budding crystallisation expert remembers experiments with a small stainless-steel reactor that could be pressurized to 40 bar and heated to 180 degrees Celsius – a little bomb, essentially. Yet, with guidance from Van Rosmalen, she found her feet.

The Dutch expert took Lewis with to meet top role-players in the South African mining industry. Van Rosmalen would carefully interrogate them about their problems, and then "drop little nuggets of insight" to offer potential solutions. "Gerda used fantastic scientific underpinnings to solve real-world problems with unique and lasting solutions," Lewis says. Following along those tracks, Lewis carved out her own expert position in the field.

She officially established the Crystallisation and Precipitation Research Unit at UCT in 2006, building it up to national and international acclaim. In addition to collaborating with TU Delft, the unit now works with many global partners, including the Universities of São Paolo, Minas Gerais, Toronto, Sheffield, Manchester, Lappeenranta-Lahti, Aalto, Tianjin, KTH Royal Institute of Technology, Swiss Federal Institute of Technology and the Norwegian University of Science and Technology.

The group, described as curious and dynamic "pattern-sniffers" aims to improve the scientific understanding of precipitation processes for scale-up, optimisation and control. Their work is mainly connected to the mineral processing industry and water treatment, with specific projects that involve treatment of desalination brines and precious metal precipitation.

A flagship is the mentioned Eutectic Freeze Crystallisation (EFC) project. The challenges associated with its application placed it right up the alley for a researcher like Lewis.

Introducing innovative solutions to the mining industry

The prevalent method in South Africa to treat acid mine drainage and hyper saline brines is the use of evaporation ponds. EFC offers an enticing alternative. Evaporation ponds are expensive (upwards of R100 million) to construct, and require large amounts of land. Furthermore, the ponds only have a life span of about five years and promises the ever-present risk of leakage.

The term eutectic refers to a mixture of substances that melts or freezes at a single temperature. With EFC, a briny solution is cooled to its eutectic temperature, which causes the water in the mixture to crystallise as ice, which floats, and the salts to crystallise out as solids, which sink. In essence the unit transforms briny wastewater into clean water and valuable individual salts.

The benefits are hugely attractive in comparison the traditional treatment methods. The potential is zero effluent discharge. It negates the need for large parcels of land and the associated environmental dangers. It's not as energy intensive as methods like heat evaporation. Then, the technology has potential for application in multiple other industries, as well as possibly treating the brines produced through seawater desalination.

The research started in 2006, with a very basic crystalliser and a rudimentary understanding of eutectic phase diagrams. Originally funded by the WRC, the EFC project has since successfully attracted funding to the order of R21-million. A full-scale EFC wastewater treatment unit was eventually constructed at Tweefontein Colliery in Mpumalanga, moving the technology from theory to reality and is now in the process of being commercialised.

Big things behind, big things ahead

Throughout, Lewis has climbed the ladder of success. She was appointed as Professor in 2007, and as head of the Chemical Engineering Department in 2013. In 2015, she became the first woman to be appointed as Dean of the Faculty of Engineering and the Built Environment. Her duties include leading and developing the faculty of 4500 students and 450 staff in line with an innovative, progressive and strategic vision; developing the faculty research profile; and leading transformation.

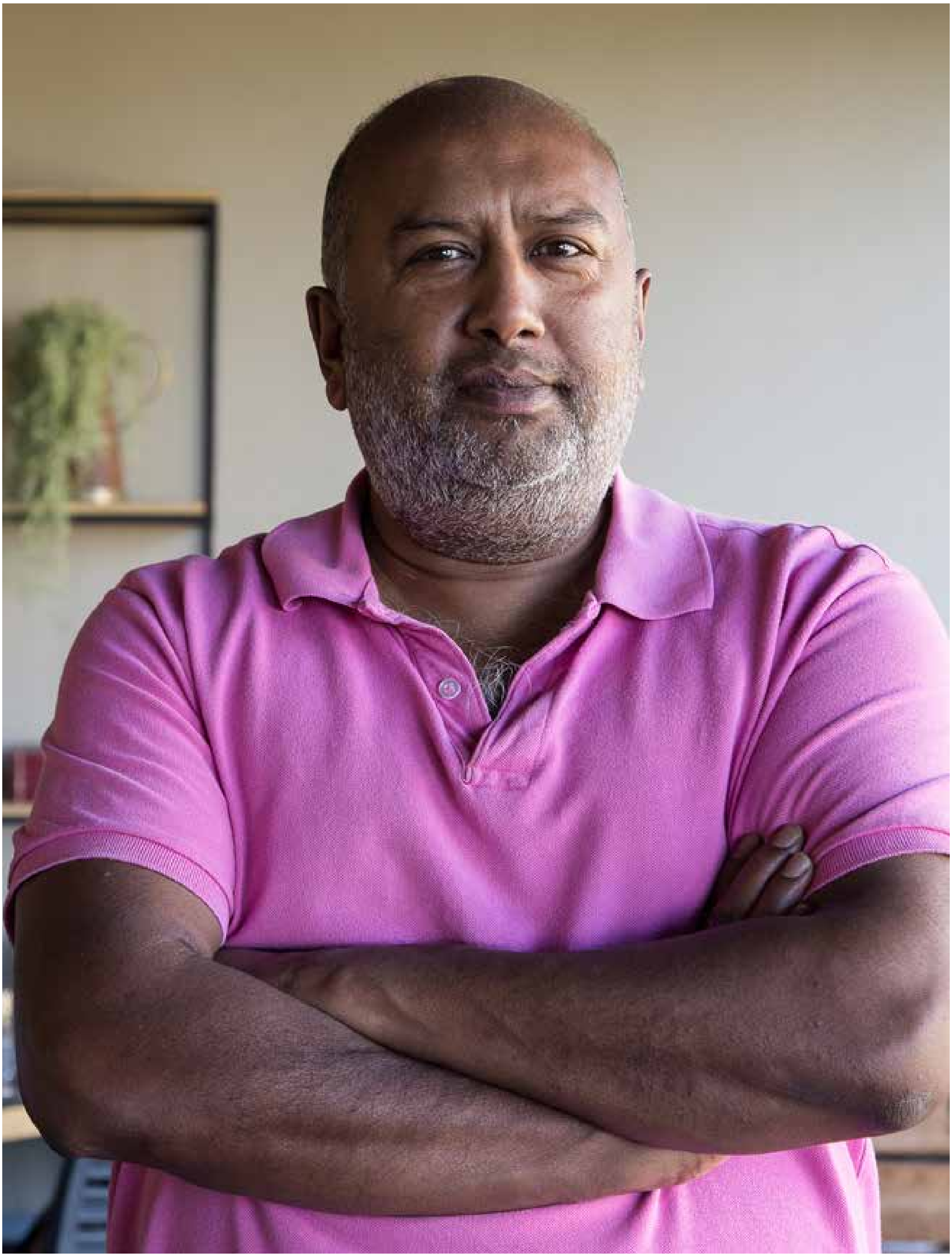
She is known as an international leader in research quality, planning and practice, delivering scientific work with impact and benefits to society. She has won wide acclaim for her research excellence, outstanding contribution to building the country's scientific and research knowledge base and for championing research capacity development. Over and above, she has been honoured for her vision, flair, acumen and professionalism to make changes and achieve results.

In spite of a demanding work schedule, she is also an avid believer in making time for rejuvenation and creativity. She surfs, reads broadly, loves doing crossword puzzles and spending time in nature, among a plethora of activities she keeps herself busy with outside of working hours. Lewis says it keeps the spark of innovation alive.

She has applied that to achieve what she sees as the most important purpose of her career: doing good. And, by boldly following that goal, mighty forces have certainly come to her aid.

In 2015, Prof Alison Lewis became the first woman to be appointed as Dean of the Faculty of Engineering and the Built Environment at UCT.

Photo credit: UCT



Dr Lingam Pillay

Photo credit: Petro Kotzé

LINGAM PILLAY

Traveller on the long road towards technologies that save lives

Current position:
Associate Professor in the Department of Process Engineering, Stellenbosch University

Research interests:
Membrane technology for potable water production and wastewater treatment and reuse, with a particular focus on novel technology development and application, suitable for developing economies.

Awards

AWARDS AND HONOURS:

2021: WRC Legend Award

2017: Runner-up: CIPC Public Sector Innovation Award in category 'Innovative Solutions Reducing the Cost of Delivering Services'

2017: Finalist: National Science and Technology Foundation (NSTF) Award in category "Research leading to innovation"

2013: WRC Knowledge Tree Award for Sustainable Development Solutions

2011: WRC Knowledge Tree Award for Innovation

For the first six months of her grandchildren's lives, Granny Josephine made weekly trips to the community hospital so they could receive treatment for chronic diarrhoea. Here in her rural village in Limpopo Province, this was not uncommon. People thought it's the price they had to pay for mixing baby food with the local, untreated water. Buying water was not an option as the price was simply too exorbitant, and the only bottled water to be had was only available at a supermarket located kilometres away.

Granny Josephine's village is not the only one suffering the consequences of unsafe drinking water. It is seen as a major barrier to the health and development of rural areas across South Africa. There are many dedicated efforts to improve the situation, but it remains a major challenge. If there's one thing that chemical engineer Dr Lingam Pillay likes, it's a challenge. He leans forward in his chair when asked about his career and achievements. "Let me digress," he says, "but, it's a good story."

An introduction to the field of engineering

"I'd like to say I felt a great desire at varsity to help humankind but," says Pillay, now Associate Professor in the Department of Process Engineering at Stellenbosch University, "it simply wasn't like that". Pillay says passion was never a driving force in his choice of career. "I never expected that." Instead, he expected to achieve success and everything that he associated with that at the time – "a massive bank balance, and outrageously expensive house and a few expensive cars cluttering up the driveway."

Whilst in high school in the late seventies, Pillay's initial choice of career was either medicine or law. "As any self-respecting member of the South African Indian community knows, in those days you were regarded as an abject failure in life if you didn't get into one of the two", he says with a smile.

Instead, Pillay investigated a degree in the then unfamiliar-to-him field of engineering since the South African Institute for Race Relations offered "huge" bursaries for the qualification. When he reported back to his father that it was a predominantly 'white' field, so he'll likely have a hard time at it, his dad promptly announced that this was what his son would study, up to the highest level possible.

Pillay duly started climbing the ladder to success. He obtained his degree and Master's at the then University of Natal (now the University of KwaZulu-Natal). He then joined the Pollution Research Group (PRG) of the Department of Chemical Engineering at the same university under the guidance of Prof Chris Buckley (featured elsewhere in this publication), for his PhD. Pillay stayed on as Senior Researcher with the PRG, renowned for its innovative research projects on water resources, wastewater reclamation, the impact of effluents on local environments and sanitation systems.

While Pillay was part of the outfit, the group developed a novel woven microfiltration membrane technology for the treatment of industrial effluent. With support of funding from the WRC, the technology looked excellent on paper, but didn't yet translate well into practice.

In 1995, Pillay took up a lecturer position at the Department of Chemical Engineering at ML Sultan Technikon (now Durban University of Technology) where he was tasked with initiating research and developing a research culture in the department. Then, in 2003, he joined the Water Technology Group at



Photo credit: Petro Kotzé

"I realised that 30 or 40% of the bottlenecks in developing economies is probably a lack of clean drinking water."

the Durban University of Technology as Associate Professor, and was appointed as Professor in 2009. The research group's main focus was the development of sustainable water and wastewater treatment technologies for developing economies, with special emphasis on membrane processes.

And early flagship project was the development of a capillary ultrafiltration system for drinking water production in rural and peri-urban areas. The team also developed a microfilter with a chemically active pre-coat for industrial effluent pre-treatment, and an immersed membrane microfilter. Other projects included capillary ultrafiltration for industrial effluent treatment and recycling; investigations into membrane bioreactors for the treatment of effluents with high organic loads; and the development of a floating media separator for raw water pre-treatment.

While there, they also revisited woven membranes, the technology that Pillay was introduced to years ago at the PRG. This time, they refined and transformed the technology into something they thought was workable. It was especially appealing because it allowed for household wastewater treatment systems that could be operated with limited skillsets, something that is often lacking in developing economies.

One day, around 2008, somebody asked if the group had considered using the woven membranes for treating drinking water. "Drinking water has never really been my interest," says Pillay but, as the question posed an interesting and perplexing challenge, he decided to take up the challenge. "I realised that 30 or 40% of the bottleneck in developing economies is probably a lack of clean drinking water," he says. He threw himself into the search for a solution wholeheartedly and set up a project for the concept that was "completely foreign" to him at the time.

From wastewater to drinking water

The aim of this initial project was to develop a point-of-use (POU) rural household water treatment unit on membrane technology. Pillay's first design was quickly shot down by a student from rural Bizana in the Eastern Cape. The student pointed out that the system was something that would never be used in his village. Pillay realised that the technical capabilities of any system would be secondary to its social acceptance. "It can be brilliant but if people don't like it, it's not going to work."

To improve the system, the researchers needed to get to know their potential users. The research team received training on how to talk to people, and extract the necessary information. By his own admission, Pillay was never really a people's person, but this was a necessary task. The researchers undertook a number of trips to rural areas in South Africa where reticulated water-supply systems were the stuff of dreams, and water was often collected from a spring, borehole or river and used untreated. An added dimension was that here, research activities had to be approved by village chiefs first.

When the researchers got back to their lab, the result would be revolutionary. The resultant product was called the VulAmanz, or the woven fabric microfiltration (WFMF) gravity filter. It is a system developed specifically for poor rural communities who have no other option than to use contaminated water and where electricity, piped water or technical skills are lacking.

The module consists of a PVC frame incorporating a permeate outlet, two sheets of fabric glued to either side of the frame, and a spacer between the sheets of fabric to facilitate fluid flow to the permeate outlet. The core of the technology is the robust woven polyester microfiltration fabric, which has an effective pore size of 1.3 microns (when clean). The pore size decreases as the membrane fouls, improving the permeate quality.

Pure water can pass through the membrane easily, but contaminants (including suspended solids, colloids and bacteria) cannot. Faecal coliforms are completely deactivated by the membranes and disinfectant.

It's very simple to operate. The user simply pours raw water into the tank, and collects it again from the tap. About 25 litres per hour can be treated. No water treatment chemicals or electricity are needed (it's gravity-driven), it's extremely robust and relatively cheap. To clean, the dirty membrane is simply brushed.

At lab scale, the project proved to be a resounding success – a simple, robust, inexpensive technology with potentially major humanitarian applications, including water provision to rural villages, clinics and schools; flood relief; emergency water supply during political crises and disease outbreaks. But, to put it into practice in the real world, they needed funding for a pilot project. It was no easy feat.

Taking technology from the lab to the field

Eventually, in 2015, about seven years after the seed for the system was planted, the WRC and the Department of Science and Technology (now Department of Science and Innovation) stepped in as funders for a pilot project. Pillay, now at the University of Stellenbosch, says it was initially a shock to the system. From building a handful of units in the lab, 1 025 rural water filters now had to be

Dr Lingam Pillay with former WRC Research Manager, Dr Jo Burgess, and his Knowledge Tree award.

Photo credit: WRC archives

"It can be brilliant but if people don't like it, it's not going to work."

deployed in participating rural communities. A total of 525 units were implemented in two villages (Malatane and Klipheuvel) in the Capricorn District Municipality and another 500 went to households in five communities in the deep rural area near Bizana in the Eastern Cape province. The last filters were deployed in 2017.

In 2019, Pillay and his team did a follow-up project to see if the units were still in operation and being used. One of the houses they visited belonged to Granny Josephine. She told them that, when the babies were seven months old, they received a surprise visit from the community clinic sister. She came to check up on them as she feared the worst: they had not been to the clinic for four weeks already. The sister was surprised to find the babies healthy and plump, though nothing in their everyday lives appeared to had changed. In fact they realised that the only change was the clean water from the VulAmanz filter, which the household had received a month earlier.

That is what I now call success, even though there is no accolade or award for that, says Pillay, while looking at a picture of Grandma Josephine and her grandchildren. Yet, theirs was not the only household where lives would have changed. Five years after the first units were implemented, 93% of them were still operating. "That kind of sustainability is beyond most rural water treatment technologies in South Africa and beyond," Pillay says.

However, the journey to get the system mass produced, was far from over. For that, the research team needed to find a funder, and tackle commercialisation of the technology.

Except for individual households, the VulAmanz filters can also be used at schools or clinics. The system, a Pressurised Water Filter (VA-WS) can be connected to a continuous water supply such as untreated water from a reticulated water system from a reservoir, pumped directly from the river or stream into a tank, or from rainwater collection tanks. Flows of up to 15,0 ℓ/min can be maintained. The system was designed after VulAmanz was approached by the Centre for Public Service Innovation (CPSI) under the Department of Public Service and Administration for help.

In the village of Malatane, deep in the rural Limpopo province where people mostly rely on rain collected in tanks for drinking and cooking, this supply was seriously threatened by the drought of 2018/19. Water from the near-empty tanks caused more stomach troubles than usual. Children began missing school as a result and schools were even running out of drinking water completely, affecting their ability to cook the staple lunch of maize meal. Up to 600 primary and 300 secondary school learners and staff were being affected.

Working closely within the local municipal, political, traditional and school leadership structures, VulAmanz supplied and installed a centralised water filtering and dispensing station in both the primary and the secondary school within a week.

Rainwater in the tanks is topped up with raw water from taps, when available, or from municipal tankers before treatment with the VulAmanz filters. The treated water is piped into 20-litre containers, one for each classroom. Follow-up audits have shown that the filter systems are fully functional, and making a difference.
Source: www.vulamanz.co.za/

Going commercial

The WFMF technology has much potential for commercial ventures beyond drinking water. It can be used for the reuse of pool backwash water, rainwater harvesting, septic tank harvesting and immersed membrane bioreactors. It can also be extended to industrial separations. The first option, the recovery of pool backwash, in particular, can potentially generate much profit from a relatively affluent market. Pillay says that for this reason, they did receive substantial interest from potential investors, though few were concerned with the technology's application for rural clean water supply.

Silent, he sat back in his chair. "I re-directed my university career for this." Instead of focusing primarily on projects that would result in journal publications, he took a big chance to instead gamble on this technology. "If it all fell apart, I'd have nothing to put down on paper."

Still, he decided to pass on the more profitable opportunities from investors that would focus on more lucrative applications, like pool-backwash recovery, only. "That was not what my fundamental funding was for," he says. Pillay subsequently formed a company with another engineer Laurie Barwell, to try and move the technology forward.

“It’s about ‘making a difference,’ he concludes “and that is something that I never planned for nor expected.”

Dr Pillay says that these days, his ideas of what success entails have changed substantially.

Photo credit: Petro Kotzé

After a couple more years of seeking investment to commercialise the technology the research group was offered, and accepted, a grant from the Technology Innovation Agency (TIA). The project primarily focuses on mass production of water filtration systems for treating drinking water, especially in rural areas. They are nine months in and the designs are “beyond anything they hoped for”. Pillay says they now “confidently expect” the technology to be commercially available by the end of 2021.

He is not interested in accolades or a life of luxury anymore, he says. Achievements that he counts throughout his career now are the people’s lives he could make a difference in, like the many students who sent him letters to thank him for the major changes he made to their lives, and the positive feedback from the people who have benefited from the technology.

“In retrospect, success is not a large bank balance, an outrageously expensive house, and expensive cars littering the driveway – Now success to me is looking into the mirror each morning and realising that there is at least one person on this planet whose life has changed for the better because of my efforts”.

“It’s about ‘making a difference,’ he concludes “and that is something that I never planned for nor expected.”

Chris Swartz

Photo credit: Petro Kotzé

CHRIS SWARTZ

The civil engineer that designed
his own way to success

Current position:
Owner of Chris Swartz Water Utilisation Engineers (CSWUE)

Research interests:
Water treatment and water supply projects, water reclamation and reuse

Award

AWARDS

2021: WRC Knowledge Tree Award – Sustainable Development Solution
2021: WRC Legend Award

Chris Swartz has never been one to wait for work to come his way. He does not like sitting still (not even in a laboratory), seeks opportunities over challenges, and is excited by solutions more than problems. He prefers his research applied. Swartz describes himself as a typical civil engineer who, especially in his younger years, focused on outcomes more than emotions. Yet, his office tells a slightly different story. Along shelves with folders on skills mapping and wastewater treatment plant control manuals are some of his own paintings. He is an artist and a musician too.

Similarly, his career has been one of variety, moulded around his unique skills, likes and interests. Instead of a research or academic institution, or a large company, his vehicle has been Chris Swartz Water Utilisation Engineers (CSWUE), the one-man business he established in 1991 to great success. This has led to both groundbreaking national projects and large international collaborations in water resources management. His track record has proven that a small consultancy engineering practice can play a very necessary role against great odds of highly competitive corporate big organisations.

His business model is based on a holistic approach to the water field, something he would recommend to anybody who wishes to follow a similar path. Over the years, he has worked in water-supply projects, the evaluation of water treatment technologies and water and wastewater treatment plants, capacity building, water reuse and desalination schemes, risk assessment and management and rural water supply, to name a few. "Don't limit yourself," is his advice.

He has never wanted to 'go big' with his business, nor has he considered a partner. Only some of the benefits include that he does not have to deal with bureaucracy or politics, he says. Neither has he ever regretted the day he decided to become an engineer.

An early knack for spotting an opportunity

Swartz was rather unsure if he should choose architecture or engineering right up to the time he reached the university registration desk, but now looks back on his choice with relief. "It has offered me a good mix of physical engineering work, research, technology evaluation, project management, water quality monitoring, environmental engineering and municipal services support, as well as exciting formats of teaching," he notes.

He was the first person in his family to go to university, and obtained his degrees in Civil Engineering, and a Master's in Water Utilisation Engineering, at the University of Pretoria. Water interested him from early on. At the time, South Africa's serious water quality issues were just coming to the fore and the topic, and aspects thereof run like a line throughout his career. His first jobs were with the South African Transport Services in Pretoria. To start, he was a project manager on the design and construction of a 28-kilometer new railway line and then, a design engineer at the specialist water office.

The young professional landed a dream job in 1987 as senior research engineer and project manager at the Council for Scientific and Industrial Research (CSIR) Division of Water Technology. "It was absolutely what I wanted to do," he says of a job that played on all the novice engineer's capabilities and strengths.

Just as he was starting to grow in his profession, the CSIR was undergoing change. Government funding was declining, and the organisation was being restructured to

Civil engineering has allowed Chris Swartz a good mix of opportunities, from the lab to many adventures in the field.

Photo credit: Petro Kotzé

generate its own income through consulting services. It didn't suit everyone, and many researchers left as a result, Swartz recalls, but he adapted exceptionally well. "It was exciting," he says of the time, which offered vast opportunities to learn new skills and develop a network of contacts.

Over and above that, it taught him how he liked to operate. Swartz had a knack for project management, and the ability to spot an opportunity and capitalise on it. He started developing projects, taking advantage of the resources and expertise that the CSIR offered.

The work straddled consulting work and development projects. Among others, there were feasibility studies for water supply to rural communities across South Africa, package plants developed for rural water and wastewater treatment in Africa, and water-supply projects in Kenya and Uganda. Swartz launched and managed the Process Technology Group, which delivered services and support to evaluate technologies. Furthermore, he started the Effluent Treatment Club, a collaborative platform for companies to exchange ideas and information on waste minimisation and encourage each other to improve process efficiency, save money and reduce their environmental impact.

"I am absolutely orientated towards problem solving," he says. As the nineties approached, Swartz and his wife, Reinarda, had a different kind of problem to solve. They wanted to raise their kids in the countryside. The couple pulled a map of the country closer and, after considering all the pros and cons, moved to Mossel Bay.

Chris Swartz's lessons on how to start your own business

- Go full out and persevere
- Believe in yourself
- Be motivated. Don't let anything distract you from your goal
- Have faith

The launch of a new business

"We literally squatted in Mossel Bay at the start," he chuckles at the memory of their move to their new home (the family has since relocated to Cape Town). In 1991, the two Swartzes both opened their own practices; hers as gynaecologist, his as consulting water utilisation engineer.

Initially, it was only a geographic move for Swartz, who worked from his new satellite office on a part-time contract for the CSIR. The rest of the time, he had to build up his new business. "It was challenging, and very scary," he remembers of those early days pounding the pavement and making cold calls to introduce himself to municipalities and potential partners. "It's only lots of prayer and mercy that got us through (those early days)," notes Swartz, but adds that in retrospect, it was also nice. "Those are forming experiences, so it's necessary."

By the time his contract with the CSIR ended in 1995, he was well on his way. One of his earliest contracts was to monitor the wastewater treatment plants for the Southern Cape Municipalities, including Oudtshoorn, Swellendam, Hessequa and initially, Mossel Bay and George. Some of this work is still ongoing. Typical Swartz, he was constantly on the lookout for more opportunities.

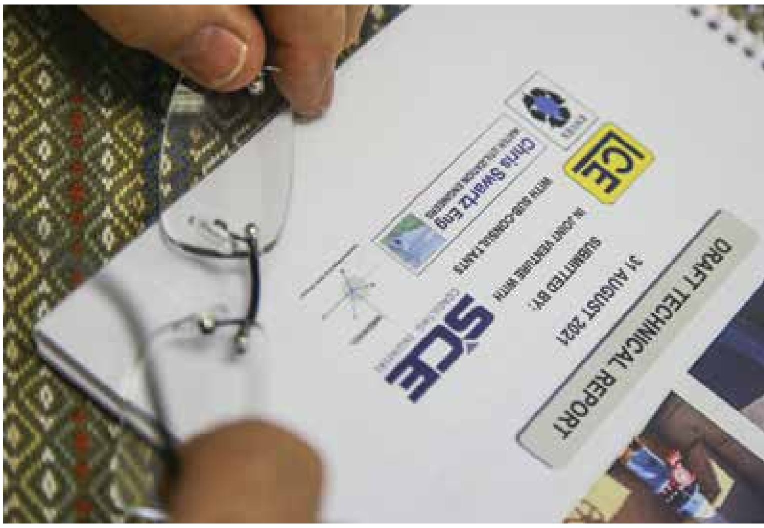
Another topic that caught his attention when he arrived in Mossel Bay was the brown colour of the region's water. In places like George, the water was so dark, it looked like cola. Swartz found almost no research had been done on the topic, and a general lack of knowledge on the effect of treatment processes, and in particular coagulation, on the removal of the different constituents of the coloured water. "The water treatment plant operators worked in an ad hoc way, and without the necessary knowledge on how to adjust processes or chemicals," he says.

A first in the country, Swartz's project characterised and classified South African coloured water and its natural organic matter, and determined to what extent natural organic material was removed during treatment. He then assessed the treatability of each of the main, coloured water types. The work resulted in a manual on the treatment of such surface waters, followed by a number of workshops to convey the results. The workshops included participants from local municipalities and provincial government. It would become a hallmark of much of his later work. "I always try and involve the end-user," Swartz says. "The people that you do the research for have to walk through the process with you."

In the late nineties Swartz looked towards small and rural water treatment systems, starting off as the project manager for the construction of new and upgrading of existing plants at various locations in the country. Again, he wrote guidelines for the end user. He evaluated numerous technologies for potable water treatment and ran national and international workshops on the sustainability of small water systems in southern Africa.

In the early millennium, the Western Cape Government acted on the ongoing deficiencies in the operation and

“It’s only lots of prayer and mercy that got us through (those early days).”



Over the span of his career, Swartz’s list of experience has grown to include many topics such as water-supply projects, the evaluation of water treatment technologies, capacity building and water reuse and desalination schemes.

Photo credit: Petro Kotzé

maintenance of the province’s water and sewerage works. Once more, Swartz stepped in to help. With the University of Stellenbosch, he developed and presented training courses and short courses in water and wastewater treatment to municipalities and Water Boards in the Western Cape and thereafter, the Northern Cape and Free State. The courses consist of on-site training, intermediate courses, advanced courses, train-the-trainer, management/ supervision courses and telematics training. Short courses are still presented nationally.

His experience had now expanded to include capacity building projects, training of water and wastewater sector personnel, the upgrading of water and wastewater treatment plants and municipal water supply and sanitation projects. “If you want to specialise in only one topic, you will probably not make a living as a consultant,” Swartz maintains.

However, for Swartz it is about more than survival. He finds inspiration in the sustainable solutions he contributes to the South African water sector. This transpires in his contributions to the continual improvement of service delivery, to healthy communities through improved water supply and, to environmental protection through wastewater treatment. In 2002, Swartz added desalination to his list of expertise, just as South Africa started to seriously consider the technology to augment water supplies. His desalination guide for South African municipal engineers was published in 2007.

His work in this area has also included pilot studies and conceptual designs for desalination plants for Suiderstrand and Waenhuiskrans, and a feasibility study for seawater desalination for Richards Bay Coal Terminal.

An alternative concept of success

Success as a small business owner and consultant looks very different than for a researcher or academic, Swartz explains. In this game, there are no promotions. Success is securing a project, especially if it comes on the back of trust and expertise you have built over time. According to this measure, Swartz has done exceptionally well.

Working with the Global Water Research Coalition (GWRC)

Swartz was the project leader for a 2014/15 GWRC project in which compendia of energy reduction and generation were compiled for worldwide use in the water sector. The project was represented by GWRC partners in Australasia, Europe, South Africa and the USA, each continental group drafting a report of their best examples from regional utilities in their region, which were combined into the global compendium.

In an earlier project, by the Water Environment Research Foundation (WERF) on behalf of the GWRC, CS Water Utilisation Engineers was part of the consortium commissioned to create a compendium on sensors and monitors and their use in the global water and wastewater industry.

In 2006, Swartz was approached by the WRC to be the South African representative on the European Union project, TECHNEAU (Technology Enabled Universal Access to Safe Water), launching his career onto international platforms. The large five-year project involved about 30 collaborators. It entailed comprehensive investigations into water-supply solutions and technologies to address future long-term challenges caused by rapidly changing impacts on water supply worldwide.

Work areas included the identification of driving forces in sub-Saharan Africa that lead to change in the water industry and the development of adaptive strategies to address these drivers. It also included a case study at the New Goreangab Water Reclamation Plant in Windhoek to evaluate new monitoring techniques and in-line sensors for raw and treated water quality monitoring and alarm systems. For this purpose, Swartz visited Windhoek numerous times. Not only did he learn a lot from the experience, but it introduced him to water reuse, a topic that he has since made a focus area.

Building up a portfolio in water reuse

In 2009, severe drought necessitated the Municipality of Beaufort West to consider water reuse to augment their dwindling water supplies. They phoned Swartz for help. “At first, I was surprised that they considered it,” he says, “but I have since learned that when disaster looms, people are easily convinced.” As an independent engineer, he helped compile the project tender documents and the evaluation of proposals. He also conducted risk assessment and risk management studies of the eventual Beaufort West Water Reclamation Plant.

Since then, he has become an established expert in the topic, and has carried out a number of projects for the WRC. These include guidelines for monitoring of water quality in reuse projects, health impact risk assessment and management,

Swartz has received honours and awards that confirm the strength of his skills and expertise.

As a consultant, success takes the shape of projects, trust and expertise, Swartz says.

Photo credit: Petro Kotzé

costing models and, recently, research on defacto (unplanned) water reuse. This refers to when towns that are situated downstream of polluted rivers inevitably treat the wastewater that they receive in their water treatment plants. Recently, he was also employed as specialist consultant to the City of Cape Town for their water augmentation projects, focusing on water reuse and desalination. Swartz also wrote the ***Water Reclamation and Reuse Guide*** for the Institute of Municipal Engineering of Southern Africa.

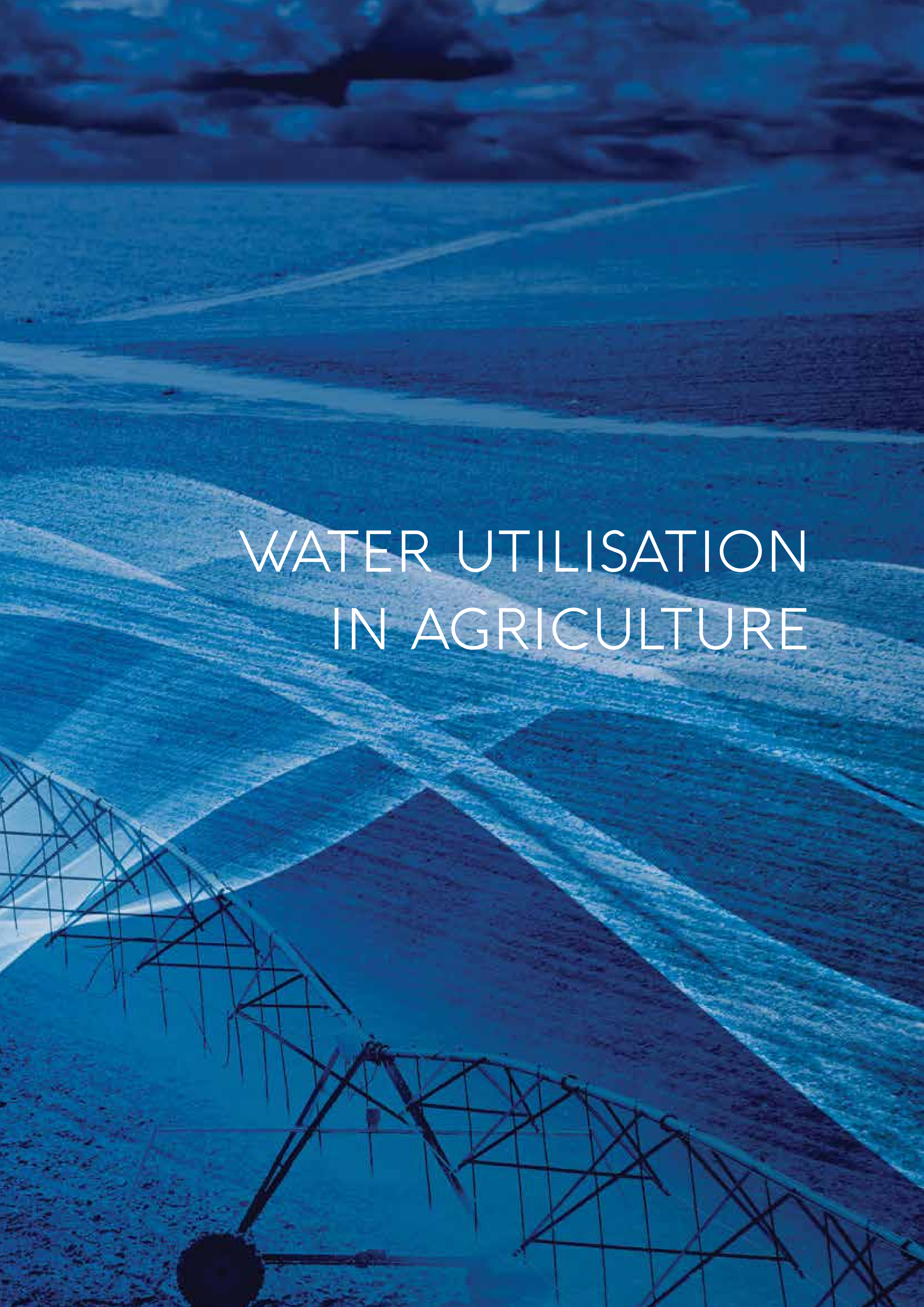
A member of the Water Institute of Southern Africa (WISA) since it was established in 1988, Swartz founded WISA's Water Reuse Division in 2013 (he was a WISA Director and Board Member in 2016 and 2017) and championed the WISA Water Reuse Western Cape Chapter.

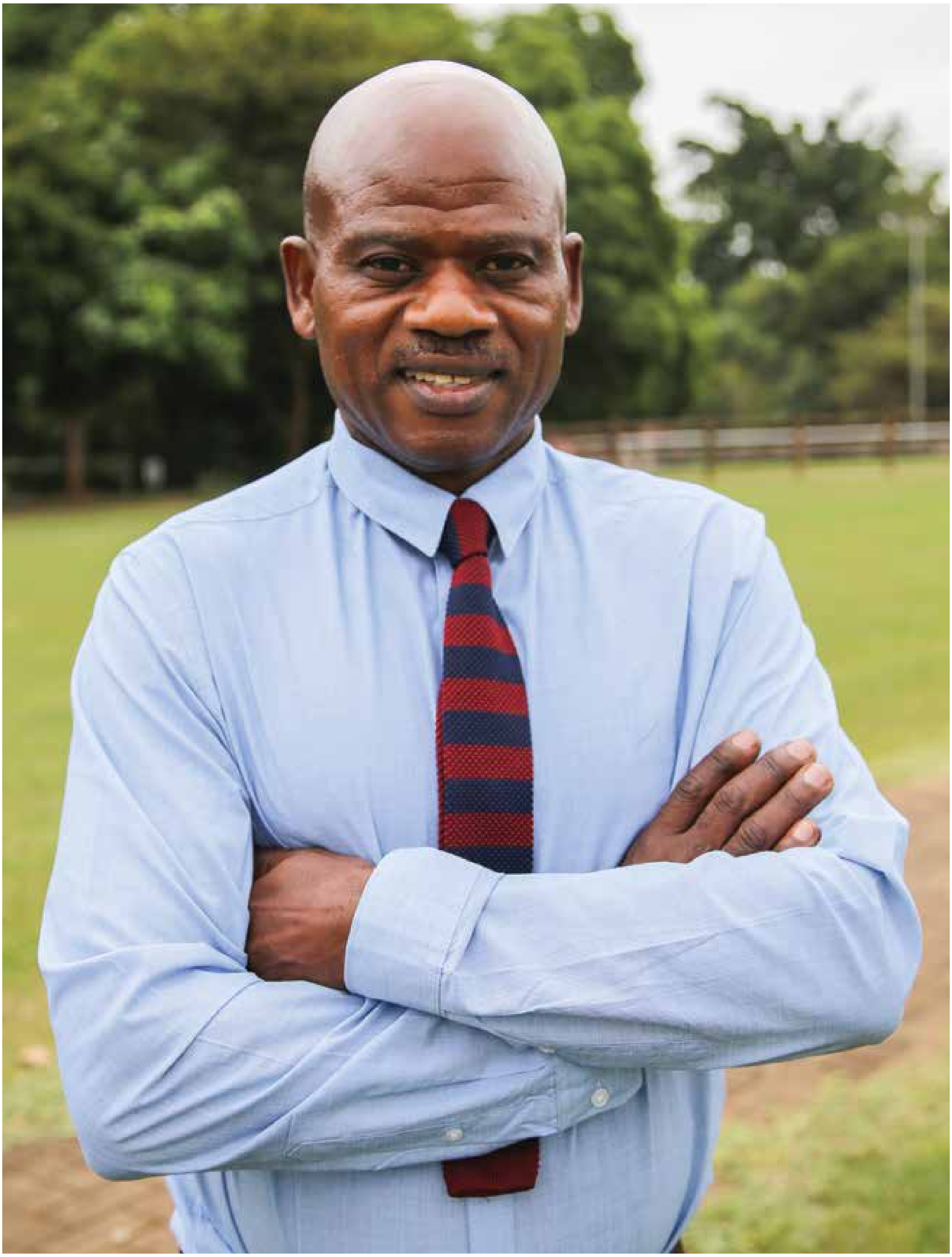
Focusing on water reuse was a strategic decision, Swartz says. "I could see this was where water provision would head to." He says it's in his character to find what will be necessary in future. The work has since created new directions of thinking. "We have shown that many small towns can apply water reuse and that it's not something to be scared of."

"I like initiating new projects, programmes and centres, he adds. "A job where I only have to act reactively is not for me." This approach has allowed him to focus on what he finds inspirational, specifically, mentoring, coaching and teaching over and above his research projects. More than 20 Master's students, and almost ten students from Sweden obtained their qualifications under his mentorship. Many more have joined his consultancy through the years to gain experience integral to their future careers.

Except for following what inspired him, building a business around his specific strengths and casting the net wide enough the make a living, Swartz says he found there to be more to his individual recipe of success. Added to the mix are, integrity, perseverance, support from his family, pride in his work and faith. Together, these have allowed him to forge his own way forward towards a legendary career in water research and management.

WATER UTILISATION IN AGRICULTURE





Prof Albert Modi

Photo credit: Petro Kotzé

ALBERT MODI

Guardian of SA's indigenous
food security knowledge

Current position:
Deputy-Vice Chancellor, Head of the College of Agriculture Engineering & Science, UKZN

Research interests:
Agronomy, including crop science, seed science,
plant physiology, field crop management,
underutilised neglected crops and sustainable agriculture

Awards

AWARDS

2021: WRC Legend Award

2016: UKZN Distinguished Teacher Award

2015: WRC Knowledge Tree Award for Human Capital Development in the Water and Science Sectors

There are spirit people that live in the sea, so you shouldn't dirty the rivers that run into it them. Water that has 'slept' is for cooking, but water for the morning's tea must be fetched fresh from the river. Crop scientist, Prof Albert Modi, grew up with stories like these, told from one generation to the next in the Transkei countryside where he grew up. These stories and culture remain important to him, and served as inspiration for a career in which he has strived to take indigenous knowledge from rural backyards to implementation in management strategies.

"As scientists we can take advantage of certain things that we are not sure of yet." Referring to the tales and legends of his youth, Modi says that you can ask whether they are true or not, without calling them lies. He looks at Albert Einstein as a mentor. When the famous physician first theorised that light could bend, nobody believed him. Years later, his general theory of relativity, that maintained that an object passing in front of another would bend the light of the more distant object, was proven to be correct. But first, Modi points out, Einstein had to believe something to be true, even when nobody else did. "Why can I also not believe in something that has not yet been proven right," he asks. "Why can I not say that light can bend?"

In his own field of expertise, Modi does exactly that. As Deputy Vice-Chancellor and Head of College, Modi fills the highest academic leadership position within the University of KwaZulu-Natal (UKZN) college structure, leading the academic, teaching and research strategy. He is also a specialist in, and an advocate of South Africa's so-called 'orphan crops' – traditional crops perceived to be of little value beyond that offered to the small-scale and traditional farmer. Modi has always believed otherwise. Among his research projects, he has worked on the water use and production of drought tolerant traditional crops as a viable alternative to the currently grown, more popular variants. These crops include Amaranthus, wild mustard, sweet potatoes, wild melon, taro, Bambara groundnut, cowpea, maize landraces, millets, proso-, pearl- and foxtail-millet and sorghum.

Modi believes that these crops could stand among their own – just as much as commonly commercially grown vegetables, when nobody else believed the same. The establishment of the Ezemvelo Farmer's Organisation (EFO), which now supplies amadumbe (taro) as a commercial crop commodity to high-end supermarkets, Woolworths, Pick 'n Pay and Shoprite, is one of his most important achievements. The project, he says, exemplifies the significance of indigenous and traditional knowledge. People were once ashamed of growing and eating amadumbe and, Modi says, for that to be taken all the way to a high-end retailer such as Woolworths, remains a very important achievement to him.

Taking taro from the fields to supermarket shelves

The EFO, a sustainable agriculture organisation of smallholder farmers in KwaZulu-Natal, was initiated by Modi in 2001 and is the first of its kind in South Africa. The farmers grow amadumbe in rain-fed fields and harvest the crop every week in season. As a collective, the farmers are able to supply viable quantities of the vegetable to market. The produce is collected and transported to a privately-owned pack house some kilometres away for cleaning, quality control and final packaging before distribution to Woolworths' nationwide food market retail points.

The EFO farmers, the Farmwise Pack House and Woolworths constitute an agri-food chain with the specific function of providing organically certified amadumbe for the traditional vegetable market niche. The pack house also serves as information hub to the farmers, and provides feedback from the retailer to the growers with respect to specific standards, presentation and quality of the produce.

The project is an example of how South Africa's rural communal spaces can be transformed into economically viable, socially stable sectors, where locals can make a living, instead of migrating to cities, Modi says. He credits his own rural upbringings as the inspiration for his career success.

The lessons from the water spirits

Modi was born in Centane, in rural Transkei. The rules were never written down, but children knew to drink water from the tributary and not the main river. "We respected the big river that takes the water to the sea where other kinds of humans and spirits lived." Because the sea, and the spirits, demanded such huge respect from the community, they looked after it carefully. Modi smiles. "You don't have to say that it's true, but don't say that it's a lie."

Let people believe in those spirits, but try to connect it with science, he maintains. Looking back, Modi now understands that the tributaries were cleaner, because the main river was used for activities like washing, swimming and fishing. The information was right, he says. "Even as scientists, we can take advantage of things that we aren't sure of yet."

The indigenous knowledge that he grew up with influenced the way he behaves.

Following his primary, secondary and tertiary education in the Transkei, Modi completed his BSc in Agriculture, majoring in Crop Science at the University of Fort Hare after he received a bursary for the course from the former Transkei government. The bursary decided the future direction of his career.

Despite all evidence Prof Modi still has to regularly convince people that indigenous knowledge can be a very important part of our movement forward as humans.

Photo credit: Petro Kotzé

He excelled, earning further bursaries and scholarships for his entire tertiary education, including from the Pannar Seed Company. Modi failed only once, a class in biometrics during his Master's at the former University of Natal (now the University of KwaZulu-Natal), prompting his lecturer to tell him he should consider going back to the Transkei to become a tractor driver. The comment changed his life. After some soul searching, Modi realised that he was without a doubt meant to be a researcher. When he realised the humour in the comment and the lecturer's attempt at motivation, he became an important mentor to the young student and he later appointed Modi as biometry tutor at the then-predominately white university.

Modi says he learned invaluable lessons from the experience. "I believe that you are on this earth to be upset and disturbed. It would be such a terrible life, if you appeal to people all the time, and you make no mistakes. As a scientist, you will fail over and again, and you will also succeed. Failure is not fatal; success is not the end, there is nothing that is a lie. If you see that, you will always be happy. And when you see somebody who is successful, you see yourself being successful."

Following the successful completion of his Master's, Modi won a coveted Fulbright scholarship to complete his PhD in the USA, another personal major achievement. Thereafter, Modi started his academic career as a lecturer at the University of Natal, becoming a full Professor of Crop Science after the university merged with the University of Durban-Westville to form UKZN. He has spent 22 years working as an agronomist for Pioneer Hi-bred International and as an academic agronomist focusing on Crop Science. His contributions include the establishment of curriculums in Seed Science and Technology and Sustainable Community Agriculture.

However, when he became a scientist, he started remembering those stories of his youth, and how it shaped a bond between him and the water – including when it must be fetched, that it must be fresh and clean and that the big river must be taken care of. Now, when he sees how dirty the Msunduzi River is that flows through the city of Pietermaritzburg where he lives, and thinks of his contribution as a city dweller, he constantly feels guilty. "That's not how I was raised." He says he believes in this way, and in countless others, there is a lot of science in indigenous knowledge that can be followed.

Modi is currently the project leader for the ongoing uMngeni Resilience project. The project aims to reduce the vulnerability of communities and small-scale farmers in the uMgungundlovu District Municipality (UMDM) to the impacts of climate change. The project team aims to increase climate resilience and adaptive capacity by combining traditional and scientific knowledge in an integrated approach to adaptation. A range of interventions will be implanted in the process. These include early warning and disaster response systems; ecological and engineering infrastructure solutions; and, integrating the use of climate-resilient crops and climate-smart techniques into new and existing farming systems.

Taking the world forward without relying on experts with titles

Though he has already reached the top of the range of qualifications, Modi constantly tries to connect with people who are not educated according to the standard definitions of society. He believes the definition of education should be updated. "Science must allow you to do things in a technological fashion that is progressive, together with the world, but the roots of your indigenous knowledge must still be there."

He has seen this first-hand time and again. His community outreach and research has seen him collaborate with farmers across the province of KwaZulu-Natal, including Umbumbulu, Mtubatuba, Jozini, Richards Bay, Swayimani (Wartberg), Deepdale, Mphophomeni, Kokstad and Vulindlela in Pietermaritzburg.

However, Modi says there's still a lot of work to do. "I still have to convince people that indigenous knowledge can be a very important part of our movement forward as humans." Modi believes in a revolution and evolution of humankind through science and technology, but that this rests in everybody's hands. "Human beings must believe in their responsibility to take the whole world forward, instead of relying on someone with the title of professor or doctor to do it."

He says he will not publish hundreds of papers, but hopes to produce one lasting solution before he dies, just like Albert Einstein. "If God makes me live another half a century, I may actually produce one, but the nice thing will be that the solution will be owned by many people."

A legacy in the making

Modi would like to leave a legacy of interconnectedness, in which everybody is respected to have knowledge without having to be labelled as 'educated'. This knowledge must be centred on the preservation of nature. This future must be built on mutual respect, he says. And, he points out, "make sure that you learn something from another person, and when the agricultural textbooks are rewritten, understand that it might be done by somebody who's never been to school."

For Modi, this journey that he is on will be handed over to somebody else one day. The race will never end, he says. "When I am no longer running, that person will still be running my race, and I will be supporting that person in a different way. My imperishable spirit will live on in the attitudes and approaches of the people whose lives I touched. They will use it in different ways. Some of them are going to become professors, some of them are going to start new companies on water."

"Why can't I believe it to be true? You can ask whether it's true or not, without saying it's a lie."

Prof Albert Modi on leadership...

"If you do something, and can look at the consequences, learn and adapt your next decision as a result – I think this is one of the most important characteristics of a leader now. You need to learn about the impact of what you've done the previous time and do it better the next time."

Dr Bongani Ncube

Photo credit: Petro Kotzé

BONGANI NCUBE

Passionate pathfinder with a heart close to the soil

Current position:
Researcher at the Centre for Water and Sanitation Research at the Cape Peninsula University of Technology, postgraduate supervisor and lecturer in Soil Science in the Department of Agriculture, Water and Waste Treatment, and Environmental Engineering at the Department of Civil Engineering and Surveying

Research interests:
Water allocation, drought impacts on agriculture, indigenous knowledge, and water resource management.

Awards

AWARDS

2021: WRC Legend Award

2020: National Research Foundation Rated Researcher (C3), 2021-2026

2017: Water Research Commission Knowledge Tree Award: Category Empowerment of Communities:

2016: Profiled as 'Extra-ordinary Woman' by CPUT

2015: Certificate of outstanding contribution in reviewing – Journal of Physics and Chemistry of the Earth, Elsevier

How do you get water to farmers? The solutions developed by Dr Bongani Ncube in answer to this age old question has earned her a string of awards, including the coveted Water Research Commission (WRC) Knowledge Tree award in the Empowerment of Communities category. This passionate researcher has been recognised locally and internationally for her outstanding work in the fields of water and agriculture.

According to Ncube, she found success in the same way that she continuously urges her students at the Cape Peninsula University of Technology (CPUT) to: "Follow your passion." Without it, you will never be able to sustain the hard work required to get there. For Ncube, the seeds that would blossom into her long and celebrated career were already planted when she was a child in Kezi, Matobo District, just south of Bulawayo in Zimbabwe, in the fields that her mother cultivated.

The child of a farmer

"My father was a salesman in Kezi town, while my mother was a smallholder farmer. She was very successful at it," notes Ncube. A very curious child, she always wanted to see the crops grow and how they were harvested. She spent her days investigating, reading whatever was available and could often be found in the fields.

Whatever my brothers did, I did and whatever I did my brothers did, she says. "My mom didn't make any distinction between her boys and girls." As a result, all the children worked in the fields, and her brothers turned out to be very good cooks. Ncube laughs at the memory. "It was natural for me to take up a man's job!"

When the time came for her to choose a career, her eldest brother was desperate for her to become something responsible like an accountant, but she told him she would "never" do that. Instead, she listened to her heart. Ncube graduated top of her BSc Honours in Agriculture (Soil Science) class at the University of Zimbabwe in 1994.

Her first job was "a lot of fun." She was employed as an ecologist in the Zimbabwean Ministry of Environment and Tourism, to undertake research and environmental monitoring. "I had to attend to issues like fish poisoning and pollution around the city." The water pollution that she saw was "aweful" but, it made her think. Until then, working in the water sector was never part of the plan, but what she saw made her curious. When she became aware of a Belgian Embassy MSc scholarship advertised through her employers, she immediately put her hat in the ring. "I was like, I'm going for that." In 1999, Ncube enrolled for her MSc in Water Resources Engineering and Management at the University of Zimbabwe.

She had to show her grit from the get-go. "In one of my first classes, this guy looked at me and asked what I was doing there, and if I was there because of privilege and affirmative action. It was apparently the first time the civil engineer encountered a 'girl' in class at university."

She looked at him and said, "my brother, there's no privilege here, I'm here by qualification just like you." Ncube cracks a broad smile at the memory. "As time went on, he was like, oh ja you were right!" It wouldn't be the last time she faced discrimination because she was a woman. Her biggest weapon, she says, is the quality of her work. "Know who you are and then let your good work speak for you."

After completing her Master's in 2000, she went "back to the farmers." She joined the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) as a

From the start of her career Dr Ncube has worked in male dominated environments. Not perturbed by discrimination she has always let her good work speak for her.

Photo credit: Petro Kotzé

Scientific Officer. This led to an opportunity to pursue a PhD in Production Ecology and Resource Conservation, which she started at the Wageningen University in the Netherlands in 2003 with a scholarship from the Netherlands Organisation for Scientific Research (NWO-WOTRO). It was a sandwich PhD, she says, which means she attended classes in the Netherlands, but went back to Africa for fieldwork.

"I have always studied and worked in male-dominated environments. My biggest challenge is not being taken seriously and being looked down upon to the extent of earning less than men, just because I am a woman. It is a continuing struggle, but my biggest weapon so far has been doing my job well and proving that I am not just a woman, but I am a human being." - *Dr Bongani Ncube, as profiled in Amakhosazana Amanzi, Celebrating our women in water and sanitation by the Department of Water and Sanitation and the WRC, 2015*

For her thesis, she looked at soil fertility problems that lead to low crop yields for smallholder farmers in Zimbabwe. She also investigated whether it's possible to grow grain legumes in the prevailing semi-arid conditions, in order to rotate these with cereals and enrich soil and ultimately, increase yield.

"At first the farmers thought it was too dry to grow legumes", she explains. She started off with 500 grams of groundnuts obtained from the ICRISAT office in Malawi, cultivated it in the research field and distributed her harvest of two bags to the farmers. Her hypotheses proved to be correct. When she finished her PhD four years later, farmers in the area were selling groundnuts that originated from that first 500 grams of seed. Plus, many started cultivating other legumes with seeds from the research project. More so than awards, Ncube says that's what she sees as a great achievement. She passed her PhD with flying colours in 2007.

Following that, her twin specialties of water and agriculture came together when she was appointed as Research Leader for the WaterNet Challenge Programme on Water and Food Project 17. The project covered both water and agriculture in the Limpopo Basin, including South Africa, Mozambique and Zimbabwe.

Towards the end of 2009, family commitments saw her relocate to the United Kingdom. There, Ncube initially worked at a small non-profit organisation, Excellent, which provided water for smallholder farmers in rural Kenya through sand dams. She then started doing social work, but soon realised that she was veering off track.

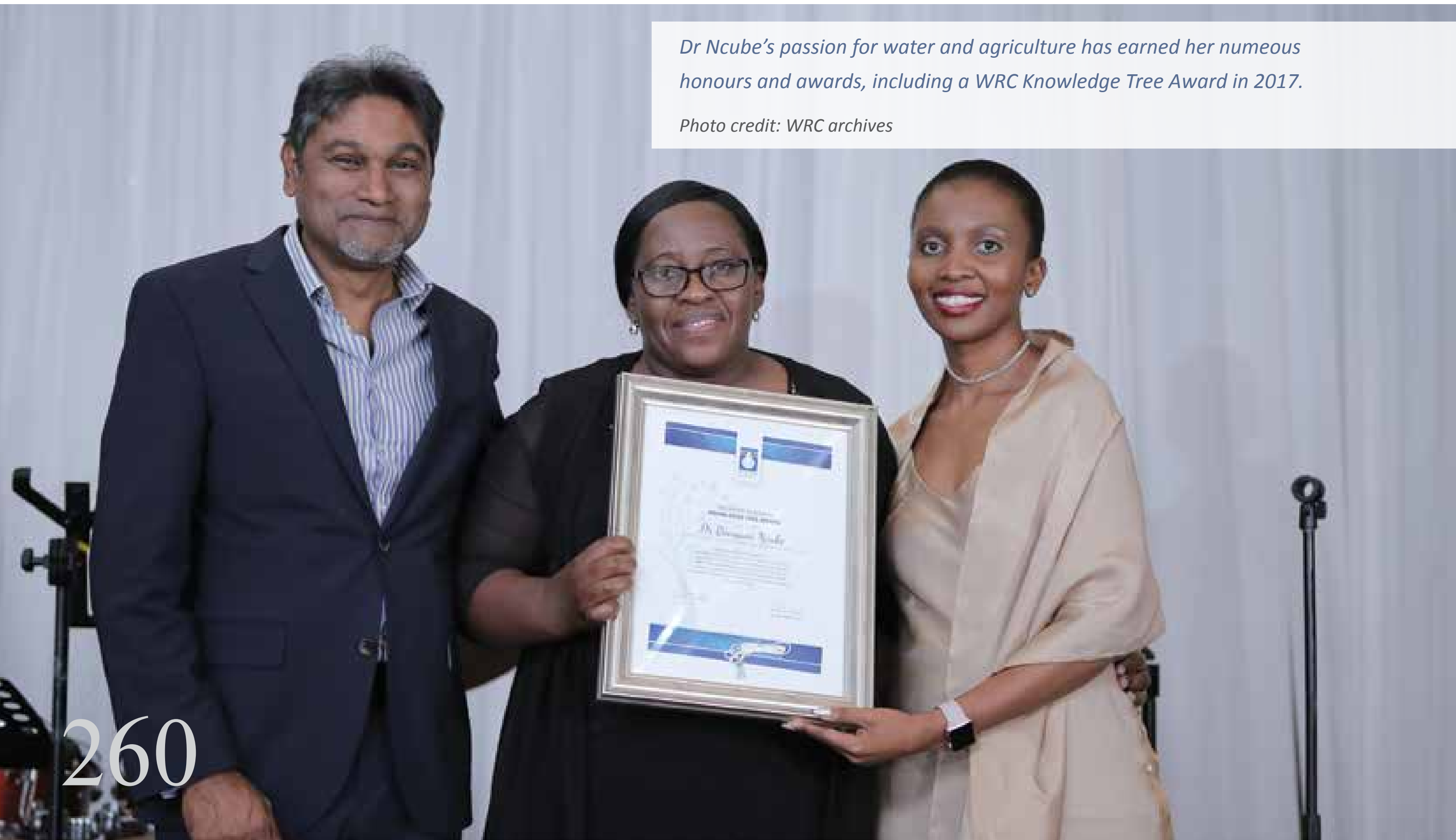
"I had to sit down and tell myself the truth about why I felt frustrated in the UK." She missed the interaction of working in the field, and finding solutions for farmers. A quiet person, Ncube says she realised she still came alive when she was in the field, like she did when she was a child. Over and above that, being able to change somebody's life, and work through challenges together to find a solution is the kind of work that gets her up in the morning.

"In any job you've got to have a passion. My passion is research." She joined the CPUT as researcher in water and agriculture in 2013, and relocated to South Africa to take up the position.

"There is a rich local indigenous knowledge base in the Karoo. The knowledge sits with every farmer, regardless of race, origin or resource endowment. Farmers have developed coping and adaptation strategies in line with available resources." - *Dr Bongani Ncube, from the report, Insights into indigenous knowledge strategies for coping and adapting to drought in agriculture: a Karoo scenario, South Africa*

Working with smallholder farmers in South Africa

Her work thrust her straight into water scarcity issues. Early projects included the identification of coping strategies adopted by farmers in the Southern Cape during droughts, to identify measures that would ensure the resilience of the agricultural



Dr Ncube's passion for water and agriculture has earned her numeous honours and awards, including a WRC Knowledge Tree Award in 2017.

Photo credit: WRC archives

“In any job you’ve got to have a passion. My passion is research.”

sector to future dry spells. She also looked into indigenous coping strategies to drought in the Karoo.

“I was interviewing a lot of smallholder farmers in the Western Cape and this issue of access to water kept coming up,” she says. The interest led her to develop a concept note and proposal in collaboration with the Breede Gouritz Catchment Management Agency (BGCMA), and it resulted in a WRC-funded project with Ncube at the helm. The main objectives of the project were to assess the progress in accessing water by small-scale and emerging farmers, challenges faced by the farmers in participating in water resource management and to explore the opportunities for engaging the farmers in water allocation processes. The research focused on the whole catchment management area, with detailed consultation with farmers in the Barrydale area and emerging farmers from Hex River Valley Water User Association.

“The first meeting was so intense,” says Ncube. “The farmers said that water institutions betrayed them and made promises that they never delivered on. It was very difficult consultations.” The researchers knew that it would take time to address land and water issues, especially since the institutions in question adhered to different policies and mandates. “We all had to sit together and find a solution that was within our reach,” she says. They realised that there was already information available on activities and sources of support for farmers, though they were unaware of it.

Together, the farmers and water institutions decided to launch a comprehensive information package that included all material of what the farmers needed, with details of where they could access it. The package would eventually be housed online on the BGCMA website, but hard copies were also made available for those without access to the internet. The Water Research Commission committed to fund the development of the website and translation of the package from English into Afrikaans and IsiXhosa.

The package was piloted at a roadshow in Barrydale in 2016. The event saw a good turnout, with about 62 farmers and institutions in attendance. The day would become one of the highlights of Ncube’s career. “The people that were shouting at us three years earlier stood up to tell us how much they had learned since we went there, and some of the farmers managed to get access to water. We thought it would be impossible to bring all the institutions and the farmers together in one room like we did that day.”

By the time the team left, there was trust built between the farmers and the institutions, which is still there even now. “You cannot touch it, or hold onto it, but that is success to me, to see relationships that were built through the project.” Ncube says she cannot take sole credit. “I was just leading a lot of people who were working together.”

Still, her dedication to the job, and skills to bring it to fruition, are renowned. Recardo Carelsen, Senior Agricultural Advisor at the Western Cape Department of Agriculture has

Leading workshops among South African farming communities. Dr Ncube sees the role of the researcher as the bridge between the farmers, communities and policy makers.

Photos supplied

been working alongside Ncube for a number of years, assisting her during various farmers and community workshops, conferences and dialogues. They often had to undertake long drives, travelling from the Overberg at one side of the Western Cape province, all the way to the other side, to the West Coast. They also worked with farmers during the crippling drought of 2015 – 2018.

Carelsen says he learned that Ncube, now his Master's supervisor, is a hardworking individual with a real passion for people and her work. "Dr Ncube's skills out in the field, leading the focus groups to dig for information was astonishing," he says. "She is not afraid to get her hands dirty, and face farmers struggling with the drought during data collection." He adds that he thinks part of her success is due to her tremendous capacity to work hard, and for very long hours.

For Ncube, her success is also thanks to learning from the best.

Success is not attained in isolation

"I managed to work with some of the best research managers in the WRC," she says. Eiman Karar, then the WRC Executive Manager: Water Resources Management, stands out for her as having played a key role in guiding her forward in her career. She also mentions Prof Sylvester Mpandeli, the WRC Executive Manager: Water Utilisation in Agriculture, whom she met during her WaterNet days. Much guidance in her research was also provided by Dr Gerhard Backeberg who was Executive Director: Water Utilisation in Agriculture until his retirement. More mentors have included her first-degree lecturer, Ms Catherine Verbeek, Dr Mary Mgonja at ICRISAT and Dr Graciana Peter at WaterNet.

Furthermore, it would be amiss to not also include the importance of her mother's wisdom, and her dependence on God, Ncube says. That's why she is able to keep going regardless of any difficulties, because, she says, she believes it is her calling.

A good researcher is someone who does their work with integrity and honesty, with the aim of solving real problems and discovering new things. In my previous jobs and PhD, I was supervised by world renowned scientists. I realised that their secret to greatness was the ability to work with others to solve real issues. The collaborations that they created have lasted for decades, and they are still growing. A good researcher is also someone who knows that they will retire one day, so they make it a priority to train the next generation of researchers. – *Dr Bongani Ncube, as profiled in the CPUT series, Extra-ordinary Women*

She says she hopes that she can impart the same inspiration to her students. "When I look back, I think of the many lives I touched and, that in, turn touched mine. If I go back today to the site where I did my PhD, and they are still growing groundnuts, and they also teach this to their children and their grandchildren, I will be grateful." Her students, in turn, can also change the lives of generations to come if they turn into good researchers and improve people's lives. "If I can be remembered for having done that, that I built relationships and made lives better for communities I think that will be a wonderful legacy."

That's why she always approaches her projects in a specific way. "If I see a community, and I find that it is not going well there; and if I can then dig until I find a solution, then I know I have achieved something," she says.

Dr Ncube contributes her success to a number of people, not least of which her mother, who was a successful small-scale farmer.

Photo credit: Petro Kotzé

"My role as an agricultural scientist is to try and make plants grow better and find out what should change, but there's another side, and that is to take the farmer and enable them to use this knowledge to change their lives. There is yet another level, she says, which is to enable the people and institutions that work with farmers, to collaborate with them efficiently.

The researcher is the bridge between the farmers, communities and policy makers," she says. Your role as a researcher is to get that hard science and present it to your peers, but also to water it down and give it to the implementer, the farmer, and ask them what is the best way they think of doing it. It's not us who have the knowledge, she says, especially when farmers and their communities are relevant. "Many have been surviving in these environments for centuries."

"Handing out knowledge and telling people what to do is long gone", Ncube says. "Rather, you go to people and tell them that this is the bit that you know, and how you see it, and then you ask how you can make it better." In her area of work, she says, that is the role of the researcher. And that, perhaps, is how you can get water to farmers.

Prof John Annandale

Photo credit: Petro Kotzé

JOHN ANNANDALE

Leading a practical approach to agricultural science

Current position:
Professor, Department of Plant and Soil Sciences, University of Pretoria

Research interests:
Irrigation with poor quality waters, mine-water irrigation, sustainable agricultural use of municipal wastewater sludge: matching nutrient supply and demand, modelling the soil water balance to assist irrigation water management and improve water productivity of crops, guidelines for irrigation management in pasture production, irrigation water quality guideline development

Award

AWARDS

2021: WRC Legend Award

2017: WRC Knowledge Tree Award for New Products and Services for Economic Development

‘Unashamedly’ applied in his scientific approach, Prof John Annandale’s career is dedicated to increasing the efficiency of agricultural production and reducing its environmental impact. He developed the user-friendly Soil Water Balance (SWB) model, which has been used widely to solve water-related challenges in his research programme in quantitative environmental biophysics at the University of Pretoria (UP). Under Annandale’s helm, the mechanistic, generic-crop model has helped address challenges such as the accurate determination of crop-water requirements, irrigation with neutralised acid mine drainage as well as guiding the responsible use of municipal sludge for crop production, and reducing agriculture’s contribution to nutrient non-point source pollution.

“Most of my water research has revolved around trying to be as quantitative as possible,” Annandale says. “I’m a bit of a pain in the backside when it comes to attention to detail,” teasing that he used to send school notes back to his children’s teachers with corrections. However, he adds that his journey is also proof that you can only build a successful career in an area that you feel passionate about.

His love for agriculture started at a young age. When he was 13, his father bought a small farm in the Cullinan district, Gauteng. Entrepreneurial in spirit, his father experimented broadly with a wide variety of crops such as asparagus, maize, sunflowers and peanuts, and kept pigs and cattle. The teenager was hooked. After his National Service, Annandale studied BSc Agriculture in Plant Production at UP. On completion of his four-year degree, he was offered the position of Irrigation and Agricultural Climatology lecturer, which he took up in 1983. Apart from a three-and-a-half year stint in the US to complete his PhD, he has been at the same university ever since.

Initially, it was not easy. He was expected to lecture a brand-new subject that he himself had no exposure to (microclimatology or environmental biophysics). The quantitative and mathematical nature of the subject suited the young lecturer well, but without support and expertise available to help him understand the textbooks, he found himself floundering in the deep end. This feeling of being out of his depth increased without a suitable expert to act as supervisor for his Master’s on the plant water relations of agronomic crops.

But, he says, “one must not lose focus, and never give up.” In recounting his journey, he says that obstacles along the way make you stronger, and they must not be seen as the end of the road.

A young scientist’s persistence pays off

Annandale obtained his Master’s and lectured for about six years, but still wanted to deepen his expertise. He aimed overseas. After many applications, he secured a place for a PhD in Soil Physics at Washington State University (WSU). The decision would be life changing, offering the budding scientist the opportunity to sharpen the unique skills that would help make his future work exceptional.

> “One must not lose focus, and never give up.”

“The big benefit for me in the Washington State experience was the exposure to mechanistic mathematical modelling,” he says. He also worked with world renowned soil physicist, Gaylon Campbell. “He was an excellent lecturer,” Annandale remembers, “who was able to make very complex topics understandable. “He liked to quote Einstein – make things as simple as possible, but not simpler.” Annandale himself would become renowned for creating user-friendly models to simulate complex challenges.

He would pick up another landmark characteristic of his work during his years in the United States. A fan of mathematics at school, he was exposed to a quantitative engineering approach to problems in agriculture, something that really excited him. Already then, Annandale started crossing the boundaries between academic disciplines. The thesis that he handed in to the Soil Science Department could just as easily have been accepted, verbatim, by the Agricultural Engineering Department, he says. “Some people can tell you very easily what they are; other people, like myself, are actually still not so sure,” he jokes, since his work in the water field has merged aspects of agricultural engineering, crop and soil science, environmental biophysics and computer programming.

With PhD in hand, he returned to UP in 1992. This time, he taught from the textbooks written by Campbell himself. “You don’t get better than that,” he says. Annandale climbed the ranks, and was promoted to Associate Professor in 2000, then later to Full Professor and acting Head of the Department of Plant Production and Soil Science.

He lists building the capacity of students through the years as one of his biggest achievements, saying he counts himself as fortunate to have worked with a number of really bright and enthusiastic pupils, and that it is very pleasing to see how successful many of them are today. A number of Annandale’s students have moved on to become Professors themselves, and take up other senior positions.

However, he will likely be best remembered for his association with the SWB model.

Prof Annandale is the developer of SWB, a real-time, soil water balance model that performs calculations on the water balance and crop growth on a daily time step to output irrigation requirements.

Photo credit: Petro Kotzé

The Soil Water Balance Model (SWB)

The inspiration for the model was born from Annandale's mentor, Gaylon Campbell. The renowned physicist visited South Africa on invitation from his old PhD student and then WRC Research Manager, George Green, and while here, discussed a simple crop growth, soil-water balance model with his protégé. The conversation spurred Annandale on to develop the brilliant concept of a user-friendly, "no-name brand, or generic" crop growth model that, if populated with parameters of different crops, could be applied to several different crop species.

Except for the significant work that was to follow, the event also points to another element of his work that Annandale feels strongly about. "Always have a mentor – one is never too old, too clever or too experienced to learn from someone else." I have been extremely fortunate to work with some very talented people during my career, and got far more from them than just scientific mentorship, he says. He is particularly grateful to the WRC, and the research managers that he has worked with, for believing in him and walking this journey with him.

With support from the WRC, SWB was first developed as a real-time, soil water balance model that performed calculations on the water balance and crop growth on a daily time step to output irrigation requirements. The model includes a crop parameter database that contains a wide range of crops commonly cultivated in South Africa.

It addresses an important challenge for farmers. Though effective irrigation is integral to saving water and improving the yield and quality of agricultural produce, only a small percentage of farmers use any irrigation scheduling aids other than their experience, to decide when and how much to irrigate their crops. One important reason for this might be the lack of quick, simple and reliable irrigation scheduling techniques. In response, the SWB model has a user-friendly interface that makes it accessible to any person with basic computer literacy, but still follows a scientifically sound mechanistic approach.

The principles behind the model have been used in numerous water research projects over the years, Annandale says, and played a pivotal role in his milestone work; projects that promise to make a real contribution to water management in South Africa. One of the most important started in the early nineties. "It was fantastic," Annandale remembers of his initial work on simulating water and salt balances of mine-water irrigated fields. It's one of the first projects where he felt the work that they were doing would make a real difference.

Proving the potential in South Africa's 'waste' water

South Africa's coalfields produce astounding amounts of wastewater. Off the top of his head, Annandale pegs it at around 360 megalitres per day. Conventional treatment costs around R26 per cubic metre, adding up to R9.36 million each day of the year, in perpetuity, if treatment is required. Beyond

"Always have a mentor – one is never too old, too clever or too experienced to learn from someone else."

Prof Annandale's research has focused on projects that can make a real difference to water management in South Africa, and beyond.

Photo credit: Petro Kotzé

coal mines, South Africa still has many gold mines that produce acid mine waters too. Putting this 'waste' water to use for irrigation would not only save billions of Rand to government, tax payers and industry on alternative water treatment approaches, but many livelihoods can be created through productive use of suitable quality mine waters. "This is especially important in areas where mines are closing and staff are being retrenched," notes Allandale. In such cases, carefully managed irrigation with mine waters could be a very cost-effective component of a long-term mine and catchment water management strategy.

Allandale led the first project to test these possibilities which entailed a screening trial at Kromdraai Colliery near Witbank. "Our models showed that it was sustainable," he says. The results proved that neutralised acid mine drainage could be used successfully for irrigation of a large variety of crops. The initial trial and the modelling results became the motivation for follow-up projects. Among others, Allandale and his team have modelled the long-term effect of irrigation with gypsiferous water on soil and water resources, and studied how to manage the environmental impact of irrigating with such water. Their research has also provided important considerations for managing irrigation with saline water, highlighting the importance of the quality of the irrigation water; the hydrological setting of the irrigated area; the management of the leaching fraction, and the fate of the drainage water.

Consequently, their later work took them to the country's goldfields too, proving it "highly probable" that goldfield mine water can be used cost-effectively to irrigate vegetation on mine tailings or salt tolerant crops such as wheat or soybean on agricultural land. At the time of writing, Annandale was developing guidelines for productive and environmentally responsible mine-water irrigation.

His work has tackled the vexing problem of the sustainable management of wastewater production in South Africa beyond mining. The principles of the SWB model have also been used to simulate nutrient balances of fields irrigated with municipal wastewater effluent. Again, the work proved the economic value of the sludge as a low-grade fertilizer.

“It is very satisfying to develop useful software that you know will enable others to make better decisions that will conserve resources and protect the environment.”

Using SWB to simulate radiation interception of hedgerow fruit tree orchards

A challenge for fruit tree crop growers is to use less water for irrigation without a decrease in fruit yield and quality. In South Africa, fruit are high value crops that cannot depend only on our generally low and erratic rainfall, and as a consequence, are mostly grow under irrigation.

Efficient irrigation of fruit orchards is particularly challenging because of the two-dimensional nature of the system being managed. Orchard crops are usually produced under micro-irrigation, where only a small part of the soil surface is wet, usually a strip under the hedgerow canopy. Evaporation of water from the soil surface can be substantial, and this is seen as an unproductive loss, as it does not have a direct relationship with production. Evaporation is controlled by the supply of water to the surface, and the energy available to drive evaporation. In most orchards, the area between rows that is not irrigated is mostly dry, and here evaporation is water supply limited. Under the shade of the canopy, in the wetted strip, evaporation is usually energy limited.

In answer to these challenges, the principles of the SWB model were adapted to a two-dimensional, hourly or daily time step model, which takes canopy characteristics and row orientation into account to simulate solar radiation interception in hedgerow orchards. In order to determine the spatial and temporal distribution of soil irradiance across the tree row, the canopy path length through which the radiation must travel to reach a certain point on the soil surface is calculated.

It’s an exceptional feat, because this changes with sun elevation angle (a function of time of day, time of year, position on the globe), row orientation and canopy dimensions which are influenced by pruning, tree age and spacing. The simulations proved to be extremely accurate, assisting with improved estimates of soil water evaporation, and thereby, with the quantification of the effect of different management practices on the reduction of this unproductive water loss.

Laying the groundwork for better decision making in water management

At the time of writing, Annandale was using SWB to assist with the development of novel, dynamic, risk-based, site specific *Irrigation Water Quality Guidelines.* One of the most widely-used tools in water quality management in South Africa, the 1996 national guidelines are significantly out of date. The updated guidelines include a user-friendly, computer model-based Decision Support System that determines multi-tier, risk based, site-specific water quality guidelines to determine fitness for use or water quality requirements of water resources. The information is of critical importance to both irrigators and regulators of our water resources.

"It is very satisfying to develop useful software that you know will enable others to make better decisions that will conserve resources and protect the environment," notes Allandale. Since the end of his seven-year appointment as acting Head of the Department of Plant Production and Soil Science, Annandale says he is now less distracted with administration, and gets to spend more time at the coalface with his water research. He is working very closely with two retired soil scientists, one a previous research manager of the WRC, as well as with an engineer who has programmed with him for decades. Not only is he finding the process very stimulating, it is also rewarding to work with colleagues and keen young post-graduate students.

The department is tackling a number of challenges to continuously improve agricultural practice with Annandale's expert guidance. For one, it is investigating the role that simple and innovative irrigation scheduling and solute monitoring tools can play in adaptive learning in order to help irrigators better manage water, nutrients and salts. The team is also running projects on water use and water relations of important fruit tree crops like citrus, macadamias, pecans, peaches and avocados; water use of pasture crops; and, the use of the Cosmic Ray Probe in irrigated agriculture.

After decades of research on the detailed aspects of agricultural water use, and the sustainable use of irrigation water, Annandale's explanation for his life-long commitment encapsulates his renowned strengths for making the science behind the solutions as simple, and relevant, as possible.

"It's as simple as the joy of planting a seed and seeing it grow." He remains, in essence, a production scientist, he says, dedicated to the use of science for the practical improvement of agriculture, and the management of South Africa's scarce water resources. Some sneer at the impact of land-use changes due to large scale agriculture, but Annandale says that although he also appreciates unspoiled nature, orchards and fields are what he finds most appealing on a drive through the countryside. "There is of course much more to it, but it really is just beautiful."

Photo credit: Petro Kotzé

Prof Sue Walker

Photo credit: Petro Kotzé

SUE WALKER

Trailblazer dedicated to food security
no matter the weather

Current position:
(Retired) Principal Researcher in Agrometeorology at Agricultural Research Council – Natural Resources and Engineering & Professor Emeritus, Agromet, Soil, Crop and Climate Sciences Department, University of the Free State

Research interests:
Crop physiology, agrometeorology and developing agriculture; water use of crops and drought adaptations; climate services, modelling of crop growth and development and water use of agronomic crops; adaptation of large-scale irrigation practices for small-scale farmers; water relations in the soil/plant/atmosphere continuum; irrigation scheduling models; peri-urban agriculture; Farm Systems Research and Extension methods; Participatory Rural Appraisal.

Award

AWARDS

2021: WRC Legend Award

Every morning at 06:30 a young Prof Sue Walker measured rainfall, minimum and maximum temperatures with her wet and dry bulb thermometers before taking the bus to school. At 16, all she wanted for her birthday was a Stevenson Screen. The teenager had countless questions about the world around her, but would dedicate her career to one: "How do we feed people despite the weather?" Her unyielding quests for answers would take her from the misty hills of KwaZulu-Natal where she was born; to dusty meetings with farmers in rural Africa; and to represent her country at the United Nation's Commission for Agricultural Meteorology of the World Meteorological Organisation.

Until recently she was the Principal Researcher-Agrometeorology at the Agricultural Research Council (ARC) Natural Resources and Engineering Campus, where she specialised in taking science to the farm. She is an expert in the development of climate services that translate scientific results into useful operational messages. As agrometeorologist and plant physiologist, she has visited over 50 countries in Southern and East Africa and South East Asia on research and development projects to help farmers, in essence, answer the question of how we can grow food more successfully.

"We have the knowledge to help them so we must," Walker maintains. For her, this knowledge entails a combination of crop-climate modelling as a mathematical explanation of the physiological and physical process interactions, and using field measurements to calibrate models for the correct answers according to agro-ecological zones. Then, through the creation of Agromet (agrometeorological) Advisories, she has helped deliver that information to farmers in their own language, packaged with advice on how to use it.

Our vision of what an agrometeorologist should do is very narrow, she says. Her vision goes far beyond the traditional concept of someone who studies the weather and climate to enhance agricultural crops and production. For Walker, agrometeorology includes everything from the plant cell to global factors like the wind, soil science and the social circumstances of the farmer.

In essence, Prof Walker's work has helped farmers answer the question of how we can grow food more successfully.

In fact, Walker has never marched to the beat of the conventional drum. She was the first to study B.Sc. Agriculture with a major in Agrometeorology at the University of Kwazulu-Natal (then the University of Natal); one of the first women researchers to be supported by the WRC; and the only female head of department at the time at the University of the Free State (then the University of the Orange Free State).

"Being a ***baanbreker***" (pioneer) she says, in jest to the predominantly Afrikaans agricultural circles she often had to break into, "was not easy". However, in order to do what she loved she had no choice but to be the forerunner. "It's a long road always, and it needs determination and commitment." According to Walker, perseverance, passion and hard work is what led to her success. That, and "God incidents" – unexpected occurrences that confirmed that she was on the right path. One of these moments occurred as she was looking for a university that could help her realise her passion for studying the climate. At the end of her tether, she visited a student advisor in Durban. He just picked up the phone to a professor at Pietermaritzburg, she recalls, and said "Hello, Prof Jimmy, how are you? I've got a student for you. She loves meteorology." Walker was on her way.

Breaking the mould

It has not always been smooth sailing, as Walker learned when she failed her first semester in Botany. It made her more determined to succeed. "It was like a red flag to a bull," she says, and she would even continue to a PhD in plant physiology. "Who would have thought! I could have just packed my bags and gone home," she says. "Not me. It taught me that failure is the backdoor to success."

After obtaining her degree with a bursary from the Department of Agricultural Technical Services, she was employed as agrometeorologist in their Pretoria offices

"Failing my first semester in Botany taught me that failure is the backdoor to success."

Prof Walker has been a pioneer for female researchers in the agricultural sector, and was one of the first women researchers to be supported by the WRC.

Photo credit: Petro Kotzé

in 1978 and, one year later, went to the UFS for her Honours Degree in Agrometeorology. Not familiar with the strict rules of the Afrikaans university's residency, the cum laude student unknowingly 'sneaked out' every weekend to go camping and fishing with friends. Walker laughs when she recounts how she received the prize for *super sluiper* (super sneaker) at the end of the year.

Back at the Department of Agriculture, Walker started her first interaction with farmers, combining her knowledge of climate and plant physiology with agriculture. Part of her job was to manage, design and organise field irrigation trials and log agrometeorological data. "Every Monday morning, I would get a phone call from the weather guy in Loskop, and I would type in the weather data for the day, run the program, and then phone back the irrigation schedule for the farmers." In the meantime, she completed her Master's degree (cum laude) on field measurement of Leaf Water Potential Components using Thermocouple Psychrometers. The topic was part of her first WRC project, and she would work on subsequent projects throughout her career. Her association with the WRC counts as one of many highlights.

There were plenty of challenges too. The commercial Afrikaans farmers didn't much like working with this Engelse *meisiekind* (English girl), she recalls. She was later taught the language by the labourers at Roodeplaat, the departmental research farm. Despite it all, Walker persisted. "Know what your calling is, and carve out a unique place for yourself," she maintains. It paid off. She received a prestigious Fulbright scholarship and completed her PhD in Plant Physiology at the University of California, Davis Campus in 1988.

Claiming her unique space in agrometeorology

On her return to South Africa, she climbed the ranks at the Department of Agricultural Development. The research component became the Agricultural Research Council (ARC) in 1992, with Walker working in the Institute for Soil, Climate and Water (ISCW). On completion of her PhD, she was appointed as Assistant Director and Crop Physiologist and after the 1992 merger, as Programme Manager for Water Utilisation and Small-scale Farmer Programmes. In 1995, she was appointed as Research Division Manager for Small-scale and Developing Agriculture Programme.

Walker made waves. She employed the first black interns in the department before democratic South Africa came into being, and focused much of her attention on development projects and small-scale farming. In particular, she worked to give small-scale farmers in South and southern Africa a voice and access to the latest scientific findings.

"If new knowledge can only come from the university, we are telling farmers that they are useless. It's not true," she says. "We have to acknowledge and honour them for what they know. We have to give credit where it is due, but at the same time we should not be afraid to ask questions." It's thus of little surprise that Walker's work is characterised by participatory methods. She is also known for applying a Farming Systems approach, which is driven as much by the overall welfare of farming households as by goals of yield and profitability. This holistic method draws on both local and external knowledge to address poverty and sustainability, especially under changing climatic conditions in semi-arid areas.

Once, on a follow-up visit to a community, ladies came to her dancing with joy when they greeted her, telling her they learned to read and write in their mother tongue, and speak English as a result of the project activities – all of which were hurdles to ultimately perform well on their farms. "Those kinds of projects are the ones that really matter," Walker says.

She worked at irrigation schemes near Hoxane-Mukhulu (Hazyview), at Tulamashe and along the Olifants River, sometimes clocking five to seven thousand kilometers a month to visit farmers and extension officers. "I wonder what Sue is doing," used to be a common question in the corridors of the research institute. 'Sue' was doing what she loved. Her work incapsulated her excitement and enthusiasm for when science takes action, and makes progress to change livelihoods. For years, her schedule was to hit the road on Monday, train extension officers on Tuesday, visit farmers on Wednesday and hold a Farmer's Day on Thursday, before travelling back on Friday to repeat it again the next week.

In this way, Walker created so-called Agromet Advisories, that she would over the course of her career implement in places all over South Africa, Africa and beyond, including Mpumalanga, Limpopo and Free State to Zambia, Zimbabwe, Uganda, Ethiopia, Sri Lanka and Indonesia. In an era of climate change, climate services (the provision of climate information to assist decision making) has become very big around the world, but agriculture was first to provide expert knowledge and meteorological information to help farmers make decisions, Walker says. In the form of Agromet Advisories, she had the trend for climate services.

It's where some her best professional memories lie. "To see people grasp and learn

With Mujika village community members in Zambia. For Prof Walker, her field of agrometeoroloy goes far beyond the traditional scope to include people, and their social circumstances.

Photo supplied

At a farmers' meeting at Mujika Village in Zambia.

Photos supplied

something that has practical application to their own everyday decisions and livelihoods were immensely satisfying." She fondly remembers those days, staying in villages, meeting in the shade of large trees and sitting in the field with women farmers to listen to what they learnt from field trials.

In 1998, Walker decided that instead of transferring knowledge informally, she wanted to enter the formal academic structure.

Entering the academic field

In 1997 she became Professor in the Department of Agrometeorology at UFS, Bloemfontein and the following year, Head of Department of Agrometeorology. Her colleagues at the ARC were initially upset at her departure but they would ultimately reap the benefit. She assisted 20 students to graduate with their PhDs. Back at the ARC today, some of them became her colleagues and one, her boss. "It's wonderful!"

She remained at the university for 15 years despite being thrust once again into a staunch Afrikaans culture. As senior staff member, she was expected to also spend weekends next to rugby and cricket fields and at departmental social gatherings. She couldn't speak ***hogere*** ('formal') Afrikaans but dutifully played the role of 'Mrs Professor'. "We all have challenges, but with God's help I can overcome stumbling blocks."

In 1998, she was appointed as the South African representative to the World Meteorological Organisation's (WMO's) Commission for Agricultural Meteorology (CAgM), a position that she held until 2014. During the same time, she was the Chairperson of the WMO-CAgMOPAG "Agrometeorological Services for Agricultural Production". She served as a member of the CAgM management group from 2006 to 2014.

For success, she says there's no excuse except hard work. But after more than a decade at the university she was tired. When an exciting job opportunity came her way, Walker decided to go for it, embracing another of her passions in the process.

"I just love to be somewhere else," she says about her love for travelling. During her career she concluded many study tours to countries including Israel, the United States, Australia, Europe, Malawi, Zimbabwe, Namibia, Swaziland, Ghana, Mozambique and Morocco. In total, she has visited more than 70 countries. In 2013, Walker was headhunted for, and accepted, a job in Malaysia.

Prof Walker spent three years on a contract in Malaysia working on underutilised crops in Asia, Africa and Sri Lanka.

Photos supplied

Prof Walker with a community group in Ladysmith, KwaZulu-Natal for roll-out of the AgriCloud App.

Photo supplied

"It was just wonderful," she says of the three-year contract as Research Theme Leader for Agrometeorology and Ecophysiology, and the Programme Director for CropBASE at Crops for the Future. The project was run from the University of Nottingham's Malaysia Campus and entailed research on underutilised crops in Asia, Africa and Sri Lanka. She remained an Honorary Professor of the School of Biosciences for some time.

Offering an expert vision and perspective

She returned to South Africa as specialist Principal Researcher in Agromet at the ARC, now contributing invaluable vision and perspective to projects that, ultimately, make good science practical and useful for people that work in agriculture. A highlight has been the Rain4Africa project, in which modern technology was used to develop and communicate real-time information to farmers, including early warning and climate services and Agromet Advisories. During the run of project, it is estimated that it helped more than 300 000 small-scale South African farmers to increase their food production and reduce their risk to weather and climate related hazards.

With Walker as project leader, the project included the development of the AgriCloud app, a free weather based agricultural advisory system that supports farmers and agribusinesses in their day-to-day work to make weather-optimised decisions. In essence, AgriCloud is an Agromet Advisory for their own farm available to farmers on their phones, available in all 11 official languages with daily updates.

Dare to ask inquiring questions

Walker says she has found the answer to her question of how we can feed the people despite the weather. We can, she says, if we make intelligent, evidence-based decisions. "The knowledge is available and it's available for the small-scale farmers, and for the commercial farmers, the provincial and municipal governments and the ministers." In this, the role of the researcher is to have an inquiring mind. We dare to ask inquiring questions, and then unpack whether these are the right ones to ask. Ultimately, to reach the right answers, you have to ask the right questions.

The ultimate role of the researchers, says Prof Walker, is to have an enquiring mind.

Photo credit: Petro Kotzé

Prof Joyce Chitja

Photo credit: Petro Kotzé

JOYCE CHITJA

The researcher that translates
hard science to transform lives

Current position:
Professor at Food Security Programme, University of KwaZulu-Natal

Research interests:
Smallholder farming systems value chains, land and water use security and access, livelihoods, vulnerability, household food security, gender and empowerment

Award

AWARDS

2021: WRC Legend Award
2018: UKZN's School of Agriculture Earth & Environment Sciences' Wonder Woman in Science

Applied research answers specific questions to solve problems. Translational researchers take such basic science discoveries and move it to practice, to enhance human society by bridging the worlds of the academic and practice. It would take time for the term to catch up with what Prof Joyce Chitja has been doing since the early days of her academic career but, she says she has often found herself at the pioneering end of things.

A transdisciplinary scientist, her work addresses food security by researching smallholder farming systems, access to markets, farming resources, farmer agency and empowerment. She also engages with food security policy-makers and industry practitioners.

She launched her career on the cusp of a young democratic South Africa, and has been riding the crest of novel approaches to agricultural research since. She was South Africa's first woman PhD graduate in Food Security and once, the youngest member of the Agricultural Research Council (ARC). She became a professor in her early forties and, at 47, she was one of the youngest people to be honoured as a WRC Legend in 2021. She says she has come to accept that her role is to sometimes crack things open, so others can follow in her wake. "I can only call it grace," she says. But her story is also one of grit and determination against great odds.

A case in point is her first day at university. Due to a glitch in the post, she only received her acceptance letter for BSc Horticultural Sciences at the University of KwaZulu-Natal (UKZN) two days before classes started. The family funds were exhausted, and there was none left for registration fees. She had never been to KwaZulu-Natal before, didn't know the province at all, and would not have a place to stay on her arrival. "But the letter came and said I was accepted so, I went." She caught a bus to Durban.

Against the odds, a door opens

The excited student-to-be had no idea that the UKZN had two campuses so, when she first queued for registration, was shown away. She had to go to Pietermaritzburg, which she first thought must be a building down the road, like a school. A sympathetic taxi driver dropped her off at the gate of the right campus an hour away from Durban. "He must have seen people like me before," she laughs, "and thought he better take care of me."

Prof Chitja's advice for young researchers on building a successful career

Spend time to try and understand who you are, what your passions are and what drives you, and out of that, find a career in which those things will be actualised. That's how success comes. When you meet challenges along the way, no one will be able to remove you from your place. The work will become your ministry. Figure out what that is. It's actually quite simple but also the most difficult thing.

Nonetheless, Chitja said it dawned on her that she had a problem. Her letter clearly stated that she had no financial aid or accommodation. She dragged the suitcase with all of her future life in it to the student representative council where, with a small group of students in a similar situation, they were given a bed on campus for the night. She was so excited, she says, because soon, she was going to be a student. The next morning, she was sent to register.

A young Prof Chitja was determined to go to university, even if against great odds.

Photo credit: Petro Kotzé

"There are other factors than good marks that make a good researcher – watch out for those that are committed, and see what happens."

"I was in the queue and could see that everyone had clearance or a bursary." When her turn came, Chitja says she could feel her insides contract. Now she had to face the problem. Her R3 800 registration fee remained unpaid. When her turn came, she showed her letter, upon which the dean, Prof de Villiers, asked if she paid her fees. In reply, she burst into tears. He didn't know what to do, she says, so he and a colleague, Dr Vusi Dladla, whipped out a small packet of Romantics, and gave her some of the pink sweets.

A scene was developing, so Dr Dlala took the distraught youth aside to ask her what her plans were. She told him that she had none, but that she really wanted to study, and she only took the lead that could take her there. The story was relayed back to Prof de Villiers who, after listening, offered to pay her registration fee, trusting that her parents would make right when they were able.

"This was 1993, and an Afrikaans man paid my registration fee," she points out. Now, she understood that this was serious. She dedicated herself to her studies, and never missed a class. The following year, Chitja received a bursary from the Kellogg Foundation to continue her studies. "Imagine if I never came," she says from her office at the same university, where she was appointed as Professor in 2019. She now looks for similar traits in her students. "There are other factors than good marks that make a good researcher – watch out for those that are committed, and see what happens."

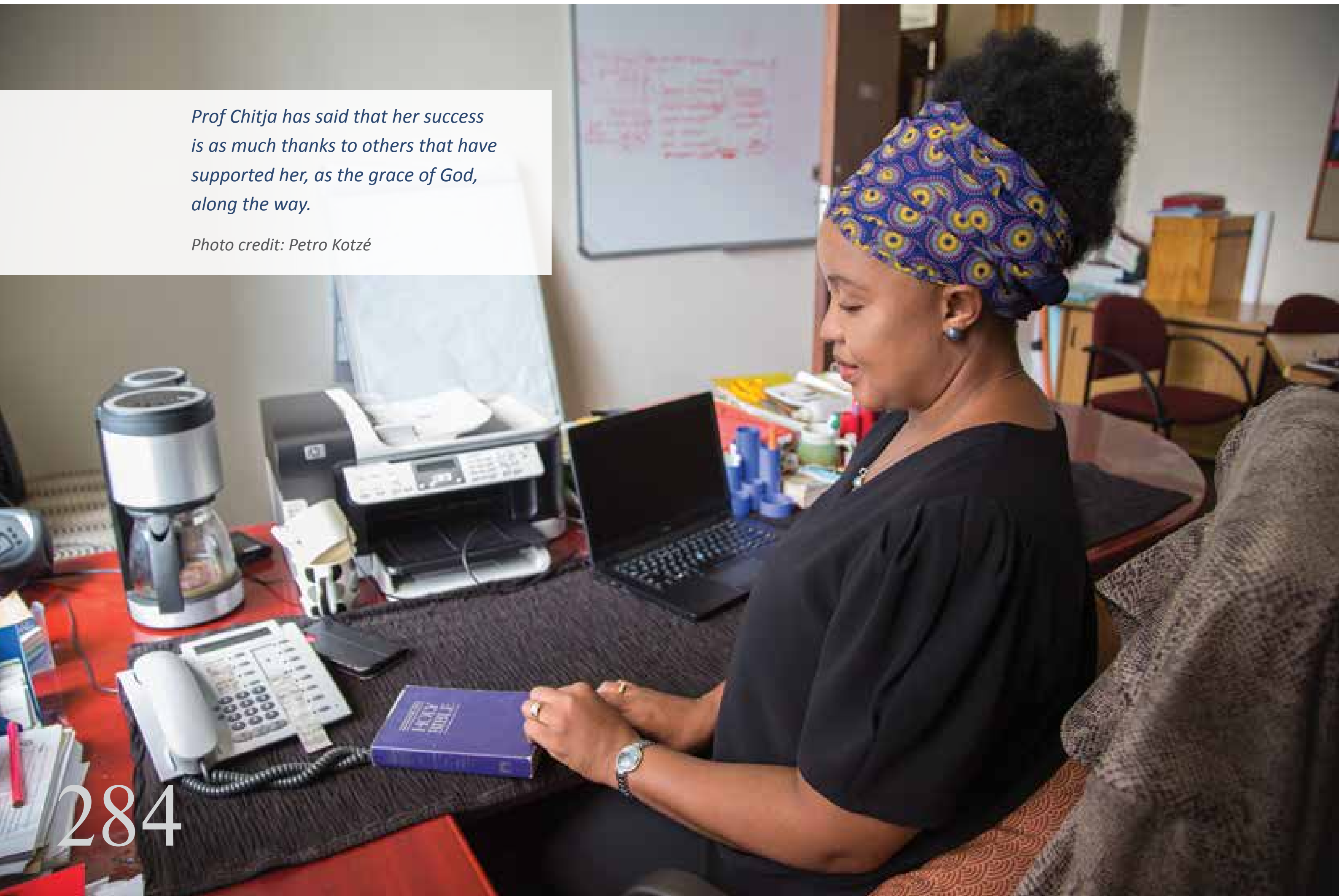
Chitja says she now believes that part of her role is to call out people's true identities and abilities "Assisting a student to become fully what they are is such a big gift to give somebody." This approach also plays out in her research with small-scale farmers. Often, they believe that they are not able to use the best technologies, compete with bigger farmers, access important markets or the right investors. Those are human problems more than agricultural problems, but part of her work is to empower people to rise above that and meet their potential. “They must be hopeful.”

She knew early on that her space in research was not the one traditional to the time.

No language for the space you occupy

For her fourth-year Honours degree the budding scientist worked on a project in which she had to extract protein from the citric acid cycle of oranges. Faced with a row of test tubes, she felt nothing but frustration. She wanted to be on the farm, not in the lab. Chitja grew up close to her grandmother, a small-scale farmer. Though somewhat successful, due to restrictions for black farmers, she was often not able to access available markets with crops throughout the year, leading to financial difficulties for the family. Chitja wanted to help farmers like her grandmother. “I wanted to translate this hard science to farmers to start showing them how to use these methods so they can apply them immediately.”

Plant physiology and laboratory science was just not for her. “For me, the excitement is to let those, ‘pure scientists’ hand over the results to me, so I can go and engage with the farmer to move the science into a product of life,” she explains. After four years of studying her BSc, she felt she was not ready for the job market. With the concept of food security just emerging, and translational science still new, Chitja knew what she wanted to learn, but this did not fit into any existing academic course or structure that she was aware of.



Prof Chitja has said that her success is as much thanks to others that have supported her, as the grace of God, along the way.

Photo credit: Petro Kotzé

“For me, the excitement is to let those, ‘pure scientists’ hand over the results to me, so I can go and engage with the farmer to move the science into a product of life.”

Determined, she walked every floor in the university building searching for a professor who understood her, what she wanted, the multi-faceted challenges that a farmer like her grandmother faced, and the unique approach necessary to finding the answers. She found what she was looking for in the Department of Community Resource Management, which later gave birth to the Food Security Programme in the School of Agriculture. Though it was not approved yet Chitja became the guinea pig for one of the first research degrees in Food Security, then called a Master’s degree in Social Science in Community Resources. The course allowed her to investigate many of her questions on how to help a small-scale farmer like her grandmother. After obtainig her post-graduate degree, she felt ready to go to work.

Jobs in a then-unfamiliar sphere like food security were spread few and far in-between. Chitja relocated to Randfontein for a position in the Department of Agriculture. As one of the only graduates with a suitable qualification, she was immediately thrust into management positions, managing people double her age. It was a rich learning experience, but after a year she concluded that she needed to learn even more. She was also now a wife, and her husband resided in Pietermaritzburg.

Chitja returned to UKZN in 2001 for a lecturer position in Community Resource Management and later Food Security Programme in the School of Agriculture, Earth and Environmental Sciences. At the same time, she enrolled for her PhD in Food Security, becoming the first South African woman with the qualification. Her academic career was about to take off.

In 2011, she was appointed to the board of the ARC, on which she served two terms before taking up the position of deputy chairperson for a three-year term. For a young academic, it could have been intimidating, but it led to one of the most rewarding periods of her career, when a co-board member helped her secure a study visit position at Cornell University in the United States.

Finding her niche

The three-month period at Cornell felt like three years, she says, thanks to the amount of experience and knowledge she gained under the fantastic mentorship of Prof Ralph Christy and Prof Anu Rangarajan. During her stint at Cornell, Chitja was thrown in the deep end, testing her academic and leadership capabilities. It’s a time that she fondly recalls as an immensely enriching experience.
It also provided her, after all these years, with the language to give structure to the

Prof Chitja with a group of scholars visiting from Cornell University to learn from her and her work with small-scale farmers.

Photo supplied

work that she was doing. It's at Cornell that she was introduced to the term and concept of translational science. "The American experience gave me a community and a language to say what I was doing."

She explains her kind of science as the translation of everything that you do to create an output and product that humans can use to transform their lives. She remembers the joy of discovering that her work fit in somewhere. She thought: "that's my science, it actually exists!" Since that time, Chitja proudly refers to herself as a translational scientist. "I'm a transdisciplinary scientist who transcends several sciences, in agriculture, in economics and sociology, and brings them together for efforts to improve livelihoods in agriculture." From her position at the UKZN, she now dedicates her research in this niche to transform farmers' lives.

One WRC-funded project, for example, investigated the empowerment of women through water use, land security and knowledge on how to achieve food security. The results showed the necessity of a multi-sectoral approach that includes integrated development and financial planning. Over and above, this must be coupled with the social and human capital development of farmers so they can use the natural, financial, physical and institutional assets made available to them, in order to achieve better food security and improve their livelihoods.

Her research projects commonly bring multi-disciplinary teams together to combine the work of translational,

“I’m a transdisciplinary scientist who transcends several sciences, in agriculture, in economics and sociology, and brings them together for efforts to improve livelihoods in agriculture.”

social, and production scientists as well as agronomists. Key to her work is the empowerment of farmers so they can participate in the project, and believe that they can reap benefits from the outcomes.

While she was once uncertain of her own unique place in the scientific world, Chitja is now partnering comfortably with others and often, shows others the way. Cornell University regularly sends her students to host at the UKZN, to teach them what translational science is about, focusing on smallholder farmers.

Her legacy is one that is still being built, Chitja says, but she has now accepted that she will often be pioneering in her chosen field. Her motivation to play the part, however unintentional, is that it will allow somebody that looks like her or is as young as her, to see that it is possible. “For those who also couldn’t imagine it, especially in a country like South Africa, they can look at me and see how far we have come.”

Photo credit: Petro Kotzé

CONCLUSION

A legacy of solid research laid the foundation for a water-secure future in South Africa

The stories of South Africa's freshwater research legends encapsulate both a nod to our past and our possible future. Over and above recordings of individual achievements, as a collection, the researchers' bodies of work form an historic overview of South Africa told from the unusual but vital perspective of water management.

Since it is uncommon internationally for all spheres of freshwater-related research to be funded by one entity, the existence of the WRC provides for this unusual perspective in South Africa. Ironically, it started with water scarcity, and the realisation that we needed science to support a country that was perceived to be running dry. Our legacies' early work reflects a focus on large-scale development of industry, agriculture and water transfer schemes. Then, there was growing recognition of the need to protect our aquatic environment; embrace the social aspect of science; support a transition to a new democratic South Africa; and, provide safe water and sanitation for all. Early on already, funding was funnelled to women scientists and researchers from previously disadvantaged groups.

The trends in funding allocation are not only a reflection of our history from the top down in the form of calls for proposals in support of government policies but also from the bottom up. As individual researchers learned, grew and evolved, they found funding support for their new and as-of-yet unsupported ideas. It goes to show that excellence is rarely achieved without support. Many have pointed out that in allowing the free development of ideas and science, and showing belief in the researchers, the WRC has become the catalyst of many careers that are now considered exemplary. In the process, large strides forward have been made to improve the most critical challenges to South Africa's future water security.

However, the journey continues. As expert scientists wind down their academic responsibilities and output, funding is channelled again to new researchers. Perhaps their work might again carry the seed to grow and eventually, also bear fruit in groundbreaking and innovative research towards a sustainable future in South Africa and beyond. It will not be easy, but it can be done. Before success, there will be challenges.

For those students that want to take up the baton and run with it, these stories can serve as a roadmap to follow. Though each one is different, there are similarities that can act as markers along the way for the next generation's journey ahead. They can be summarised as follows:

Know yourself

As a start, know yourself and what motivates you and build your career around that. Passion drives the inevitable grinding work necessary to achieve success, provides the ambition to deliver more work than is called for, and fuels the thirst for knowledge needed to push you forward.

Then, believe in yourself. You must have self-confidence in your potential, ability and work. If you believe ardently that your work is necessary, you will pursue it. If you are lucky, you will end up being paid to do what you love. Learn to work independently, take responsibility for your work and be proud of your achievements.

Always keep a positive attitude and, have fun! Without it you can't sustain the work and perseverance necessary to build a career that makes a difference.

Recognise the importance of other people

Success is as much an individual as a team effort. Look for mentors. They are critical to a person's development. Learn from experts and create opportunities to interact with them.

A community of practice is equally important. You have to be able to work with others, and you need people to guide you, to bounce ideas off of, and to help rectify the mistakes you will make. Build partnerships and collaborations with positive, passionate and proactive people. Remember to listen.

At the same time, be generous with your time and knowledge. As others have created an enabling space for you, you must do the same for others. As you have received opportunities, create opportunities for others too.

Show integrity in your work, and maintain courtesy and respect to those that you work with.

Become the expert

As a start, you have to have academic ability. Then, you have to get to know your discipline deeply, based on a very strong technical grounding in your chosen discipline. It's only once you grasp the fundamentals that you can apply strategic thinking. For most, this entails focusing on a specialty, producing high-quality, stand-out work, and over time, becoming the expert at it.

Though it's never too late to start, a legacy is built over time. Determination, commitment and perseverance are all integral. Failure along the way is a given, but the key is to not become despondent in the face of setbacks. You have to get up and move on. The journey is taken one step at a time, and a strong track record is more important than an isolated event. To do this, you have to be dedicated to your field, and find the drive to contribute to it, and raise a new generation of scientists that will walk the road after you, as you have followed in the footsteps of those dedicated scientists that showed you the way.

As theirs were, your career too will be built over a series of small, calculated decisions that move you forward in a particular field. However, don't miss any opportunities presented to you. In life, they often only knock once. These stories are as much tales of relentless dedication, as they are of the potential pay-offs of taking (calculated) risks – leaving country and home behind, stepping into a new environment as the inevitable underdog, or convincing those above you that your as-of-yet untested ideas must be tried. Almost without fail the interviewees are risk-takers – and their lives reflect the twists and turns they had to take to achieve their current positions.

Therefore, you have to be brave. Reach beyond your grasp again and again. Do not retreat in the face of opposition or rudeness. Stand your ground.

Deliver quality work

Your work is what will speak for you. Always produce high quality work that is practical but also displays perspective and vision to be ahead of the rest.

Last, accept that success and opportunities will not be handed to you on a platter – it will far more likely reach you on the back of hard work, like it did for all those interviewed.

In these ways, new experts will also contribute to solutions to our water-related problems. As it was five decades ago, it is still widely accepted that water security is critical to South Africa's future and, as it was stated at the time, the solutions can come from innovative research and development. However, the next suite of researchers will be able to continue working towards this vision from the strong foundation built by the legacy of the researchers that have come before them.

– Petro Kotzé (author)

Last, accept that success and opportunities will not be handed to you on a platter – it will far more likely reach you on the back of hard work, like it did for all those interviewed.

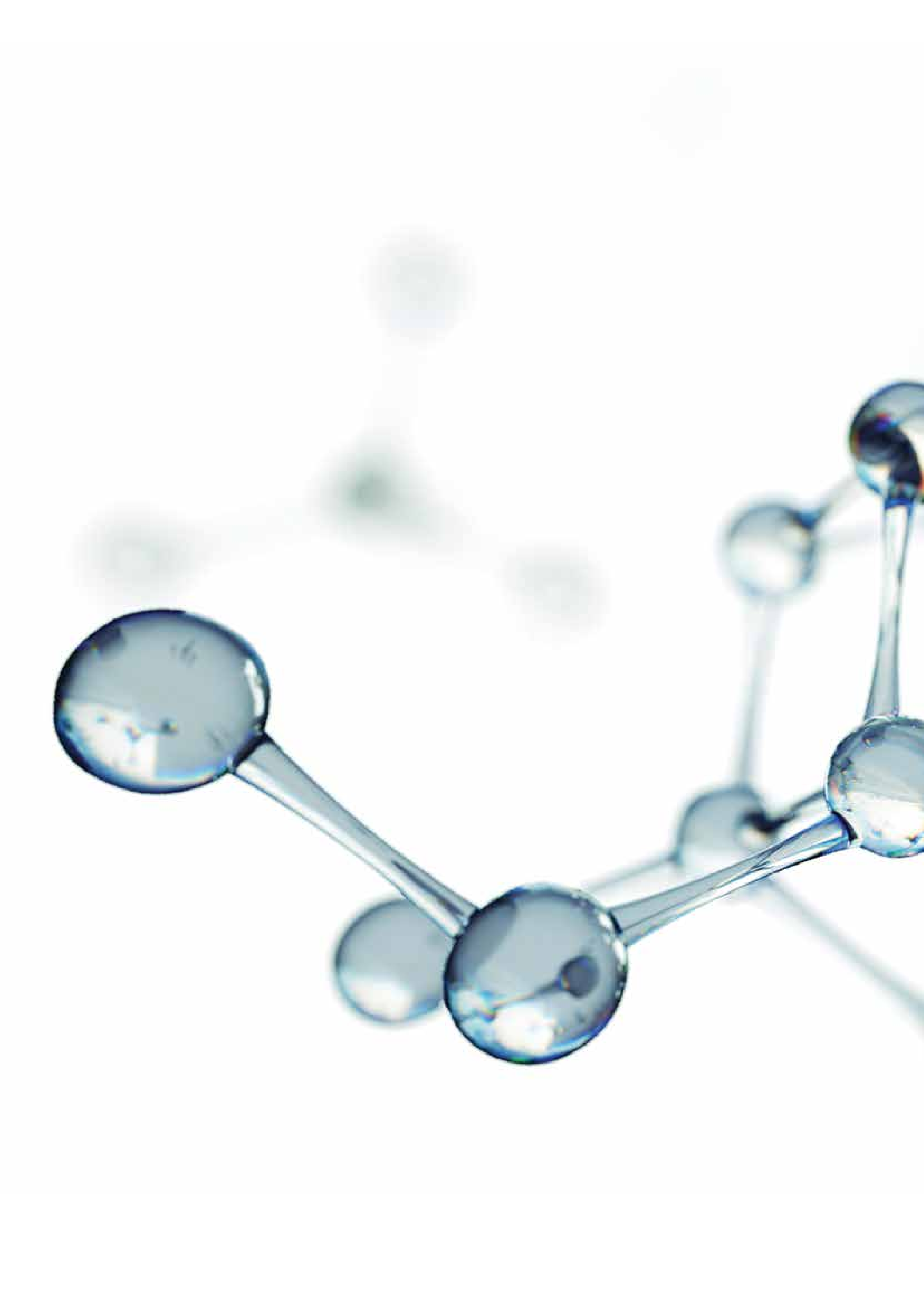
ABBREVIATIONS

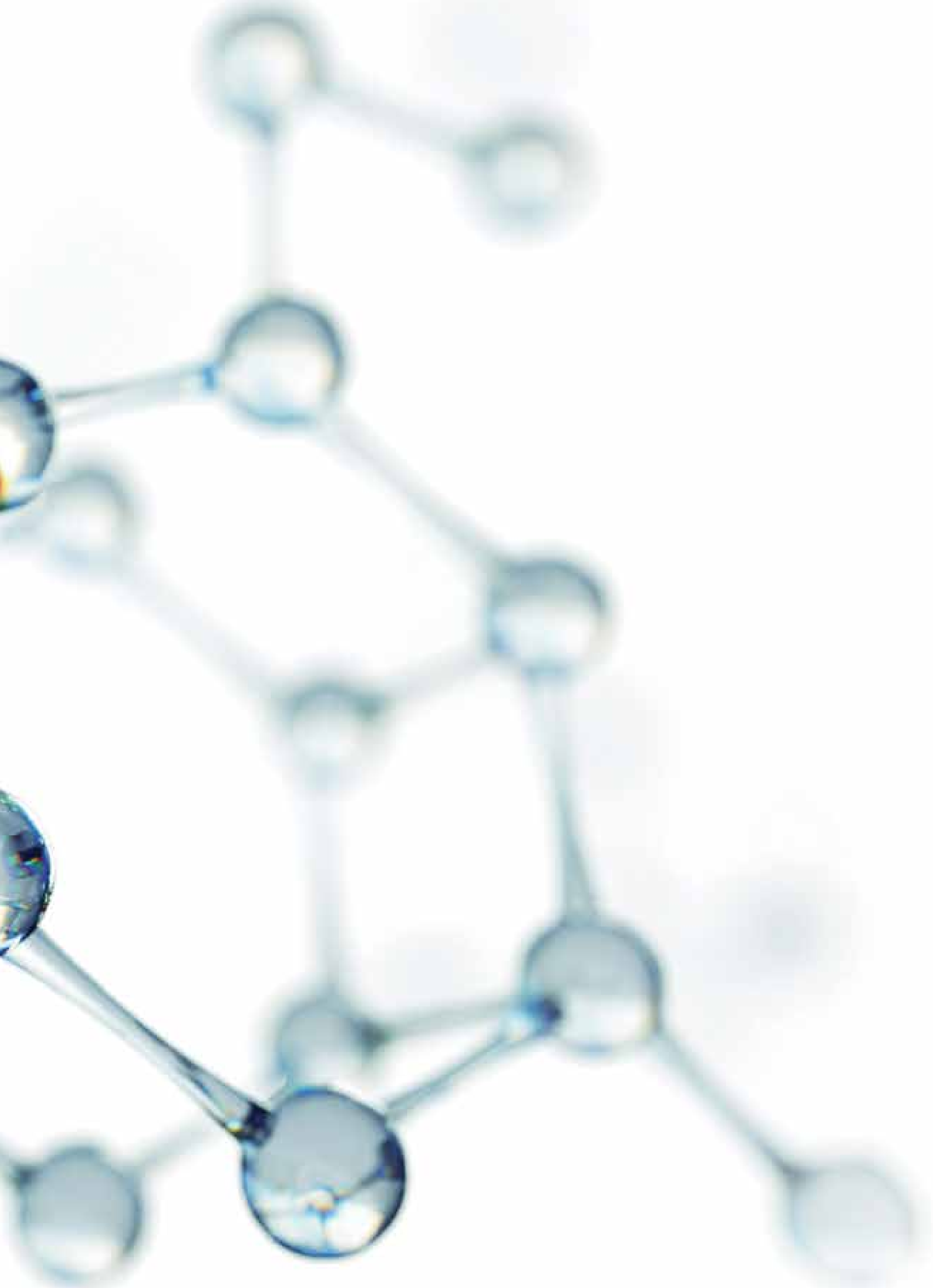
AAAS	American Academy of Arts and Sciences
ACRU	Agricultural Catchment Research Unit
AMD	Acid mine drainage
AMR	Antimicrobial resistant (organisms)
ARC	Agricultural Research Council
ARUA	African Research Universities' Alliance
ASSAf	Academy of Science of South Africa
AWARD	Association for Water and Rural Development
BBM	Building Block Methodology
BORDA	Bremen Overseas Research & Development Association
CAgM	Commission for Agricultural Meteorology
CEAD	Centre for Environment and Development
CERM	Consortium for Estuarine Research and Management
CEO	Chief Executive Officer
CMA	Catchment management agency
CPUT	Cape Peninsula University of Technology
CSET	College of Science Engineering and Technology
CSIR	Council for Scientific and Industrial Research
DAGEOS	Deep Artesian Groundwater Exploration for the Oudtshoorn Supply (project)
Danida	Danish International Development Agency
DDT	Dichloro-diphenyl-trichloroethane
DEA	Department of Environmental Affairs
DEWATS	Decentralised wastewater treatment system
dti	Department of Trade Industry and Competition
DRIFT	Downstream Response to Imposed Flow Transformation
DSI	Department of Science and Innovation
DUT	Durban University of Technology

DWA	Department of Water Affairs
DWAF	Department of Water Affairs & Forestry
DWS	Department of Water and Sanitation
EDC	Endocrine disrupting compound
EFO	Ezemvelo Farmer's Organisation
EIA	Environmental impact assessment
EWR	Environmental water requirement
FRD	Foundation for Research and Development
FRIEND	Flow Regimes from International Experimental and Network Data (project)
GEF	Global Environment Facility
GSSA	Ground Water Division of South Africa
GWRC	Global Water Research Coalition
HRU	Hydrological Research Unit (Rhodes)
HYMAS	HYdrological Modelling Application System
IAHS	International Association of Hydrological Sciences
ICMA	Inkomati Catchment Management Agency
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFCS	International Forum on Chemical Safety
IFWS	Institute for Freshwater Studies
IHP	International Hydrological Programme
iNanoWS	Institute for Nanotechnology and Water Sustainability
INC	International Negotiating Committee
INR	Institute of Natural Resources
IPCC	Intergovernmental Panel on Climate Change
IUCMA	Inkomati-Usuthu CMA
IUCN	International Union for Conservation of Nature
IWR	Institute for Water Research
IWRM	Integrated water resource management
IWWT	Institute for Water and Wastewater Technology
KNPRRP	Kruger National Park Rivers Research Programme
MRC	Medical Research Council

NEMA	National Environmental Management Act
NGO	Non-governmental organisation
NICD	National Institute for Communicable Diseases
NMU	Nelson Mandela University
NRF	National Research Foundation
NSTF	National Science and Technology Forum
NWU	North-West University
OGP	Oudtshoorn Groundwater Project
ORASECOM	Orange-Senqu River Commission
PAH	Polycyclic aromatic hydrocarbon
PCA	Permanent Court of Arbitration (The Hague)
POPs	Persistent organic pollutants
POPRC	POPs Review Committee
PRG	Pollution Research Group
RISE	Regional Initiative for Science Education
SA	South Africa
SADC	Southern African Development Community
SAFRI	South African Forestry Research Institute
SAIChE	South African Institution of Chemical Engineers
SANParks	South African National Parks
SARChI	South African Research Chairs Initiative
SASAqS	Southern African Society of Aquatic Scientists
SAWS	South African Weather Service
SCS	Soil Conservation Service [model]
SIA	Social impact assessment
SKA	Square Kilometre Array
SMME	Small, medium and micro enterprise
SPATSIM	Spatial and Time Series Information Modelling
STAP	The Scientific and Technical Advisory Panel
SWB	Soil Water Balance (model)

TAP	Technical Advisory Committee
TECHNEAU	Technology Enabled Universal Access to Safe Water
TIA	Technology Innovation Agency
TMG	Table Mountain Group (aquifer)
TPNP	Towards Practising a New Paradigm [project]
TRPPC	Treehouse Research Programme for People and Conservation
TUT	Tshwane University of Technology
UCT	University of Cape Town
UFS	University of the Free State
UJ	University of Johannesburg
UKZN	University of KwaZulu-Natal
UNEP	United Nations Environment Programme
UNDRR	United Nations Office for Disaster Risk Reduction
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNISA	University of South Africa
USDA	United States Department of Agriculture
UTS	University of Technology (Sydney)
UWC	University of the Western Cape
VIP	Ventilated improved pit (latrine)
WARMA	Water Resources Management Authority (of Zambia)
WasteMin	Waste Minimisation (clubs)
WEF	Water-energy-food (nexus)
WFMF	Woven fabric microfiltration (gravity filter)
WIP	Water Information Project
WISA	Water Institute of Southern Africa
Wits	University of the Witwatersrand
WMO	World Meteorological Organisation
WRC	Water Research Commission
WRF	Wits Rural Facility
WWF	World Wildlife Fund





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