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WATER RESOURCE MANAGEMENT

The plastic connection between rivers and oceans

WATER RESOURCES

Drought management initiatives in Port Elizabeth

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Editorial Committee:

Dr Sylvester Mpandeli (Chair), Ms Khosi Jonas, Ms Manjusha Sunil, Mr Bonani Madikizela, Dr Mamohlong Tlhogale and Sudhir Pillay.

Editorial offices:

Water Research Commission, Private Bag X03, Gezina, 0031, Republic of South Africa.

Tel (012) 761 9300. Fax (012) 331-2565.

WRC Internet address:

<http://www.wrc.org.za>

Follow us on Twitter:

 @WaterWheelmag

Editor: Lani van Vuuren,

E-mail: laniv@wrc.org.za;

Editorial Secretary: Dikeledi Molutsi,

E-mail: dikeledik@wrc.org.za;

Layout: Anja van der Merwe,

E-mail: anjavdm@wrc.org.za

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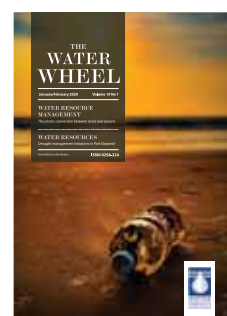
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AT A GLANCE

New partnership hopes to boost rollout of safe sanitation

Marine litter has become a global crisis, with rivers cited as a significant contributor to the problem. Article on page 10.



FLUID THOUGHTS

New water perspectives for 2020



WRC CEO, Dhesigen Naidoo

When she addressed the Water Institute of Southern Africa (WISA) conference, which took place in 2018 in Cape Town, Sunita Narain of the Centre for Science and the Environment, India, made the observation that change in weather patterns on the back of major climatic changes can be evidenced through both droughts and floods occurring simultaneously in the same country.

This is a phenomenon we are currently living through with the serious flood damage in some parts of the country while others are still in the grip of extreme water scarcity.

This physical phenomenon of extreme weather, which is rapidly defining our new normal, is greatly exacerbated by the metaphoric drought of ideas and imagination compounded by the floods of prejudice and negativity. This is particularly pronounced in the commentary of some regular water and development experts that fill our media spaces. A clan of Afro-pessimists in general and South African nay-sayers. They also happen to be of a certain gender, race and of a particular age.

One of the questions raised in response to the launch of the Water Masterplan by Minister of Human Settlements, Water and Sanitation, Lindiwe Sisulu was “where would the water come from?” South Africa has the accolade of being in the world’s top 10% of water knowledge producers on the back of a highly productive research community of practice, so let us assist in hydrating this drought of ideas. Accepting that the public is aware of the plans for various surface water augmentation schemes of dams and pipelines in process at the Department of Water and Sanitation, let us concentrate on the other even more attractive options.

Firstly, we have the potential of sustainable groundwater harvesting from renewable aquifers of between 8 to 12 billion m³ (a m³ is 1 000 litres) annually. Our current use is only between 2 and 4 billion m³ depending on the season. Core to the sustainability of this resource is frequent and regular replenishment. Groundwater also trumps surface water storage as it is largely immune from the evaporation index. A great example is the Atlantis aquifer outside Cape Town, which is being replenished with a combination of stormwater and treated wastewater. Its current potential for supply is 15-20 million litres a day.

A further unexploited resource is seawater along the coast and brackish and polluted waters inland. The traditional barrier to entry of energy demand has been largely solved by technological advancement and renewable energy options, and costs will depend on economies of scale on the one hand and the planning model on the other. Desalination investments could

easily decrease the current strain on surface water systems by at least 10%. For this to work it is essential that desalination plants are retained as a permanent part of the water mix and not only for emergencies. The possibilities were shown in the Ndlambe district municipality in the town of Albany in the Eastern Cape where Minister Sisulu launched the next phase of its desalination, now utilising a sand water harvesting system to supplement the seawater feed. The town is now predominantly supplied with these sources, supplemented by rainwater harvesting tanks. It is, if you like, an off-the-surface water grid.

The quickest win of all lies in reticulation efficiency. We currently lose about 25% of treated, expensive drinking quality water to leaks in our cities and towns. One out of every four litres of water is lost before it reaches the tap. A dramatically reimagined “**war-on-leaks**” initiative designed to build the plumbing capacity we need, building entrepreneurs to permanently provide this service to maintain the reticulation systems and the use of the latest technological platforms, including drones and robotics, will not only win back the 25% of water currently lost, but will support an industry platform that will provide livelihoods and economic growth in an inclusive manner. This is not pie-in-the-sky. The Water Research Commission, in partnership with the African Development Bank, has successfully piloted the social franchising model for school sanitation maintenance in the Eastern Cape, creating in the process 20 new companies employing at least 3 people each now active players in the industry. This is a model that can easily operate with similar efficacy and effectiveness in address the water leaks challenge.

If we delve deeper into the new non-sewered sanitation technologies, we have the potential to save 30% of water in every household and workplace in the country. What we observed when we launched the second phase of the SASTEP (South African Sanitation Technology Evaluation Programme) with the WRC’s partners, the South African Government and the Bill and Melinda Gates Foundation, was the high interest from both the business sector and the investment community. We add to this scaled recycling systems as part of the global purple pipe revolution where up to 80% of water in an average household can be reused for further purposes. The water arithmetic now begins to look very positive. In fact, with these demand management interventions we can easily reduce our South Africa’s per capita use from its current 253 litres per person per day to the global average of 173 litres per person per day. This will be an immediate saving of 30% overall. If we move to the global best practice of 108 litres per person per day as claimed by the likes of Denmark, then an amazing 57% of the current water asset will be available for new use. We will be in the realm of water prosperity. To answer the expert’s question – that is where

the water will come from even before you consider the classical augmentation schemes.

Let us address the other side of the coin – the flood of bigotry and prejudice infused with a deep Apartheid nostalgia garnished with thinly veiled hyper-privilege. That the current water woes are only there because there are new folk, black folk, in charge, completely ignores the fact that the notion of water crisis has been in the top five risks in the World Economic Forum's Global Risk Register for 9 years continuously. That the vagaries of extreme weather events and climate change is driving two thirds of the world to water stress. No, it must be a lament on the loss of skills in the water sector, of course in particular the white male skills base. Let us remind ourselves that the great efficiency of water services that these folks long for was one in which only 58% of South Africans had access to safe water and far fewer had the benefit of dignified improved sanitation. In short, the nostalgia is not shared. Also, the comments are not only deeply insulting to the millions of men and women, black and white, that put their best foot forward every day, toiling hard to provide for their families while keeping SA Inc ticking over.

This expression of hyper-privilege has become a major hurdle to the Mzansi Social Democracy project. Also, there is another way. In 2011, 80% the WRC's research portfolio was led by white male

researchers, today the majority of projects are led by women and black researchers. The key enabler to this great transformation story was, in fact, the generosity and willingness of the older white male researchers to come on board as the mentorship group to enable this very important change.

The future is not what it used to be. When we were pegging our hopes on 2020 in the 1990s, we were in the middle of what Clem Sunter labelled the long (economic) boom. Our optimism was further driven by our own liberation from Apartheid and our re-entry into the Global Community of Nations. The fact that the Kyoto Protocol was still the main game in town added to our positive views that we had a handle on making the world a much better place for future generations.

Much has changed and the world has become a much more challenging place. Let us reflect this festive season on the South Africa we really want and whether our current actions help us to get to the right space or is it taking us the other way. If there was one truism worth repeating from the Apartheid era it is *Eendragt maakt magt*, a national motto shared with several countries. Unity is indeed strength! A Mzansi united is the only way we can navigate our way out of the doldrums into prosperity.

WATER DIARY

Water governance

11-13 February

The Water Institute of Southern Africa (WISA) is offering a three-day training course in Stellenbosch on water governance. The course has been designed to facilitate understanding of the principles of water governance from a human rights perspective, and covers international water governance approaches, sustainable water resource management initiatives, and the implementation of measures in South Africa through the relevant legislation.
Visit: www.wisa.org.za

Large dams

4-10 April

The 88th annual meeting and symposium of the International Commission on Large Dams (ICOLD) will be held in New Delhi, India, under the theme 'Sustainable development of dams and river basins'.
Visit: www.icold-cigb.org

Water

31 May – 4 June

The Biennial conference and exhibition

of WISA is taking place at the Sandton Convention Centre. The conference is the region's biggest water conference – bringing together water sector professionals and other stakeholders from across the country and beyond. The conference will consider the broader impacts of water on society and the environment.
Visit: <https://wisa2020.org.za/>

Water and the environment

11-10 June

The IUCN World Conservation Congress is taking place in Marseille, France. The congress comes just four months before the world's governments come together to set conservation and sustainable development priorities and to mobilise action to reach them.
Visit: <https://www.iucncongress2020.org>

Sanitation

21-24 July

The First IWA Non-Sewered Sanitation specialist group conference is being hosted at the Future Africa Campus in Pretoria in partnership with the Water

Research Commission and the University of Pretoria. The aim of the conference is to provide stimulus for research and innovation for non-sewered sanitation and off-grid sanitation solutions, including faecal sludge management, build the technical and scientific base for sanitation and to contribute to scientific knowledge and good practice learnings. Enquiries: Dr Sudhir Pillay, Email: sudhirp@wrc.org.za,
Visit: www.shorturl.at/DIJQ0

World Water

18-23 October

The IWA World Water Congress will take place in Copenhagen, Denmark with the theme 'Water for smart liveable cities'.
Visit: <https://worldwatercongress.org/>

Municipal water

28-30 October

The Institute of Municipal Engineering of Southern Africa will be holding its annual conference in Cape Town.
Visit: <https://www.imesa.org.za/>

NEWS

Parliament welcomes DWS financial recovery plan



The Parliamentary Portfolio Committee on Human Settlements, Water and Sanitation has welcomed the Department of Water and Sanitation's financial recovery plan.

In a statement released in November the committee said that the plan gave them assurance that the current leadership would be able to overcome the department's long-standing challenges.

"An efficiently-run department is a precursor to improved service delivery. The plan and the impacts it has made so far are reasons for optimism," the committee believes.

One of the major areas of improvement has been the reduction in accruals and payables, which had been reduced to around R808 000 by November. The payment for services received ensures that service providers remain viable and that projects are completed.

The committee also welcomed the DWS's consequence management initiatives to deal with the over R16 billion in irregular expenditure. As many as 86 guilty verdicts, 13 dismissals, one demotion and various suspensions have been meted out against errant officials.

In respect to debt owed to the

department and its entities, the committee emphasised the need for constructive discussions coupled with strong implementation in areas of agreement to deal effectively with the debt and to assist water agencies to improve their balance sheet.

The committee also noted the department's intention to exit the War on Leaks programme. "While the committee acknowledges the need to conclude the programme, the department should improve its planning capacity, as the intentions of War on Leaks were noble and much could have been achieved, especially in relation to decreasing non-revenue water."

The committee has requested regular updates from the department on the financial recovery plan.

Water sector gearing up for biggest technical event of the year

The Water Institute of Southern Africa (WISA) Biennial Conference and Exhibition will be held at the Sandton International Convention Centre from 31 May to 4 June.

Southern Africa's water demands are on the rise, as a rapidly growing and urbanising population, changing lifestyles and economic growth place increasing pressure on this resource. The result is a growing water crisis worsened by insufficient water infrastructure maintenance and investment, recurrent droughts and floods driven by climatic variation, inequities in access to services, deteriorating raw water quality, and a lack of skilled water practitioners.

WISA believes that in order to address these challenges, the sector needs to have

#AllHandsOnDeck, the theme for this year's event. The WISA 2020 conference will, therefore, provide a platform for these issues to be discussed, solutions shared and decisions taken in a pledge to action. The theme calls for local and regional players to work together towards a sustainable water future, and WISA 2020 aims to speed up delivery and bring purposeful feedback to the leadership of South Africa.

The conference will cover various sub-themes, including reducing water demand and increasing supply; managing the resource for a capable ecology; managing and monitoring effective water and sanitation services and infrastructure; governance and regulation; improving raw water quality and management;

and developing skills and technology innovations and disruptors.

"Our past conferences have provided a platform to discuss problems and solutions facing the water and related sector. Now is the time to create the mechanisms and an enabling environment to set us on a path of implementation and impact," notes Dr Shafick Adams, Chair of the local organising committee. "Water is everyone's business and everyone should be involved in ensuring that we have water security. This is now more important than ever, as we need to navigate issues of climate change, weather variability, demand growth, infrastructure needs and so forth."

Dam safety adherence slips – Minister expresses concern



Water and Sanitation Minister, Lindiwe Sisulu, has called on dam owners across the country to adhere to dam safety legislation in the wake of extreme weather patterns.

Sisulu warned that failure to stick to the rules may prompt the department to take legal action against transgressors.

“We are faced with water security challenges as a country and key to this is deteriorating infrastructure. I therefore urge dam owners to do their bit to safeguard water infrastructure by conducting the required [dam safety] evaluations, which will not only protect society from potential dam failures, but will also ensure guaranteed storage,

especially in the current climatic conditions facing our country,” she noted.

South Africa’s dam safety legislation requires that all dams with a storage capacity of more than 50 000 m³ and a wall height of more than five metres must be registered as a dam with a safety risk and is subject to dam safety inspections by registered persons. The Dam Safety Office (DSO) currently has over 5 600 such dams registered across the country.

Sisulu noted that for the 2018/19 period, at least 313 dam safety evaluation reports were expected to be submitted to the DSO, but only 207 (66%) were submitted. “Each dam must have a safety inspection conducted every five years. In this case, dam owners are required to arrange for the execution of a formal dam safety inspection by an approved professional person.”

The minister said that her department remained committed to safeguarding South Africa’s water resources. “As such, dam owners are encouraged to play their role by abiding to dam safety legislation, as set out in the National Water Act.”

(Photo for illustrative purposes only)

Environmental assessment practitioners body officially recognised

The South African Qualifications Authority (SAQA) Executive Committee has recognised the Environmental Assessment Practitioners Association of South Africa (EAPASA) as the first statutory environmental assessment professional body for a period of five years.

EAPASA Chairperson, Snowy Makhudu, has hailed the recognition by SAQA as a historic achievement for the organisation, the country, and the African continent. “This gives credence to our work as we seek to promote ethical practice and quality of environmental assessments in South Africa.”

EAPASA was appointed by the Department of Environment, Forestry and Fisheries as the single Registration Authority for environmental assessment practitioners in South Africa in 2018. The recognition of EAPASA as a professional body is beneficial to the environment sector, contributing to skills development of environment assessment practitioners and enhancing quality assurance and professionalism in South Africa, the association said in a statement.

“Registration with EAPASA enables environmental assessment practitioners to comply with the national legislation in

their operation. It also creates a platform to independently address incompetent and unethical behaviour, while protecting those who comply and uphold the EAPASA Code of Ethical Conduct and Practice.

For more information, Visit: www.eapasa.org

GLOBAL

World Toilet Day highlights rights, dignity of sanitation workers



The plight of sanitation workers in the developing world should be addressed urgently, according to the World Health Organisation (WHO).

Highlighting the dangers for the millions of people who clean toilets, sewers and septic tanks, ahead of World Toilet Day on 19 November, the WHO insisted that while the workforce performs an essential public service, their own health is compromised and they are often

shunned. "Workers often come into direct contact with human waste, working with no equipment or protection to remove it by hand, which expose them to a long list of health hazards and diseases," the international organisation said.

"It is only when those critical services fail, when society is confronted with faecal waste in ditches, streets, rivers and beaches or occasional media reports of sanitation worker deaths, that the daily practice and plight of sanitation workers come to light," it maintains.

The publication, *Health, safety and dignity of sanitation workers* was produced jointly with the International Labour Organisation, World Bank, and WaterAid. It examines nine case studies of sanitation workers in low and middle-income countries, who empty pits and tanks, transport faecal sludge and perform sewer maintenance.

The publication describes the workforce as "invisible, unquantified and ostracised" and insists that many of the challenges that sanitation workers face stem from a lack of acknowledgement for what they do.

While the workers include full-time employees with health benefits, pensions and legal protection, a significant proportion comes from some of the "most marginalised, poor and abused members of society."

The report also highlights where sanitation work has been officially acknowledged and formalised, citing South Africa as an example, where public and private employees follow national labour standards and have proper equipment and training.

"Many of the challenges sanitation workers face stem from their lack of visibility in society," WHO said, noting that few countries in the developing world had any guidelines to protect sanitation workers. "Where laws do exist, governments may lack the financial or technical means to implement them, and the informality of the roles present further challenges."

To access the publication, Visit: https://www.ilo.org/sector/Resources/publications/WCMS_728054/lang-en/index.htm

US shift away from coal saving significant volumes of water

The ongoing transition from coal to natural gas and renewables in the US electricity sector is dramatically reducing the industry's water use, a new study has found.

"While most attention has been focused on the climate and air quality benefits of switching from coal, this new study shows that the transition to natural gas – and even more so, to renewable energy sources – has resulted in saving billions of gallons of water," notes Avner Vengosh, professor of geochemistry and water quality at the Nicholas School of the

Environment at Duke University.

These savings in both water consumption and water withdrawal have come despite the intensification of water use associated with fracking and shale gas production, the study shows.

"For every megawatt of electricity produced using natural gas instead of coal, the amount of water withdrawn from local rivers and groundwater is reduced by 10 500 gallons (about 39 747 litres), the equivalent of a 100-day water supply for a typical American household," says Andrew

Kondash, a post-doctoral researcher who led the study.

At these rates of reduction, if the rise of shale gas as an energy source and the decline of coal continues through the next decade, by 2030 the US will save about 483 billion cubic metres of water each year.

The study was originally published in *Environmental Research Letters*, Visit: <https://iopscience.iop.org/article/10.1088/1748-9326/ab4d71>

In memoriam – Arjen Hoekstra, father of the water footprint



The international water sector has expressed its shock and sadness at the unexpected death of Arjen Hoekstra, co-founder of the Water Footprint Network.

Hoekstra, who passed away on 18 November at the age of 52, was a professor of Water Management at the University of Twente and the inventor of the 'water footprint' concept. The water footprints Hoekstra invented in 2003 gave the sector a framework to analyse the link between human consumption and production and the appropriation of the world's freshwater. This innovation not only kicked off a whole new academic field, Water Footprint Assessment, but also made it possible for companies, governments and consumers to understand their water dependence in locations around the world and how their water footprint contributes to social, environmental and economic impacts in vulnerable river basins.

The water footprint is the actual volume of freshwater consumed or polluted by a process, a product or an organisation. "Thanks to Arjen Hoekstra, the international discussion about production and consumption and the trade of goods moved to a new level of clarity, making it much easier to go from intentions to

action," noted the Stockholm International Water Institute (SIWI).

Over the years thousands of students have followed the e-learning courses that have been organised by Hoekstra's network. Several companies, including Tata Steel, Ikea, Coca-Cola and Heineken have used the concept of water footprint to raise awareness about water conservation within their own organisations.

Hoekstra worked tirelessly to expand the scientific understanding of the real appropriation of water required for different human activities. He was one of the most cited researchers in his field. He also authored several books.

"With the death of Arjen Hoekstra, the water world has lost one of its most brilliant and innovative minds," said SIWI in a statement. "Furthermore, many of us have lost a friend, a colleague who inspired the best in us and a co-conspirator who challenged us to become better advocates for sustainable development."

Nile River 'older than thought'



Ancient Egyptians considered the Nile River to be the source of all life. The steady northward path of the river has nourished the fertile valleys of northeast Africa for millions of years and in doing so, shaped the course of human civilisation.

The Nile's unchanging path, however, has been a geologic mystery because long-lived rivers usually move over time.

Researchers at the University of Texas at Austin have cracked the case by linking the river's flow to the movement of rock in the Earth's deep mantle. In the course of their investigation, they found the eternal river to be much older than anyone realised, with the scientists estimating the age of the Nile to be 30 million years – about six times as long as previously thought.

The research, published in the journal, **Nature Geoscience**, found that if it weren't for the mantle movement keeping the river on course, the Nile would have turned west long ago, probably changing the course of history along with it.

The results should settle a long-running debate about the age of the river and provide evidence that the slow movement of the deep mantle is one of the key forces shaping our Earth's landscape and geological processes.

To view the original article, Visit: <https://www.nature.com/articles/s41561-019-0472-x>

WATER RESOURCE MANAGEMENT

To keep the oceans clean, look towards our rivers

Marine litter has become a global crisis. As the impact of the waste that we generate become clearer, so is people's alarm, their willingness to take action and the search for solutions. Now, instead of looking for ways to clean-up the seas, researchers are saying that a large part of the answer lies elsewhere; not in the ocean, but in our rivers. Petro Kotzé takes a closer look.



According to Senior Manager for the Stockholm International Water Institute (SIWI) Water Governance Department, Ruth Mathews, the issue of plastic pollution in the marine environment was first recognised as an ocean problem. As such, the necessary action was to clean up the ocean by removing the plastic that was already there. This led to beach and ocean cleanups, and the development of technologies to capture plastic waste from the surface of coastal and marine waters. However, she says, more recently research has begun to quantify the amounts of trash in the ocean, and where it comes from.

What goes into our oceans?

According to the United Nations Environment Programme (UNEP), marine litter is any persistent, manufactured or

processed solid material discarded, disposed of or abandoned in the marine and coastal environment.

It mainly consists of plastics, wood, metals, glass, rubber, clothing and paper, although the World Bank reports that about 80% is plastics. This is confirmed by Geoff Tooley, eThekweni Municipality Senior Manager for Catchment Management, when asked about what the bulk of trash that ends up on Durban's beaches consists of. "Plastic and polystyrene form the base," he explains. "There are things like furniture, but most of it is either plastic, the largest portion, and the next is polystyrene, in the form of fast food outlet packaging."

Where does the trash come from?

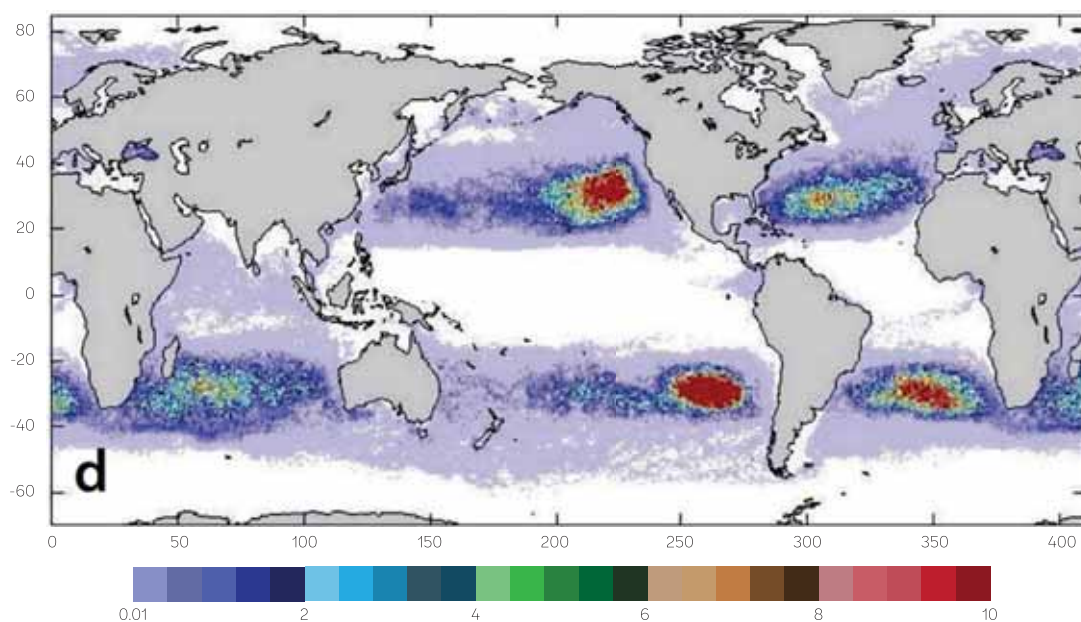
International studies (in particular by the Jambeck Research Group at the University of Georgia) estimate that the largest quantities of marine litter and plastic waste originate from a relatively small number of countries in Asia and other middle income, rapidly developing countries. Of the top 20 countries South Africa is ranked eleventh and, together with the rest of top perpetrators, account for 83% of the mismanaged plastic waste entering the ocean.

Rank	Country	Econ. classif.	Coastal pop. [millions]	Waste gen. rate [kg/ppd]	% plastic waste	% mismanaged waste	Mismanaged plastic waste [MMT/year]	% of total mismanaged plastic waste	Plastic marine debris [MMT/year]
1	China	UMI	262.9	1.10	11	76	8.82	27.7	1.32–3.53
2	Indonesia	LMI	187.2	0.52	11	83	3.22	10.1	0.48–1.29
3	Philippines	LMI	83.4	0.5	15	83	1.88	5.9	0.28–0.75
4	Vietnam	LMI	55.9	0.79	13	88	1.83	5.8	0.28–0.73
5	Sri Lanka	LMI	14.6	5.1	7	84	1.59	5.0	0.24–0.64
6	Thailand	UMI	26.0	1.2	12	75	1.03	3.2	0.15–0.41
7	Egypt	LMI	21.8	1.37	13	69	0.97	3.0	0.15–0.39
8	Malaysia	UMI	22.9	1.52	13	57	0.94	2.9	0.14–0.37
9	Nigeria	LMI	27.5	0.79	13	83	0.85	2.7	0.13–0.34
10	Bangladesh	LI	70.9	0.43	8	89	0.79	2.5	0.12–0.31
11	South Africa	UMI	12.9	2.0	12	56	0.63	2.0	0.09–0.25
12	India	LMI	187.5	0.34	3	87	0.60	1.9	0.09–0.24
13	Algeria	UMI	16.6	1.2	12	60	0.52	1.6	0.08–0.21
14	Turkey	UMI	34.0	1.77	12	18	0.49	1.5	0.07–0.19
15	Pakistan	LMI	14.6	0.79	13	88	0.48	1.5	0.07–0.19
16	Brazil	UMI	74.7	1.03	16	11	0.47	1.5	0.07–0.19
17	Burma	LI	19.0	0.44	17	89	0.46	1.4	0.07–0.18
18*	Morocco	LMI	17.3	1.46	5	68	0.31	1.0	0.05–0.12
19	North Korea	LI	17.3	0.6	9	90	0.30	1.0	0.05–0.12
20	United States	HIC	112.9	2.58	13	2	0.28	0.9	0.04–0.11

*If considered collectively, coastal European Union countries (23 total) would rank eighteenth on the list

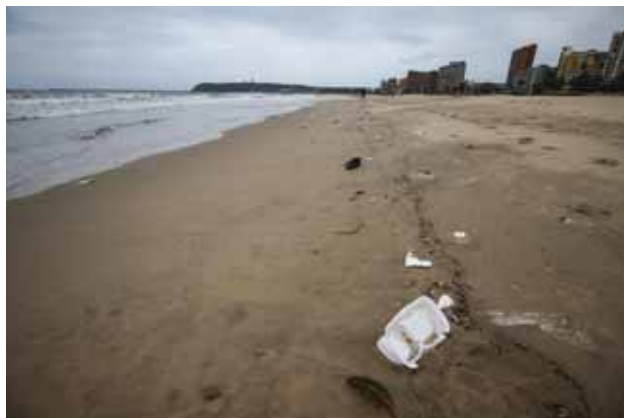
Waste estimates for 2010 for the top 20 countries ranked by mass of mismanaged plastic waste, indicated in units of millions of metric tons per year. Mismanaged waste is the sum of inadequately managed waste plus 2% littering. Total mismanaged plastic waste is calculated for populations within 50 km of the coast in the 192 countries considered. Economic classification is indicated according to World Bank definitions based on 2010 Gross National Income, as follows: high income (HIC), upper middle income (UMI), lower middle income (LMI), and low income (LI).

Regardless of where the litter comes from, it adds to a global problem. Plastic pollution is moved throughout the world's oceans by the wind and currents, but congregate in five highly concentrated subtropical gyres: North Marine Litter Pacific, North Atlantic, South Pacific, South Atlantic, and Indian Ocean.



Note: Units represent relative change in drifter concentration. Source: IPRC Climate 2008.

A mock-up of the evolution of marine debris by 2018 after 10 years of advection by currents, as determined from real drifter movements, indicating the five subtropical gyres.



Marine litter and other waste has long found an easy way to the sea – via the rivers that transport it there.

Figuring out how much plastic there is in the ocean exactly (by number of pieces and weight) is an ongoing process. This is made more difficult because the plastic does not remain on the water's surface. The UNEP estimates that only 15% of marine litter floats on the sea's surface. The rest remains in the water column (15%) while the bulk (70%) rests on the seabed.

Furthermore, plastic progressively breaks down into smaller pieces, and is digested by various forms of marine life, making the true state of plastic presence in the ocean even more difficult to quantify.

Researchers have placed conservative estimates of the global weight of plastic pollution in the sea surface at a minimum of 5.25 trillion particles weighing 268 940 tons (as published in *Plos One*). This is still only 0.1% of the world annual production of plastic. Plastics Europe, a trade organisation representing plastic producers and manufactures, reported that 288 million tons of plastic were produced worldwide in 2012. The researchers

thus stressed that their estimates of the weight of plastics in the ocean are highly conservative and based on a limited inventory of ocean observations. Furthermore, it does not account for the potentially massive amount of plastic on shorelines, on the seabed, suspended in the water column, and within organisms that ingest it.

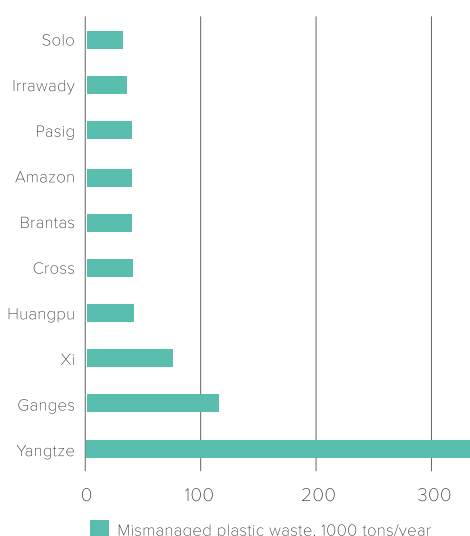
The route of plastic to the sea

The main sea-based sources of marine litter are shipping and fishing, but various reports indicate that up to 80% of the litter comes from land. Sources are listed to include tourism, sewage and illegal or poorly managed landfills. Tooley estimates that at least 90% of the litter that plagues Durban's beaches is from their river basins. Another 5 – 6% reach the sea directly from the stormwater drainage system, and the balance is windblown or chucked on the beach by people.

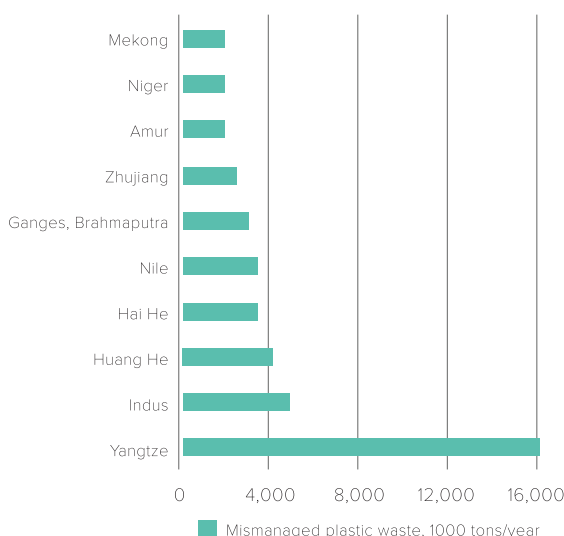
All over the globe, an astounding amount of litter and other forms of pollution enter our seas in the same way. The Jambeck study, using worldwide data on solid waste, population density and economic status estimated the amount of plastic waste generated in 192 countries at 275 million metric tons (in 2017). Of this, an estimated 4.8 to 12.7 million metric tons was estimated to enter the ocean. Looking at plastic pathways, the study found that 10 rivers basins are responsible for 90% of land-based leakages to the ocean.

“Researchers have placed conservative estimates of the global weight of plastic pollution in the sea surface at a minimum of 5.25 trillion particles weighing 268 940 tons.”

Estimates by Lebreton et al, 2017



Estimates by Schmidt et al, 2017



The top ten rivers contributing to marine litter. Both studies show the Yangtze River basin as the main contributor. The ranks for other polluted rivers differ due to the entry data used in two studies: Lebreton used the global river plastics input model for estimation whereas Schmidt's made calculations as a product of mismanaged plastic waste generated per capita and population size in the catchment.

Mathews notes that research like this has brought attention to the urgent need to address land-based sources of plastic pollution. The challenge, both locally and internationally, is substantial. Says the Department of Environmental Affairs (DEA) Chief Director of Communications, Albi Modise: "Despite ongoing efforts to clean the Republic of South Africa's beaches, litter continues to flow to the coast through rivers and waterways from inland sources."

There are positive signs that the tide is slowing turning, however. And increasingly, attention is being turned to the route litter follows to the sea.

SIWI recently released the Source-to-Sea Framework for Marine Litter Prevention, highlighting the central role of the river basin. In South Africa, the DEA too is piloting a source to sea approach to address marine litter at selected river basins. Tooley says, every time they experience a big storm, and the beaches are left full of litter, the same discussion is raised: "How do we stop it from getting there in the first place?"

South Africa's source-to-sea intervention

The DEA's approach involves catchment wide or river basin wide interventions in five rivers in coastal KwaZulu-Natal. Modise says these rivers consistently generate beach and marine litter, especially after heavy rain, when pollution throughout the catchment tends to be flushed out via the rivers towards the coast. "Coastal clean-up activities downstream of these loaded river systems have not been successful due to the constant and ongoing flow of litter," he says.

The five rivers in question are the uMngeni River that flows into the Blue Lagoon at Durban North Beach; the uMlazi River that flows towards Cuttings Beach; and the uMbilo, uMhlatuzana and aManzimnyama rivers, all three of which flow into Durban Bay.

The DEA's aim is to "reduce the impacts from land-based sources and activities and sustainably manage critical coastal-riverine ecosystems through the implementation of waste management practices, advocacy, education and job creation," says Modise. The initiative is cross-sectoral in nature and includes key roleplayers and stakeholders.

To reach a long-term goal of cleaning up the catchments to reduce marine litter, the project has various short-term objectives. Among others, litter hotspots are to be identified, from where litter is to be recovered for 24 months. This includes the installation of litter 'booms' to intercept waste floating on the water surface. The types and quantities of litter collected will be recorded, and an assessment made of the micro-plastics present. At least one waste management intervention per pilot river is to be identified, explains Modise. This can include waste sorting, recovery and recycling. This will be followed by educational activities and awareness campaigns.

"The medium to longer term goal is to expand the footprint of the source-to-sea initiative nationally," adds Modise. Once the results of the pilot project have been reviewed, he says, it could potentially be replicated at other coastal areas in South Africa.



Debris and litter washed up on the shores of Mabul, a small island off the south-eastern coast of Sabah in Borneo, Malaysia.



There are many sources of marine litter, including from the sea itself, in the form of material lost at sea, or deliberately left there or on the beaches and shores, such as fishing gear and cargo.

“Ten rivers basins are responsible for 90% of land-based leakages to the ocean.”

Still, Modise admits that there are ample challenges, some of which include the lack of waste management in informal settlements, for which innovative solutions are necessary. Another challenge is to change the communities' behavior and attitudes to not dump illegally, and to recycle, he says.

Mathews says they hope that their framework can help address such challenges. “Ultimately the framework is aimed at supporting local and national governments in gaining control of plastic waste and guiding the investments of international organizations, financiers, NGOs, and others who can bring knowledge and financial resources and build awareness and political will to address plastic leakage.”

The SIWI Source to Sea Framework

The Source-to-Sea Framework for Marine Litter Prevention focuses specifically on addressing plastic leakage from river basins. The framework calls for first, an understanding of the sources, types, behaviour and impacts of plastic pollution in riverine and marine environments. Then, stakeholders who are impacted by, contribute to and provide solutions for plastic leakage should be engaged.

Failures in governance, finance, management and operations must be analysed. Commitment towards preventing plastic pollution must be built. Then, action should be taken on individual to global levels. Progress should be monitored and learning fostered by doing and adapting. Transformation to a circular economy must be supported. Last, the framework should be applied to key challenges. This includes the many other issues that contribute to the degrading of riverine and marine environments, beyond poor solid waste management and the uncontrolled consumption of plastic goods.

Such a source-to-sea approach takes a global concern, and filters it down to local interventions, with the river basin at the core. At the same time, the changes in behavior and practices on various levels combined, can achieve a large improvement in river basins that will ultimately filter back again, to the oceans.

“My hope is that the Source-to-Sea Framework for Marine Litter Prevention will be used in river basins around the world to establish the governance, management, finance, and behaviours that will gain control of plastic waste and prevent plastic leakage from river basins,” notes Mathews.

“Initially, investments should be made to improve solid waste management locally,” she says. For this, stakeholders at global, national, and regional levels who can bring financial solutions and build the political will to address these challenges must be engaged. Simultaneously, a circular economy that will

add value to plastic must be developed. This will shift plastic waste management from disposal to reuse and recycling, she says. "The framework supports this two-pronged approach of strengthening local management of plastic waste while developing a circular economy globally."

SIWI is currently piloting the framework in two locations, namely the Vu Gia – Thu Bon River basin in Vietnam and Lake Hawassa basin in Ethiopia. "We have held stakeholder workshops and capacity training and have received strong interest in using the framework to address plastic leakage," explains Mathews. The project will be continuing into 2020.

Components of a good plan to solve marine litter

According to Modise, research shows that reducing the amount of mismanaged waste by 50% in the top 20 countries where the most marine litter and waste originates from, would result in a nearly 40% decline in inputs of plastic to the ocean. And, he says, the research also suggests that solutions to the growing problem of plastic pollution are possible, given sufficient resources and commitment.

For any such success the whole community has to be involved, says Tooley, including residents, government, the private sector and businesses. He adds that a convincing factor is the cost avoided should marine litter not exist. These could include the cost of collecting the waste from the marine and beach environment, and the harbours, for example. "It's cheaper to get it out of the system before it gets into the system," he explains. "If we can

get that right, we won't even have to talk about marine waste." Concludes Tooley, the cheapest way to get rid of the problem, is to tackle it at the source.

Sources:

- *Plastic Pollution in the World's Oceans: More than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea* by M Eriksen, LCM Lebreton, HS Carson, M Thiel, CJ Moore, JC Borerro, et al published in PLoS ONE (2014)
- *Plastic waste inputs from land into the ocean*, by Jenna R. Jambeck, Roland Geyer, Chris Wilcox, Theodore R. Siegler, Miriam Perryman, Anthony Andrady, Ramani Narayan and Kara Lavender Law published in Science, 13 February 2015
- *Solving marine pollution - Successful models to reduce wastewater, agricultural runoff, and marine litter*, a World Bank report by Olha Krushelnyska, September 2018
- *Source-to-Sea Framework for Marine Litter Prevention: Preventing Plastic Leakage in River Basins* by RE Mathews, R.E. & J. Stretz, 2019 for the Stockholm International Water Institute (SIWI)



Minh Hai in the Vu Gia – Thu Bon River basin in Vietnam.

WATER RESOURCES

Port Elizabeth – Planning, engineering and science combine to avoid Day Zero

Forward planning for the Algoa Bay Water Supply System has helped reduce the risk of a drought-induced 'Day Zero' in Port Elizabeth. Article by Sue Matthews.



The Kouga Dam is the largest dam in the Algoa Water Supply Scheme. Apart from providing water for Nelson Mandela Bay Municipality and the towns of Hankey and Patensie in the Kouga Municipality, a large allocation is set aside for the Gamtoos Irrigation Board.

At the beginning of December, residents of Port Elizabeth and adjacent towns in the Nelson Mandela Bay (NMB) Municipality were facing another holiday season of harsh water restrictions due to the ongoing drought. Yet the situation was not quite as dire as might be expected from the area's startlingly low dam levels.

Two weeks earlier the level of the second largest dam, the Krom River's Impofu Dam, had fallen below the lowest intake point, which meant that its water was no longer accessible.

Subsequently, good rains in the catchment caused the small Churchill Dam, 21 km upstream, to overflow, and by 2 December this water had raised the level of the Impofu Dam a percentage point to 17.5%. The larger Kouga Dam (previously called the Paul Sauer Dam) on the Kouga River stood at 32.8% – a huge improvement from the record low of 6.7% in July 2018.

But it is thanks to planning initiated a decade ago that there is room for optimism. In 2008 the then Department of Water Affairs, in collaboration with Nelson Mandela Bay (NMB)

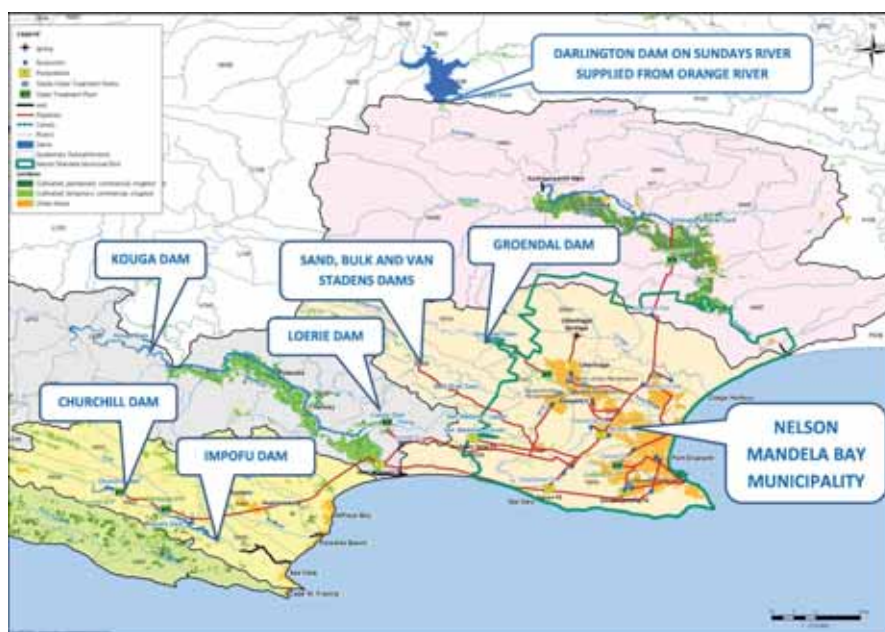
Municipality, commissioned the Algoa Reconciliation Strategy Study to ensure a sustainable future supply from the Algoa Water Supply System, which serves the area extending from the Kouga River system in the west to the Sundays River system in the east.

The study was completed in April 2010, but updated in April 2011 to address emergency interventions planned as a result of the 2009-2011 drought, as well as the anticipated water requirements of the Coega Industrial Development Zone (IDZ). Since then, a strategy steering committee set up to monitor implementation of the study recommendations and update them as necessary has continued to meet regularly. Technical support has been provided by Aurecon, which also conducted the reconciliation strategy study with the assistance of AfriCoast Engineers, Palmer Development Group, Groundwater Africa, MGP Consulting, and Scherman Colloty & Associates.

The final report of the reconciliation strategy study identified a number of potential interventions and made recommendations about their order of priority. Among others, they included options for water re-use (using treated wastewater from the existing Fishwater Flats wastewater treatment works and planned Coega wastewater treatment works) and desalination (of both seawater and Sundays River irrigation return flows), some of which were investigated further and either ruled out as not feasible or put on the backburner, being unaffordable or impractical at this time. For example, environmental approval for the rezoning and development of the Coega IDZ was conditional upon treated wastewater being used as a source of industrial water supply. But the NMB Municipality does not have the funds to implement this – and the IDZ does not yet have any big industry players with significant water requirements – so currently there is only limited re-use from the Fishwater Flats wastewater treatment works, mainly by the surrounding Deal Party industries.

The reconciliation strategy study supported the fast-tracking of the Nootgedacht Low-Level Scheme, an extension of the existing Nootgedacht High-Level Scheme that treats water from the Gariep Dam, delivered via the Orange-Fish-Sunday's transfer system. Although Treasury made R450 million of emergency drought funding available to the NMB Municipality in 2011, this still left a massive shortfall. Phase 1 was completed by mid-2013, but numerous delays due to funding issues meant that Phase 2 was only completed in mid-2017, and the completion date for the final Phase 3 has recently been pushed back to April 2021. National government has footed the bill, but the total cost has escalated by some R300 million over the past decade. Nevertheless, the scheme is designed to provide an average of 160 Mℓ potable water per day for distribution by the NMB Municipality, which is a significant contribution. Water restrictions, leak repairs and pressure management had succeeded in reducing potable water use to approximately 280 Mℓ per day in November 2019 – it had risen to 345 Mℓ per day in 2017, before the current drought took hold.

The reconciliation strategy study also supported the NMB Municipality's emergency intervention to investigate groundwater resources close to existing infrastructure. Dr Ricky Murray of Groundwater Africa explains that he was asked by the municipality to start looking for areas with promising groundwater potential in 2010. Two years previously – before the 2009-2011 drought began – he had completed a Water Research Commission (WRC) project on the development of a GIS-based approach for identifying municipal groundwater exploration target areas. The final report, co-authored with Marc Goedhart and Jane Baron, was titled *High-yielding groundwater areas around the Nelson Mandela Bay Municipality (WRC Report No. TT 327/08)*, and it focused on areas within an economically acceptable distance of existing water-supply pipelines and electricity sources. This was a desktop study that drew upon an earlier WRC and Council for Geoscience project by Goedhart, Small and Hulley, completed in 2004.



The main dams supplying Port Elizabeth and other towns in the Nelson Mandela Bay Municipality and the Kouga Municipality. There are also a number of smaller dams, plus water is transferred from the Gariep Dam on the Orange River via the Orange-Fish-Sundays interbasin transfer scheme to the Nootgedacht water treatment works.

Eastern Province Annual for 1940

THE REMARKABLE ZWARTKOPS MINERAL BATHS SANATORIUM

4 MILES FROM PORT ELIZABETH

ONE is naturally and wisely guided by the opinion of experts ... and the voice of experience ... when choosing the Spa at which one will "take the cure." In "Town and Country News" (London), Arnold Richardson describes Zwartkops Baths as "One of the most effective mineral baths in the world." This view has been confirmed by other experts. These remarkable Radio-active Chalybeate waters contain ... in ideal proportion ... medicinal properties which world-famous Continental spas lack and have to add artificially.

Amazing cures have been effected in cases of rheumatism, sciatica, lumbago, gout, insomnia, nervous complaints, painful affections of the muscles and joints, strains, sprains, indigestion, also intestinal, liver and kidney disorders, obesity, anemia, general debility, etc. Thousands, from all parts of Southern Africa, including long-suffering invalids, have regained health through drinking of and bathing in these wonderful waters. Special medical and other treatments available at the Sanatorium.

"Zwartkops" has other great claims to the patronage of health-seekers—it is the only Coastal spa in the Union ... it is unique in South Africa in that the Spring, Baths and Hotel are all in one building (a wonderful convenience to guests) ... it has the distinction of being the hottest Chalybeate Spring in the world: 100°F. (Pure cooled Mineral water is used to reduce temperature as desired)

... It enjoys the equable climate with which Port Elizabeth is blessed. All these, and breezes from the warm Indian Ocean, conspire together to pleasantly and quickly restore vitality and health.

The modern hotel accommodation is all that could be desired ... well-balanced menus include the famous Nelson Pearson health food products ... the club, river and beach are near ... long wide lawns invite one to relax and enjoy the freshness and beauty of it all.

Single and Double Rooms, also Suites with private bath and toilet, at varying terms ... hot and cold mineral water installation in every room ... radio ... 26 private baths ... guests have easy access to Port Elizabeth's cinemas and shops.

Visitors by rail should book to Zwartkops Junction (for meals guests by arrangement). Proprietor: Nelson Pearson, Box 3006, Port Elizabeth. (Phone 107, Zwartkops, or 2842, Port Elizabeth).

The distant water swimming pool with sun-bathing lawn. Pools at right. Filled by over-riding, health-giving mineral spring water at body temperature.

The initial spa at the kilometre-deep Zwartkops borehole in 1914 was replaced by a swish 'sanatorium' hotel in 1936.

The area to the north of the Port Elizabeth central business district, extending along the coast to the Coega IDZ and inland to Uitenhage, has long been recognised as an important groundwater area. This is the Uitenhage Artesian Basin, which was so heavily exploited for irrigation in the first half of the 1900s that it was declared a Subterranean Government Water Control Area in 1957. Subsequently, the basin was extensively researched in a variety of projects, and the findings on its hydrogeology were synthesised by Maclear in a paper published in *Water SA* in 2001.

The basin is divided into two independent systems, separated by the Coega Fault. To the north is the relatively shallow Coega Ridge Aquifer, subject to large-scale abstraction to supply some outlying suburbs and the town of Uitenhage, while the much deeper Swartkops Aquifer to the south is relatively underutilised. Interestingly, in 1909 a borehole drilled there in search of oil struck artesian groundwater at a depth of 1 082 metres, and 55°C water, rich in iron and manganese, gushed to the surface. This put paid to the oil exploration at the site, but the Zwartkops Spa was established instead, and later upgraded to a swish hotel that incorporated 'mineral baths' and a drinking fountain for those who wanted to 'take the waters'. In 1965 the borehole's steel casing rusted through and groundwater leaked under artesian pressure at a rate of 13 l/s into the surrounding sediments, so the Department of Water Affairs drilling division grout-sealed the borehole a few years later to prevent further loss of groundwater from the aquifer.

This very deep borehole is believed to have tapped into water from the basal bedrock – the fractured quartzitic sandstones of

the Table Mountain Group's Peninsula Formation. The Formation can be seen buckled up as mountain ranges inland, but it dips below the surface at the coast, apart from isolated outcrops at Coega Kop and the Algoa Bay islands. Murray and his team knew that the section of the Coega Fault close to Coega Kop offered the potential to access this TMG Aquifer water much closer to the surface than the kilometre-deep Zwartkops borehole. But first they had to find it.

Dr Murray explains that in the 1970s a wide swath depicting the fault zone had been mapped by the state oil-exploration company SOEKOR from data collected during seismic surveys, but pinpointing the exact location of the main Coega Fault would require some additional detective work.

"The challenge was trying to look with geophysics through about 200 metres of soft material to find a near-vertical fault below that," says Dr Murray. "It really was like trying to find a needle in a haystack, but the haystack was buried 200 metres below the ground! And since you're looking for a near-vertical target, if you're off by a few metres you can miss it."

First he commissioned Dr Edgar Stettler – a geological consultant and University of the Witwatersrand honorary professor – to re-interpret SOEKOR's seismic data and construct a 3D model of the Coega Fault.

"That put it in a zone about a kilometre wide, which got us in the right area, and then we did a gravity survey to try and narrow it down to a point where we could do more precise geophysics."

He explains that the gravity survey was conducted with a handheld metre that is used to take density readings, since the quartzitic rock has a higher density than the soft Cretaceous sediments that had filled the displaced area at the fault zone. The gravity model developed from the survey results allowed them to narrow their target down to a 200 metre wide zone.

"Again, that doesn't help us pinpoint a near-vertical fault, but it told us where to focus our geophysics efforts. Then we tried a variety of different methods, and the one that gave us the most precise data to work with at depth was magnetotellurics."

Magnetotellurics, or MT, makes use of natural variations of the Earth's magnetic and electric fields, caused by solar wind and lightning strikes, to measure the electrical resistivity of the subsurface.

"Essentially, you use electrodes to measure the differences in the conductance of the rocks in a particular area," explains Dr Murray. "Quartzites are far more resistive to electrical currents than the more clay-rich, younger Cretaceous sediments, which conduct electricity very easily."

Ensuring accurate and noise-free results meant that the electricity supply to the area had to be switched off for six hours, but the MT survey allowed the team to peg the position of the faults. In 2014 they drilled a number of exploration boreholes, and made a massive strike that confirmed they were on the right track in targeting the Coega Fault. In late 2018 they returned to start drilling production boreholes, and on 21 March 2019 they



Groundwater spurts up from a depth of 265 m in the first strike at a production borehole at the Coega Kop wellfield.

hit their target at a depth of 265 metres. A second borehole was drilled at the site and the combined drilling yield of these two holes was 150 l/s.

Drilling of all five production boreholes that make up the Coega Kop Wellfield is now complete. The boreholes have not yet been test pumped, but initial indications are good as their combined drilling yield is 357 l/s. The groundwater cannot yet be fed into the NMB Municipality's water supply system because – like the Zwartkops Spa 'mineral waters – it is very high in iron and manganese.

Treating it to meet SANS 241 standards is best done in a dedicated biofiltration plant, similar to the 10 Ml per day Preekstoel plant in Hermanus, which treats groundwater tapped from the Overstrand Municipality's Gateway and Hemel en Aarde

wellfields. The Coega Kop plant will have the capacity to treat 20 Ml per day, and although its design has been completed – by Aurecon, using some innovative 3D modelling and virtual reality (VR) tools – construction has not yet started.

Given that the current drought will probably have broken before the plant is up and running, why should the groundwater development work provide any cause for optimism?

Dr Murray explains that using drought-relief funding provided by National Treasury to NMB Municipality, the groundwater team drilled over 23 km of boreholes between late 2018 and mid-2019, both in the Port Elizabeth city limits and further afield. They included, for example, areas close to reservoirs and hospitals, on the Churchill Dam property and St Georges Park Cricket Ground, as well as in the Bushy Park area, which the 2008 WRC study had highlighted as the top priority.

"The total drilling yield was just under 1000 l/s and the results are still being analysed to finalise production yields," he says. "But there are some boreholes that could potentially be equipped very rapidly and brought online if the water supply situation got really bad. At the same time, National Treasury also gave Kouga Municipality drought-relief funding, and we drilled boreholes for them too. Since their towns of Jeffreys Bay, Humansdorp, Hankey and Patensie all partly depend on water from the Algoa Bay Water Supply System, the increased groundwater use by Kouga Municipality will relieve pressure on the surface water supply, to the benefit of the Port Elizabeth metro."



Ricky Murray of Groundwater Africa led a field trip to the Coega Kop wellfield as part of the GWD 2019 Groundwater Conference, held in Port Elizabeth in October 2019.

WATER AND SOCIETY

Connecting to water in a dry Johannesburg

Petro Kotzé explores how stories and art can keep the city of gold, and the people that live there, connected to water.



"My grandmother often extolled the powers of sea water and it was not uncommon in our house to find bottles of ocean water reverently stashed away. These stashed bottles seemed to represent an extra layer of protection over the family," says Confidence Joseph, a PhD student at the Oceanic Humanities for the Global South project based at the Wits Institute for Social and Economic Research (WISER). "She also believed that there were benevolent as well as malevolent water gods who could either bless or smite, depending on how one related with them. Decades later, finding myself in Johannesburg, my connection with water has not changed much. This should not be surprising considering that Johannesburg is as dry and land-locked as Bulawayo."

Joseph recently presented her paper on how water, and the absence of it, can help us think differently about the plight of the global citizen. A student of African Literature, she says she also wanted to show that there are alternative ways of replenishing ourselves in waterless spaces like Bulawayo and Johannesburg. One is through stories of water spirits who defy time and space, and make their presence felt in urban and modernised settings.

Her talk was one of a series of lectures, screenings, live musical performances, immersive installations, live readings and public city walks led by artists and scholars. Called Holding Water, the programme was a collection of interpretations of the politics and poetics of ocean flow, from the perspective of Johannesburg.

The project is also investigating how our stories and histories can help us understand each other, our past, and the current environmental crisis we are experiencing.

A city far from the coast, but close to the ocean

Charne Lavery, research associate at WISER (and lecturer at the University of Pretoria), says thinking about the ocean from the perspective of land-locked Johannesburg is not that far-fetched. “Despite the paradox of the ocean versus the landlocked city, they are connected,” she says. Hints of Johannesburg’s unlikely connection to the sea are scattered throughout its streets. For one, it’s home to Africa’s largest dry port. Reportedly, more than half of the cargo received at our seaports at Durban and Cape Town lands at the City Deep container terminal. Hurrying along the transport of goods between land and sea, it’s our only inland terminal where customs clearance takes place.

Then there was the South African Institute for Maritime Research, a shadowy apartheid-era paramilitary force, the existence of which emerged during the Truth and Reconciliation Committee meetings. Once, Wemmerspan in the South of Johannesburg was home to one of our two inland navy bases (the SAS Rand Naval Base). Back in the day, the best restaurant was known to be the Carlton Hotel’s Three Ships.

The city’s very location connects it to the sea. Straddling the watershed that divides the Limpopo and Orange rivers’ basins, rain falling north of Johannesburg’s Parktown ridge drains into the Limpopo River to flow towards the Indian Ocean. Rain falling south of the ridge, again, drains into the Vaal River and eventually into the Atlantic. Lavery says their research has shown that Johannesburg itself is located on what was once a prehistoric ocean floor.

The connection can also be drawn to environmental impacts. “It seems out of sight and out of mind, but it’s not,” she maintains. The impact of climate change, for one, will also be felt in Johannesburg. Possible droughts are connected to the hydrological cycles that start in the ocean. Johannesburg may also, in future, become waterlogged again, as a dry island amid rising seas or sunk into acid mine water.

Environmental humanities analyse and investigate exactly this - the complex interrelationships between human activity (cultural, economic and political) and the environment.



Johannesburg is located on top of an escarpment which functions as a continental drainage divide or watershed.

Oceanic humanities for the global south

Within this field, oceanic humanities engage with the human and non-human aspects of the ocean. Oceanic Humanities for the Global South, in particular, focuses on themes of decolonialism. Critical of knowledge dictated by the Euro-North point of view, global maritime trade and the oceanic environment is instead approached from the viewpoint of the Indian Ocean and other southern seas.

This approach favours South-South connections instead of the history of European explorers that came to Africa. “Indian Ocean studies puts the Indian Ocean at the centre, highlighting links between Africa, India and the Arab world,” notes Lavery.

Within this field of academia, scholars have recently started to call for critical ocean studies, she adds. Not only should we speak about themes of decolonisation, but it should include critical environmental issues. Lavery says, “It’s asking how to think about environmental and social justice at the same time.”

The Holding Water programme was part of WISER’s attempt to engage a broader public in this field of thought. They want to “bridge the gap between ivory tower academia and the wider public.” The events took place throughout Johannesburg, in collaboration with POOL, described as an emergent platform for curatorial and artistic production, experimentation and research, working with artists to support and commission new work.

Taking oceanic humanities to the streets of the city

One of WISER’s aims is to provide a platform for experts from different fields to collaborate, and then to develop the ideas that emerge. Lavery, for example, specialises in oceanic literary studies, but the project includes varied experts across fields that include visual art, maritime archaeology and architectural history. As such, the topics presented throughout the programme varied vastly, but all of them approached Johannesburg’s relation to oceans and water.

Jonathan Cane is a Mellon Postdoctoral Fellow in Oceanic Humanities at Wits, with research interests in landscape art, architectural modernism, post-colonialism and urban queer studies. His presentation, ‘Concrete Oceans’ is part of a larger research project investigating concrete and modernity in the Global South. Cane explains that so far, he has written about the use of precast concrete panels in Chile, high-rise concrete structures in Maputo and the London Zoo’s concrete penguin pool.

“The focus of ‘Concrete Oceans’ is to apply an oceanic humanities lens to my broader project,” he explains. “This means looking at the relationship between the southern oceans and concrete through a 1964 invention called the *dolos*.” Cane says this modular interlocking ‘coastal armour’ works to attenuate wave energy and thereby stabilise the water-land relationship. “Through my analysis of the history of this invention, I offer a critical reading of apartheid science and technology and hope to suggest alternative ways of conceptualising the ocean-earth binary.”

WISER senior researcher, Dr Pamela Gupta’s research interests include connecting Lusophone India (Goa) and Africa,

ethnographies of decolonisation, heritage tourism and visual cultures. She chose to approach the Holding Water project through Johannesburg's public pools, "precisely because they hold water in some sense in a dry land-locked city like Johannesburg." Gupta says this city's aridity is always related to its wetness, and as a Johannesburg resident and regular swimmer for the last 15 years, she has continually gone in search of it in places that she is also fond of frequenting, and where she knows she can find and feel water. "I think this viewpoint of Joburg is valuable because swimming pools hold many of the city's complex histories within its infrastructural borders, those of apartheid (whiteness), sexuality, freedom, (black) leisure, and disrepair."

During her talk, Gupta presented a series of contemplations on Johannesburg's public pools which, for some residents, is the closest thing to an ocean they have in the city. Gupta says "pools supply/provide water oases in cities, yet they are as evil as they are gentle and tranquil, and portend our dry futures in an era of the Anthropocene. I am reminded of flying into Cape Town in March 2017 and seeing eerily empty swimming pools from my aerial view window seat."

In reference to a series of paintings of abandoned pools by artist Willem Pretorius, Gupta says: "That so many dried up pools exist (and have been captured on canvas by Pretorius), scattered throughout South Africa's barren landscape suggest they are an important part of Joburg's landscape of ruination, decay, and abandonment, much like its leftover mines. They too portend

an anthropogenic future of dramatic climate change and water restrictions, a future Joburg in which, during crises (such as the one that hit Cape Town in 2017, suggesting that Joburg is perhaps not so far off), the filling of pools will be strictly forbidden except for the chosen few, a luxury in a sea of dryness, thus producing an aerial view of a landscape littered with mostly empty squares and circles."

Lavery notes that personal experiences, individual beliefs and cultural representations such as those presented during Holding Water are important in order for us to understand diverse views and contribute to deeper understanding of the environmental issues we are currently experiencing.

The importance of stories in our world today

"If you don't engage with hidden stories and histories to deal with the aftermath of colonisation, you cannot understand where people come from, or try and instill positive change," she says. As example, Lavery mentions different culture's historical experiences with beaches. In Mozambique, for example, the beach is, among other things, the place where people were taken away from their homes during the slave trade. "Beaches are not only a places of leisure, but also of deep historical wounds."

This perspective was one of the many explored during the programme. The below is an excerpt from the poem 'Water' by Koleka Putuma published in *Collective Amnesia* (part of the list of suggested reading for one of the Holding Water events):



Johannesburg's connection with water goes much further than its water reservoirs.



If you don't engage with hidden stories and histories to deal with the aftermath of colonisation, you cannot understand where people come from, or try and instill positive change.

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"I often wonder why I feel as if I'm drowning every time I look out into the sea,
this and feeling incredibly small.
And I often hear this joke
about Black people not being able to swim,
or being scared of water.
We are mocked
and we have often mocked ourselves
for wiping our faces the way that we do when we come out of the water.
Compare to how they do it, all *Baywatch*-like,
And how we so ratchet-like with our postures and kink.
Yet every time our skin goes under,
it's as if the reeds remember that they were once chains,
and the water, restless, wishes it could spew all of the slaves and ships onto shore,
whole as they boarded, sailed and sunk.
Their tears are what have turned the ocean salty,
This is why our irises burn every time we go under."

If you do not engage that history, you cannot demand that people help conserve and keep the ocean clean, says Lavery. "The humanities and arts angle is one of the resources that we have to think through our ecological crisis."

Yet, she thinks there's more to it. "There's something deeper to these symptomatic reactions that we're swiftly cycling through," she says, in reference to the suite of issues like the hole in the ozone layer, the use of plastic straws and acid mine drainage that have received so much public attention for relatively short periods of time. "There seems to be a panicked, short-term view of the environmental crisis as it's hitting people." In comparison, environmental humanities calls for a long-term, vigorous view of what is happening in our culture, what brought us to this crisis, how we talk about it and the metaphors we use to describe it.

"Good historical and cultural research needs to be done," she says. "We have to learn what the metaphors and stories are that can have damaging and empowering effects." Stories have power, she maintains, "and we need to understand how stories work in order to help us harness them as one of the tools to solve our environmental problems."

While the Holding Water programme has come to an end, Lavery says they are considering more events for next year. Updates will be posted on the Wits Institute for Social and Economic Research Facebook website, the Oceanic Humanities for the Global South Facebook page, and the mailing list and social media of the POOL project.

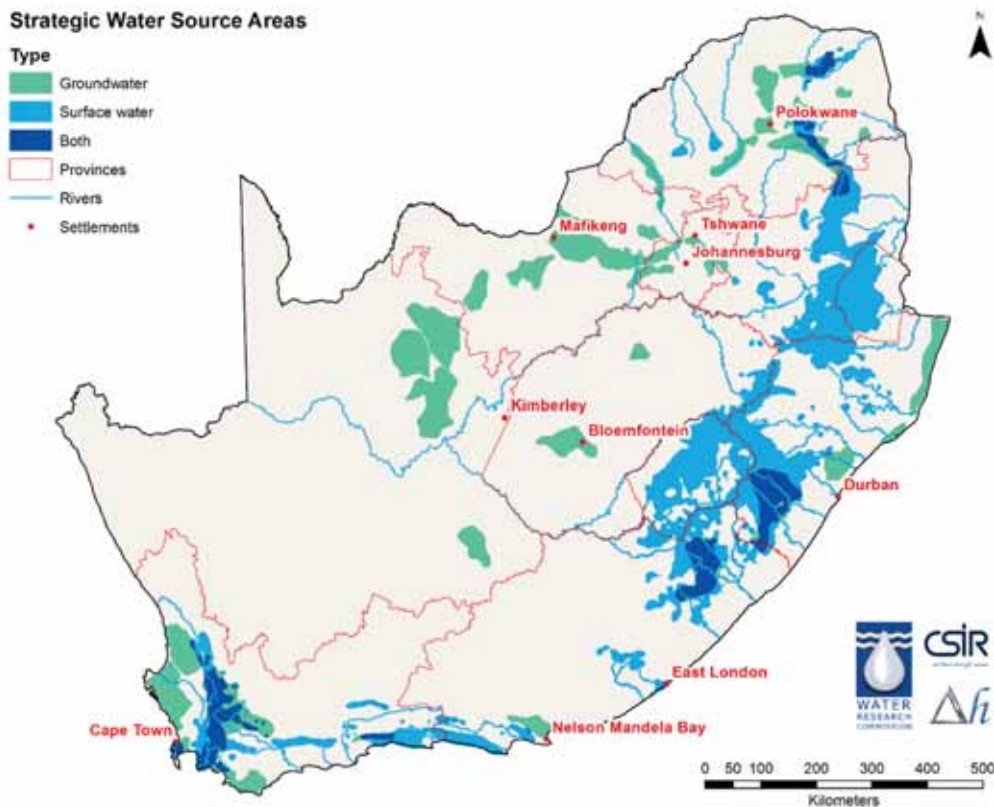
Artist Willem Pretorius's style can best be described as observational realism. His work can be seen as a type of visual diary where he documents a specific time and place in our history and in doing so, remembering. It also reminds us of our own transience and mortality. Everything is temporary.



ECOLOGICAL INFRASTRUCTURE

Investing in ecological infrastructure to improve drought resilience and enhance water security

Chantel Petersen, Lindie Smith-Adao, David Le Maitre, Nebo Jovanovic



Strategic Water Source Areas for surface water and groundwater in South Africa, Lesotho and Swaziland (Le Maitre et al., 2018).

South Africa is among the most water scarce countries per capita in the world, a situation which is made more complicated by the uneven distribution of water availability across the country. Rainfall varies from over 1 900 mm in the east of the country and in the mountainous areas, to almost zero in the west and north-west of the country.

With an average rainfall of less than 500 mm/year, and significant annual and seasonal variability, only 9% ends up as water in rivers and aquifers (DWA, 2013). Like precipitation, runoff is highly variable in both space and time. Much of South Africa's water is generated in small areas identified as Strategic

Water Source Areas (SWSAs) for surface water (SWSA-sw) and groundwater (SWSA-gw) (see map elsewhere).

These areas are considered strategically important at a national level for water and economic security for the country, supporting growth and development needs. The transboundary SWSA-sw cover only 10% of the country's land surface area but produce 50% of its surface runoff and most of its groundwater recharge, sustaining most of the perennial rivers.

The SWSA-gw cover around 9% of the land surface of South Africa and account for up to 42% of the baseflow. Sustained

river flows are important because they support people and communities who depend directly on rivers for their water, especially during droughts. Society obtains many water-related benefits from water source areas, including water for urban and industrial purposes, and for irrigation. Water from these areas are also critical for cooling at the power stations, which generate most of South Africa's electricity (Le Maitre et al., 2018).

South Africa's water security therefore depends not only on our built or hard water infrastructure but also on well-managed land in our catchments. Most of the cost-effective, hard infrastructure options such as large-scale dams and pipeline schemes are exploited in key catchment areas, with planners historically relying heavily on such engineering solutions to secure the country's water security.

Healthy wetlands, rivers and groundwater ecosystems in the multi-purpose landscape will however make our future more water secure. They are ecological infrastructure that can

generate and deliver significant improvements in water quantity and quality if we look after them. Ecological infrastructure refers to naturally functioning ecosystems that deliver valuable services to people, such as fresh water (water purification), climate regulation, soil formation and disaster risk reduction (e.g. flood attenuation and drought mitigation). It is the nature-based equivalent of built infrastructure, and is just as important for providing services and underpinning socio-economic development.

Investing in water-related ecological infrastructure in conjunction with built infrastructure, will deliver more clean water from our land. Investments are particularly important in our SWSAs where ecological infrastructure assets are under-protected and degrading. Currently only 11% of all water source areas fall within protected areas. Investment in this kind of infrastructure includes clearing invasive alien vegetation like pine trees and black wattle from mountains, rivers and wetlands as well as river and wetland rehabilitation (Figure 1).

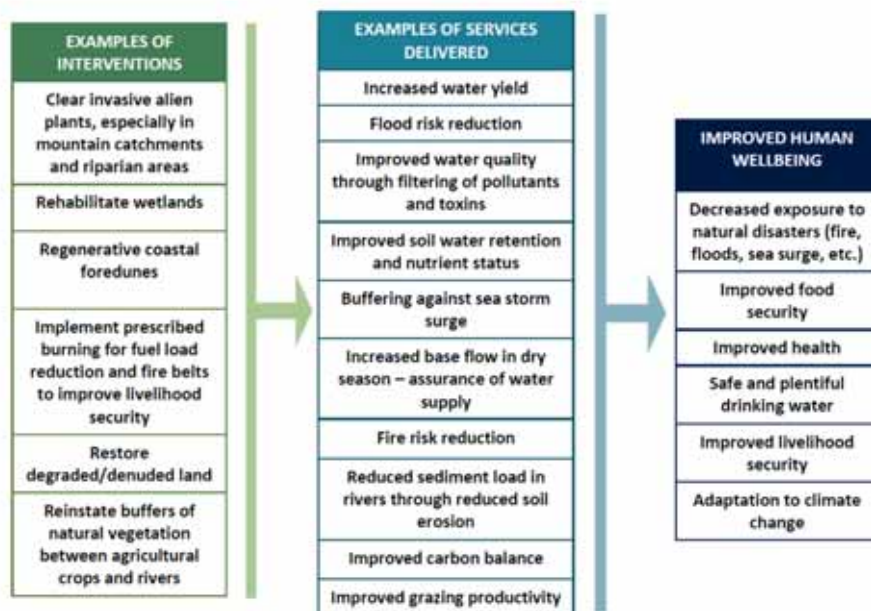


Figure 1: Examples of benefits flowing to society from investing in ecological infrastructure (after SANBI, 2014).

Water security underpins economic development but is at risk from the pressures created by a growing population, land degradation and an increasingly variable climate (CSIR, 2010 and 2015). Many predictions of climate change have been made and they have improved over time, but some uncertainty still remains (Pearce, 2014).

What is certain is that our climate is changing based on the overwhelming evidence of its impacts and knock-on effects observed in many sectors of the environment including cities. Climate change is shifting rainfall patterns, causing increases in temperatures and accelerating the risks of extreme weather events across the country.

Recent droughts that occurred in the Southern African region (2015-2017) exacerbated issues of water scarcity and equitable water allocation in the country. The drought, which started in 2015, was a result of the combined effects of a severe drought and a strong El Nino event (Baudoin et al., 2017). This has resulted in some South African Provinces declared as disaster areas (e.g. KwaZulu-Natal), declines in harvest being experienced, which resulted in the necessity to import crops, and heavy water restrictions were implemented to cope with dwindling water resources and the need to adapt to the "new normal" of water scarcity.

The Western Cape Province and the City of Cape Town in particular experienced one of its worst droughts ever during 2015 to 2017. Water shortages occurred with low dam levels experienced (e.g. Theewaterskloof Dam) and six levels of water restrictions were imposed as a means to reduce usage and conserve water (Booyesen et al., 2019).



Low dam levels at the Theewaterskloof Dam located on the Sonderend River near Villiersdorp, Western Cape, South Africa. The dam is responsible for storing more than half of Cape Town's surface water supply yet water reached less than 20% of its capacity in 2017. Photograph on the left shows the dam in March 2017 while the photograph on the right is the dam in August 2017.

These severe droughts appear as a 'surprise' to the country despite the fact that South Africa is susceptible to such a hazard (Bruwer, 1989). The first detection of El Niño conditions in the Tropical Pacific in 2015, months before the impacts were observed, provided governments with the earliest possible warning of likely adverse impacts on water supply and food production.

Notwithstanding the warning signs and the notable disaster risk legislation (the National Disaster Management Act, 2002), it seems that early warnings about a likely severe drought did not catalyse the swift implementation of risk preparedness measures that it should (Baudoin et al., 2017). This delayed reaction is of concern within the context of future climate change across the region.

Broad-scale predictions show that sub-Saharan Africa will get drier. Meteorological drought (the occurrence of reduced precipitation), is expected to become increasingly more frequent in the country. Even in the best-case scenario, South Africa, like the rest of the region, is expected to become more vulnerable to water insecurity in the coming decades. This increases the urgency of implementing the best and most cost-effective and effective adaptation plans, including those related to ecological infrastructure and nature-based solutions.

The Council for Scientific and Industrial Research (CSIR) and its institutional partners recognised the importance of finding innovative ways to reduce risk vulnerability. The CSIR in

partnership with the National Disaster Management Centre developed an open access online tool, called the Green Book (visit www.greenbook.co.za). The Green Book was funded by Canada's International Development Research Centre and launched on 8 March 2019.

This state-of-the-art climate risk profiling and adaptation tool is intended to be an applied knowledge resource for municipalities to address climate change impacts and vulnerabilities in human settlements. The Green Book is a unique attempt at interdisciplinary, applied sciences that combined the expertise of researchers in climatology, demography, disaster risk sciences, environmental sciences, geography, informatics, urban planning, economics, ecology, architecture, anthropology, hydrology and statistics.

The multi-disciplinary nature of the Book, combined with the high-resolution scientific evidence, makes this one of the most novel, innovative and information-dense research platforms about disaster risk and climate adaptation planning on the African continent. Its ultimate goal is to contribute to resilient, sustainable and liveable human settlements through climate change adaptation.

Likewise, to support decision making for this type of investment, a short-term project entitled, 'Review of WRC drought research and gap analysis' was funded in 2019 by the WRC to fill the overall knowledge gap in drought research so as to establish a focused strategy for future research.

A longer-term WRC project entitled, 'The role, benefits and prioritization of ecological infrastructure (EI) in mitigating the impacts of droughts in South Africa,' will integrate the environment and the people utilising it by determining how well-managed ecological infrastructure can mitigate the impacts of droughts on human livelihoods and well-being. Strategic responses will be developed with communities aimed at maintaining and enhancing the value of this ecosystem service that people will embrace and implement.

The focus these days is on making environments work for both ecosystems and people. A way of achieving this is by concentrating on improving ecosystem and land degradation as these are the leading causes of risk and vulnerability, and to invest in nature-based solutions as an adaptation measure. These approaches have the added benefit of being cost-effective to implement which is an essential consideration, especially in developing countries. An additional benefit is that nature-based approaches are flexible, easily adapting to change, making them resilient in coping with climate unpredictability.

Adaptation measures to drought that are researched and implemented are already moving in this direction. Mitigating drought is a shared responsibility, which includes the general public and awareness should be created. People and their environments are interlinked and future planning and the country's development goals should integrate the two.

WATER RESOURCES

Water scenarios for the future: A glimpse of what is to come

Taking into account future uncertainties, what kind of realities do we need to adapt to ensure we use our water resources sustainably while promoting economic development and food security? Jorisna Bonthuys reports on the latest research looking at the country's future water management scenarios.



Change is taking place in the climate system and this could have a significant impact on the future of water and agriculture. This reality has been highlighted in the latest research on South Africa's water management scenarios for the future. Experts from the University of the Free State (UFS) have been researching the different drivers and enablers that could determine South Africa's water futures. This has enabled them to come up with four detailed scenarios that can now inform policy responses and adaptation practices.

This project, funded by the Water Research Commission (WRC), provides a glimpse of what is to come in future decades. Prof Andries Jordaan, a research fellow at the UFS, led this comprehensive scenario-building process. The researchers considered key trends and drivers reshaping the water and agricultural future and the road ahead. They also investigated different policy responses and decision-making concerning water realities.

"The challenge now and in the future is to produce more food with the same quantity of water or less given the depleting state of water resources in the country," Prof Jordaan said. "It is

empirical to promote the productivity of agricultural water use to enhance agricultural output and increase the contribution of the sector to the economy."

The paradigm of scarcity

There are major challenges with water availability and quality across the country. South Africa is expected to face a water deficit of 17% by 2030, and this shortage will only be worsened by climate change.

South Africa receives 450 mm of rain a year, which is half the global rainfall average. Only 12% of the land area generates 50% of available surface water resources. Pollution remains a serious problem, causing water quality and quantity problems in various regions. Most of the major urban hubs and industrial developments are also situated far from the country's larger watercourses, which necessitates large-scale transfers of water across catchments.

Decadal rainfall variability also results in extended periodic dry and wet periods across the country. As the country's water resources become more constrained, the amount of water

allocated to irrigation will come under increasing pressure.

The recent multi-year drought has put immense pressure on local water systems and has had a devastating impact on agriculture and communities, including in the Eastern Cape and the Northern Cape. This was highlighted in President Cyril Ramaphosa's recent open letter to South Africans that focused on the current water crisis facing the country.

"Our existing water systems are already over-exploited as usage increases rapidly due to population growth and as more homes get connected to water. Combine this with the worsening effects of climate change and we are clearly facing a dire situation," he said. "Unless we take drastic measures to conserve water sources and promote efficient use, water insecurity will become the biggest developmental and economic challenge facing this country. Our current energy challenges will seem small by comparison."

South Africa intends spending R900 billion over the next decade to improve its water-supply and storage infrastructure and tackle a growing shortage of the resource. The investment is outlined in a new national plan, recently unveiled by Human Settlements, Water and Sanitation Minister Lindiwe Sisulu.

Economic growth is a 'surprisingly thirsty business,' Prof Jordaan highlights. Poor management of water resources also threatens the resource base on which agriculture depends.

Researchers consider climate change as a key factor that will influence our future water realities. Climate risks for southern Africa are increasing. Climate change prediction models suggest that average temperatures will rise and rainfall events will become more infrequent but also more intense, thereby increasing the unpredictability of (water availability for) agricultural production. The risk of more frequent extreme events, including floods and droughts, is also on the rise.

Climate change will increase water-related shocks on top of already demanding trends in water used, Prof Francois Engelbrecht from the University of Witwatersrand's Global Change Institute emphasised. This would affect a wide range of economic sectors and livelihoods, impact on the development of infrastructure and catchment management, and demand management into the future. The challenges of feeding South

Africa's growing population in a climate-altered, resource-constrained future are "substantial", he pointed out in a recent interview.

A glimpse of what's to come

South Africa's water-related agricultural future can unfold in many ways as the recent scenario process has shown. Prof Jordaan highlights the following: "It is important that South Africa take note of potential future outcomes in the agricultural space and specifically water and agriculture. Policy decisions today will have a direct impact on food security in the future."

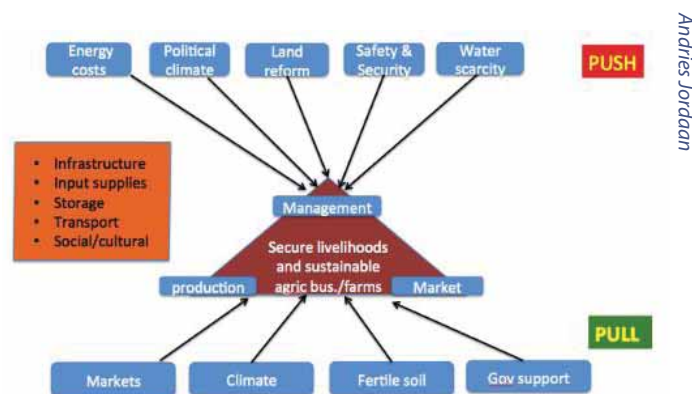
Scenarios are not predictions, forecasts or projections. Rather, they are stories about the future with a logical plot and narrative governing how events unfold.

The researchers developed qualitative water management scenarios and then modelled those quantitatively. The scenarios were discussed with stakeholders including AgriSA, the National African Farmers' Union (NAFU) and the African Farmers' Association of South Africa (AFASA) at workshops and a national symposium. This information was also used to inform the mathematical simulation models to analyse the qualitative scenarios, explore some of the consequences, and to help fill in some of the gaps.

The results allow the government to identify critical drivers that will impact on the future. These critical drivers need policy and implementation attention. Prof Jordaan elaborates: "Agriculture needs to align itself with future challenges and opportunities in the water space. Understanding the drivers in the different scenarios will allow for timely strategic, operational and tactical decisions."

In future, the shift in agricultural production patterns will be affected both by push-and-pull factors, according to the research. Push factors include energy costs, the political climate, land reform, and water security. Pull factors include markets, management and production climate change, fertile soil, and government support.

So far, the most surprising result of this research is the common agreement from different sectors regarding the drivers and potential outcomes. Prof Jordaan said: "We completed workshops with AFASO, NAFU and AGRISA and all farmers;



Push pull factors in food production in southern Africa.

emerging, communal, small-scale and commercial is largely in agreement of the key drivers and potential outcomes in the water sector and that agriculture is not governed properly.”

Scenarios for the future

Prof Jordaan and his team identified four basic scenarios. These include the ‘Traditional scenario’, the ‘Best-case scenario’, the ‘Z scenario’ and the ‘Frustration scenario’.

The **Z scenario** is the result of poor leadership in both the political and water environment with low education standards and a private sector that withdraw from the national discourse due to extreme polarisation between the private sector and the government. In this scenario, South Africa will experience a continuous recession, with negative economic growth. Unemployment will increase dramatically and the safety and security situation will get out of hand. Violent civil unrest will be a daily occurrence with security forces (SAPS and SANDF) using deadly force to control the masses. South Africa will become a net importer of food. This is the chaos scenario – very similar to Zimbabwe today.

In this scenario, South Africa experiences water shortages, hyperinflation and disinvestment in agriculture. This scenario, really a worst-case scenario, leads to food insecurity, land grabs, and a poor, small-scale agricultural sector. Commercial farmers move to other countries and food-importing increases significantly. At the same time, water infrastructure is not maintained, and rivers and dams are heavily polluted. The ‘Day Zero’ threat becomes a reality for urban areas and agriculture during dry periods.

The **frustration or polarisation scenario** is the result of poor governance and political leadership with a strong private sector that is still functioning in a hostile political climate. More people are educated and civil society takes responsibility for its functioning. The gap between the haves and have-nots will continue to increase with the poor totally dependent on the State, who is nationalising all resources. In this scenario, researchers foresee slow economic growth of about 2%, which is mainly driven by the private sector. Production from commercial agriculture will slow down with many farmers investing in other countries. South Africa will become a net importer of staple food 5 out of every 10 years.

In this scenario, the gap between the haves and the have-nots increases. Poor enforcement of policies and laws, conflict about water use and unequal access to water could also become more pronounced. Only the private sector will benefit from the advantages of the fourth industrial revolution (4IR) with the State still working with outdated systems and not able to apply regulations and policies. The private sector will take responsibility for water management where it is possible, but many towns and cities will experience Day Zero scenarios during dry periods because of poor management at all governance levels. The private sector will, however, also invest the bulk of their funds in other countries. Agriculture will be heavily taxed with high water and electricity tariffs.

In the **traditional scenario**, political leadership takes strong action to reduce corruption and increase productivity and good

governance in the State. Distrust remains high between the private sector and the government. This scenario will see slow economic growth with less than 2% and little innovation in the water sector. Food insecurity will increase, and the country will become a net importer of staple food 7 out of every 10 years.

In this scenario, South Africa becomes a welfare state. Land and other resources are nationalised with new farmers having no title deeds for their land. It entails centralised water management and policies, low productivity and innovation in agriculture as well as increased competition between water users. Farmers do not trust government and food production will slow down, with many farmers investing in other countries. The smallholder sector will increase dramatically with the government enforcing more socialist policies.

The **best-case scenario** is the result of strong leadership, good governance, more people receiving a good education and a private sector who work together with the government to reduce unemployment rates and increase efficiency in production and water use through innovative technologies. Economic growth increases to more than 5% annually. All sectors and people have equal access to water resources. The smallholder sector received good extension support from the government and the commercial agricultural sector actively assist with mentoring new farmers. South Africa remains a net exporter of food, even during dry years. The exchange rate is stable and global markets reacted positively to developments in the country.

In this scenario, decentralised water management is embraced by water management agencies. New water infrastructure is built with the newest technologies. Current infrastructure is well — maintained and pollution levels in all rivers and dams are within limits. In this scenario, there is good regional collaboration in terms of water management, decentralised water management through water management agencies and efficient institutions that manage water resources. There is strong enforcement of water user guidelines, and water management authorities are efficient. There is also good collaboration between the private sector and the state where water is concerned. The country as a whole benefits from the 4IR.

Where are we heading?

The strength of the scenarios is that it considers all drivers that might impact on the future and the classification of the drivers into different clusters allows researchers to systematically analyse all drivers. The weakness of this process is that it remains looking into the future between different extremes.

“We cannot for sure say which scenario we will experience 10 years from now,” Prof Jordaan said. “The global economy and political landscape, as well as our own political landscape, is just too unpredictable and unstable to tell for sure where we are going. What we can do now is identify the drivers that will push us into the direction of the Z-scenario and address those as a priority and implement the drivers that will put us on a path to the best-case scenario.”

“Until recently, we were definitely leading to the Z-scenario or frustration scenario,” Prof Jordaan continued. “That is where

the government falls apart and does not provide responsible leadership and management in the water sector. "The deterioration of the Department of Water and Sanitation the past decade steered us into the path to the Z-scenario. The private sector, however, was still actively involved with society and came to the rescue in some rural areas. The threat, however, was that the private sector will eventually decide to withdraw and relocate to elsewhere.

"New developments since the election of President Ramaphosa give me hope that we will not enter the Z-scenario — yet. Positive things are taking place in the water space under Minister Sisulu but to change such a big organisation around can take years. "As a country we need expertise and we need visionary and innovative thinking. We need implementation if we want to achieve sustainable water management."

According to Prof Jordaan, "no-regret options" should start with strong leadership not only in government but also in the water and the agricultural sector. That should be supported with the expertise to implement innovative future planning but also to maintain and manage current infrastructure.

Municipalities did not maintain water infrastructure, he added. "Governance requires urgent attention at the district and local level. The appointment of qualified engineers and water managers at the local and district level is non-negotiable."

The path ahead

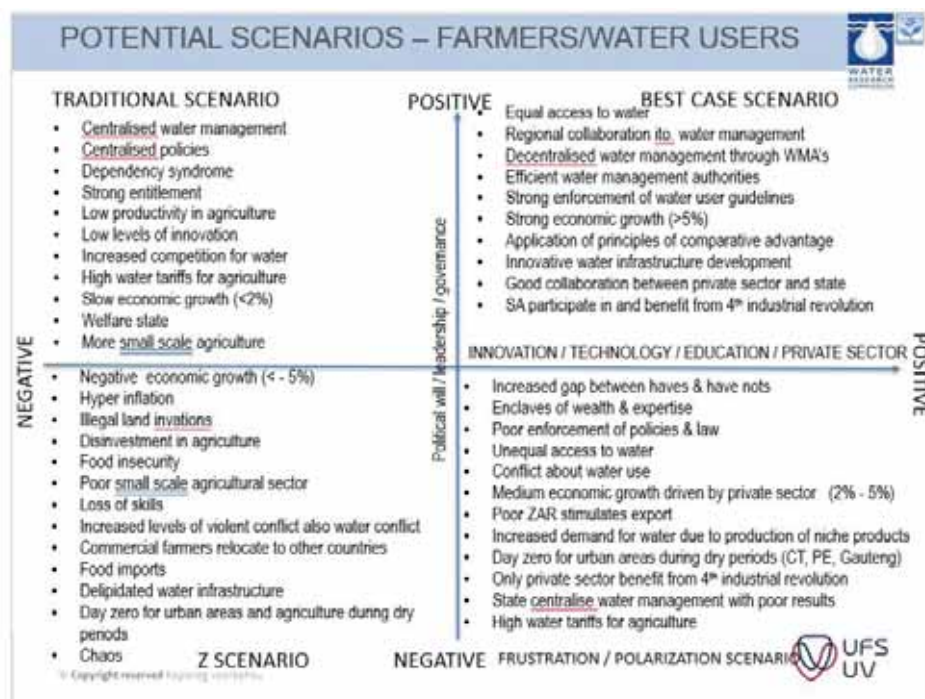
What can be done to enhance agricultural production in the context of emerging water scenarios? Agriculture should implement more innovative drought-resilient strategies, Prof Jordaan believes. "The current drought forced agriculture to re-think current production systems. Dry periods and droughts and water shortages are the 'new normal'."

What are the practical suggestions based on this assessment to government, the private sector and farmers? And what are the direct and indirect interventions needed? "This is the most important outcome of scenario building — the 'so what' question," Prof Jordaan said.

On the one hand, the government needs to sort out political issues for the country as a whole and to provide strong leadership. It needs to appoint qualified people in the water and agricultural sector, improve extension services in agriculture and sort out safety and security, among others. On the other hand, the private sector needs to continue to support the government in spite of frustration and continue to invest in agriculture and the water sector.

"Government also has a responsibility to enforce water management regulation, and to implement measures to support agriculture in times of need," Prof Jordaan maintained. "The implementation of an index insurance scheme for drought losses, for example, is something that requires urgent attention."

Agricultural systems need to adapt to warmer conditions and more extreme events; farmers need to plan for droughts as part of a normal production cycle. Irrigation farmers, for example, should measure production output as a unit output per kilolitre water instead of output per hectare. Farmers also need to put in place strategies that are aligned with dry periods and droughts. They need to plan for dry periods and drought, ensure enough water reserves for dry periods, measure production output against water efficiency (kilogram per kilolitre water and not per hectare), implement water-saving irrigation technology and remain innovative and resilient.



Potential scenarios

WETLANDS

Nature-based solutions for the future: Securing wetlands for water security in the Western Cape

The rehabilitation of priority wetlands as part of an investment in nature-based solutions can contribute significantly to water security in the Western Cape Water Supply System, according to the latest research. Article by Jorisna Bonthuys.



A view across the Theewaterskloof Dam. It is estimated that alien invasive plants are currently reducing the water supply to the dam by 55 million m³ per annum.

Alien plant infestation is a huge problem in many parts of the country. Often, these alien plants form a thick, almost impenetrable wall high up in important catchments. Research shows that the catchment area for the Theewaterskloof Dam – the biggest dam providing water to the City of Cape Town – is, for instance, nearing natural thresholds due to land-use changes and the impact of alien plants on water supplies.

It is estimated that alien invasive plants are currently reducing the water supply to the Theewaterskloof Dam by 55 million m³ per annum. This is equivalent to almost the full capacity of the Wemmershoek Dam. Should no clearing be done, the reduction in water supply by 2045 will double per annum.

Luckily, water yield from catchments can be improved

significantly by removing alien invasive species from the landscape and key catchments. Ecological engineering ('soft' solutions) can also be used rather than constantly turning to expensive 'hard' solutions. At the very least, wetland management should complement traditional engineering solutions (municipal dams and water treatment works), the research highlights.

"Alignment of solutions to ensure water security in the Western Cape is needed, and this includes wetland rehabilitation and other nature-based solutions," says Louise Stafford from the global non-profit organisation, The Nature Conservancy. Stafford and colleagues developed the business case for establishing the Greater Cape Town Water Fund. A key focus of this new fund will be the potential to make investments in nature-based solutions,

including catchment restoration, to address water security for the City of Cape Town (for more information on the fund, see the November/December 2019 issue of *the Water Wheel*).

Prioritising wetland rehabilitation efforts are key given resource constraints and growing pressures on freshwater resources, Kate Snaddon from the Freshwater Research Centre indicates. "Catchment restoration is listed as only marginally more costly than dams, with the main emphasis being on control of invasive alien plants," Snaddon says.

Long-term water security begins at the source with 'ecological infrastructure' that regulates source water quality and supply, according to The Nature Conservancy. This type of 'green' infrastructure is defined as naturally functioning ecosystems that deliver valuable natural goods and services that people benefit from. The rehabilitation of wetlands is strengthened through sound catchment restoration and management.

Until now, few studies have, however, documented evidence of whether and how wetlands perform the ecosystem services with which they are credited; and there has been varied results from those studies that have documented this evidence.

These and other issues are under the spotlight in a recent study commissioned by The Nature Conservancy. This analysis provides new insights about wetlands and considerations about their ecosystem services when rehabilitation efforts are determined. The research is part of work to evaluate the impact of nature-based solutions on water supply in the region. The researchers prioritised wetlands for water security in priority dam catchments in the Western Cape Water Supply System (WCWSS).

The researchers undertook a prioritisation of wetlands located within catchments upstream of the six major dams supplying water to the City of Cape Town – Steenbras Dams (Upper and Lower), Theewaterskloof Dam, Wemmershoek Dam, Berg River Dam and Voëlvlei Dam. Criteria were selected as a means of ranking the wetlands in order of importance for water security. This included wetland size, slopes, soil types and rainfall intensity, among others. This allowed the researchers to rank the wetlands in order of their perceived importance for the supply of ecosystem services related to water security.

Snaddon and her colleague, Katherine Forsythe, collaborated with Jessica Dietrich from The Nature Conservancy and Jane Turpie from Anchor Environmental Consultants on this project.

The potential return on investment

Based on the assessment, seven sub-catchments were identified for control in the water source areas of the WCWSS in terms of their potential return on investment. They comprise a total of 54 300 hectares and are the sub-catchments for the Wemmershoek, Berg River and Theewaterskloof dams, which supply 73% of the surface water contribution to the WCWSS.

Within these catchments, six wetlands and wetland clusters ranked highest in relation to their criteria. These are the Upper Riviersonderend and Du Toits River wetlands that feed into Theewaterskloof Dam, the Olifants River wetland supplying water to Wemmershoek Dam, a cluster of wetlands upstream of Steenbras Dam, a similar cluster in the upper catchment of the

Berg River, and the Zuurvlaak wetland supplying water to Voëlvlei Dam.

Three wetlands satisfied all the criteria – the Upper Riviersonderend, Du Toits River, and the Wemmershoek wetlands. These wetlands were assessed for condition and ecological importance and sensitivity, and also for opportunities for rehabilitation.

In terms of organic content, run-off potential of soils, and the catchment rainfall intensity, the Upper Riviersonderend wetland also emerged as likely the most critical wetland for the supply of important wetland functions relating to water security, while also being located in a part of the catchment where there is a high demand for such services. "Prioritising wetland rehabilitation efforts are key given resource constraints and growing pressures on freshwater resources in the region," Snaddon indicates.

The ability of wetlands to perform water quality amelioration services depends on their area and type of vegetation as well as their overall health and management. Wetlands on a gentler slope are, for instance, likely to be more effective in terms of the attenuation of flows, retention of water over time, and filtration of water into the ground (should the soils and geology allow).

Unsurprisingly, the study showed that pristine wetlands provide a greater suite of ecosystem services than those that are degraded. Specifically, pristine wetlands scored higher for water-related ecosystem service provision as well as carbon storage, compared to degraded wetlands. Wetlands located in areas of



Kate Snaddon

Erosion present in the Upper Riviersonderend wetland.



Kate Snaddon

Palmiet occurs in the Riviersonderend wetland.

Summary of rehabilitation gains

	Total wetland area influenced	Number of hectare equivalents gained or secured	% increase in streamflow regulation	% increase in nitrate removal	% increase in erosion control	% increase in carbon storage	% increase in biodiversity maintenance
Upper Riviersonderend	222	77	0	0	33	25	23
Du Toits	680	56	0	0	6	11	16
Wemmershoek	323	0 (no rehab opportunities currently identified)	n/a	n/a	n/a	n/a	n/a
Zuurvlak	925	227	8	8	25	25	32

Summary of potential costs avoided through rehabilitation of priority wetlands (R'000s per year)

Wetland	Increase in water quality amelioration benefits	Increase in sediment retention benefits	Increase in carbon benefits	Increase in tourism value	Total gain (R'000s/yr)
Upper Riviersonderend	-	164-328	18-71	-	182-399
Du Toit	-	116-232	22-89	-	138-321
Zuurvlak	472-937	-	10-130	10-26	492-628
Total	472-937	280-560	50-290	10-26	812-1348

Preliminary estimates of present values of costs avoided through rehabilitation and costs of rehabilitation as well as the potential range of return on investments

Wetland	Present value of ES gains (6% discount rate over 30 years)		Present value of rehabilitation costs (6% discount rate over 30 years)	Return on investment	
	Lower Bound	Upper Bound		Lower Bound	Upper bound
Upper Riviersonderend	2 496 000	5 478 000	3 842 000	0.65	1.43
Du Toit	1 898 000	4 406 000	691 000	2.75	6.38
Zuurvlak	6 757 000	9 636 000	6 744 000	1.00	1.28

high total rainfall are likely to be more important in terms of the demand for services relating to attenuation of flows, streamflow regulation and infiltration into groundwater.

The presence of fibrous peat (and to a lesser extent amorphous peat) is also likely to increase the capacity of the wetland to store water and ensure infiltration of water into groundwater (should the geology allow). Water is more likely to be released slowly throughout the year.

To calculate the return on investment for rehabilitation of these priority wetlands, the researchers calculated the present values of the costs avoided through rehabilitation and the present value of the rehabilitation costs over a 30-year time frame using a 6% discount value. They assumed that the capital costs were spent in the first year with ongoing maintenance costs of 2% per year (based on an average of costs reported in the literature for wetland rehabilitation works).

The preliminary analyses suggest that through rehabilitation

of priority wetlands, the economic gains in terms of ecosystem services could be in the order of R0.81-R1.35 million per year (see accompanying tables for more information).

This analysis suggests that rehabilitation of the Zuurvlak wetland could, for instance, save treatment costs in the order of R472 000-R937 000 per year. This large range of values highlights the need to collect more site-specific data.

The Du Toits River wetland also showed the highest return on investment compared to the other two wetlands. This is due to the lower rehabilitation costs, even though the costs avoided through rehabilitation were the lowest of the three wetlands.

The study lays the groundwork for prioritising investments in wetland restoration and alien clearing efforts in the region, Snaddon indicates. Unfortunately, the National Inland Aquatic Ecosystem Inventory map was not completed at the time of this study's conclusion. There was also not enough information on the prioritised wetlands to allow an in-depth ecosystem service

valuation within the time available. Ideally, the prioritisation done for this study should be repeated when this becomes available, she says.

“There are still many gaps in our understanding of wetland ecosystem services,” Snaddon concludes. “But what we do know is that since it is so difficult to restore damaged wetlands, the priority must be to halt damage to pristine wetlands.”

More about the priority wetlands

Upper Riviersonderend wetland

- The Upper Riviersonderend wetland is a weakly channelled valley-bottom wetland that flows into the Theewaterskloof Dam near Vyeboom.
- It is situated in a priority catchment due to the good condition of the river.
- The upper end of this 222 hectare wetland lies within the Hottentots-Holland Nature Reserve.
- Most of the wetland has been classified as an aquatic critical biodiversity area in the Western Cape Spatial Biodiversity Plan for the Theewaterskloof Municipality.
- The upper reaches of the Riviersonderend are known to provide sanctuary to the endangered Giant Redfin (*Pseudobarbus skeltoni*), which is endemic to the Breede River.
- The vegetation is dominated by dense stands of palmiet (*Prionium serratum*). This wetland plant has been described as an ‘ecosystem engineer’ due to its ability to block water flow where the plant proliferates, leading to the accumulation of organic material and the development of wetland conditions.
- Some rehabilitation interventions, all of which are considered to be ‘soft’ engineering options, are recommended for this wetland.

Du Toits River wetland

- The Du Toits River wetland is located on the north-western margin of Theewaterskloof Dam. It is an extensive weakly channelled valley-bottom wetland, dominated by plant communities that are very similar to the Upper Riviersonderend wetland.
- Palmiet grows in large, dense stands, with more mixed plant communities inhabiting other portions of the wetland.
- There has been extensive invasive alien plant removal over the past few years, and the vegetation now appears to be in good condition.
- The rehabilitation strategy for this wetland is follow-up alien invasive plant clearing.

Zuurvlak wetland

- The Zuurvlak wetland is located on the Waterval River, a tributary of the Klein Berg River, which supplies water to Voëlvlei Dam.
- The wetland is situated on a gently sloping valley floor or plateau with seeps and streams feeding into it from the side slopes.
- Until approximately a decade ago, the wetland was completely under SAFCOL pine plantations, managed by MTO, but the pines have been systematically cleared since the early 2000s. A 30-year lease agreement was signed in 2015 between the Department of Public Works and a private renewables company who have plans to construct a wind, solar or a pumped storage scheme on the site.
- A high waterfall separates the wetland plateau from downstream, leading to the isolation of this plateau from the rest of the catchment. This is likely to have influenced species diversity and speciation.

SMALLHOLDER FARMING

Creating climate change resilient communities Part 3: A decision support system for smallholder farmers

In this third article based on the Water Research Commission (WRC) funded project titled, 'Collaborative knowledge creation and mediation strategies for the dissemination of water and soil conservation practices and climate smart agriculture in smallholder farming systems' we focus on the design of a farmer level decision support system. Article by Erna Kruger.

The project is exploring best practice options for climate resilient agriculture (CRA) for smallholders and evaluating the impact of implementation of a range of these practices on the resilience of agriculture-based livelihoods. Alongside this, a decision support methodology and system has been designed to assist smallholders and the facilitators who support them to make informed and appropriate decisions about choices of a 'basket of options' for implementation at a local level.

The smallholder climate change adaptation decision support process

The decision support process focuses on a bottom-up approach, where individual farmers in a locality make decisions regarding the 'basket' of climate resilient agriculture approaches and

practices most suited to their specific situation. To do this in a way that also includes the concepts of social learning, innovation and agency the following decision support concept has been developed.

The process is designed to also support and assist the facilitator in their decision making, in support of the smallholder farmers; meaning that the facilitator accesses information such as the basic climate change predictions for the area, the agroecological characteristics including rainfall, temperature, soil texture etc) and an initial contextualised basket of practices from which to negotiate prioritised practices with farmers. Practices are thus chosen by both facilitators and farmers.

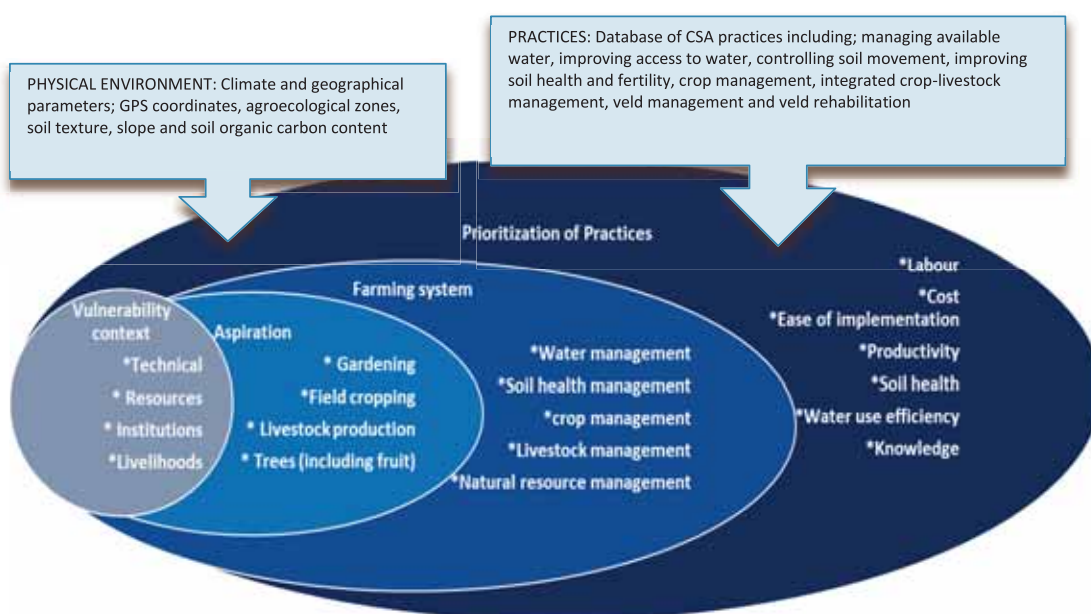


Figure 1: The smallholder decision support model.

Situation and vulnerability assessments

The model for vulnerability assessments used in this process provides for a combination of socio-economic (livelihood) and socio-ecological (access and utilisation of natural capital) indicators, in a climate change context (wellbeing, adaptive capacity and governance). This is a new process design, built from elements of existing international best practice options.

The process consists of focus groups discussions, individual interviews (baselines) and household visits, or walkabouts as we call them – as they include a broad and initial assessment of the

'lay of the land'.

This information is pulled together into a database that has been put together to provide for a farmer segmentation/ farmer typology approach. Farmer typologies allow for differentiation between different levels of vulnerability in a community to target interventions/ practices more specifically.

The three typologies developed within this process are shown in the figure below:

Typology A (2,5 million)	Typology B (250 000)	Typology C (10 000)
<ul style="list-style-type: none"> •Female headed, •Farm for food only, •Very low incomes – mostly unemployed, •Access to small plots of land (<0,1ha), •No household level access to water, •Lower education levels (Primary school) •No access to formal markets, •Belong to village savings and loan associations and •Engage in other livelihood activities 	<ul style="list-style-type: none"> •Male and female headed, •Farm for food and sell surplus, •Slightly higher incomes, •Access to larger plots of land (0,1-1ha) •Some access to hh level water, •Somewhat higher education levels (High school), •No access to formal markets and •Belong to village savings and loan associations 	<ul style="list-style-type: none"> •Male headed, Farm mainly for income, •Much higher incomes from employment in the household, •Good access to water at household and field level, •Higher education levels (Matric nad post scholl qualifications), •Acess to formal markets. •Belong to cooperatives or farm individually

Figure 2: Smallholder typology for a climate resilient farming decision support system.

A typical participant is thus:

A 51 year old woman, who is the head of her household, has Grade 9-11 level of education, is unemployed, has an average monthly income of R2170, engages in field cropping, gardening and livestock husbandry, has no access to water in her household, engages in local markets only and belongs to a savings group



These typologies are one of the input categories into the decision support system.

The web-based platform

The model is designed primarily as a participatory and facilitated process at community level. In support of this process, a computer-based model can be used alongside this methodology to provide further information and decisions support to the facilitator. It is also possible for a farmer to access this model independently to derive an initial basket of CSA practice options for themselves.

The computer model information flow is designed as shown in the figure below – and follows the same basic steps as the facilitated model shown in Figure 3 on the following page.

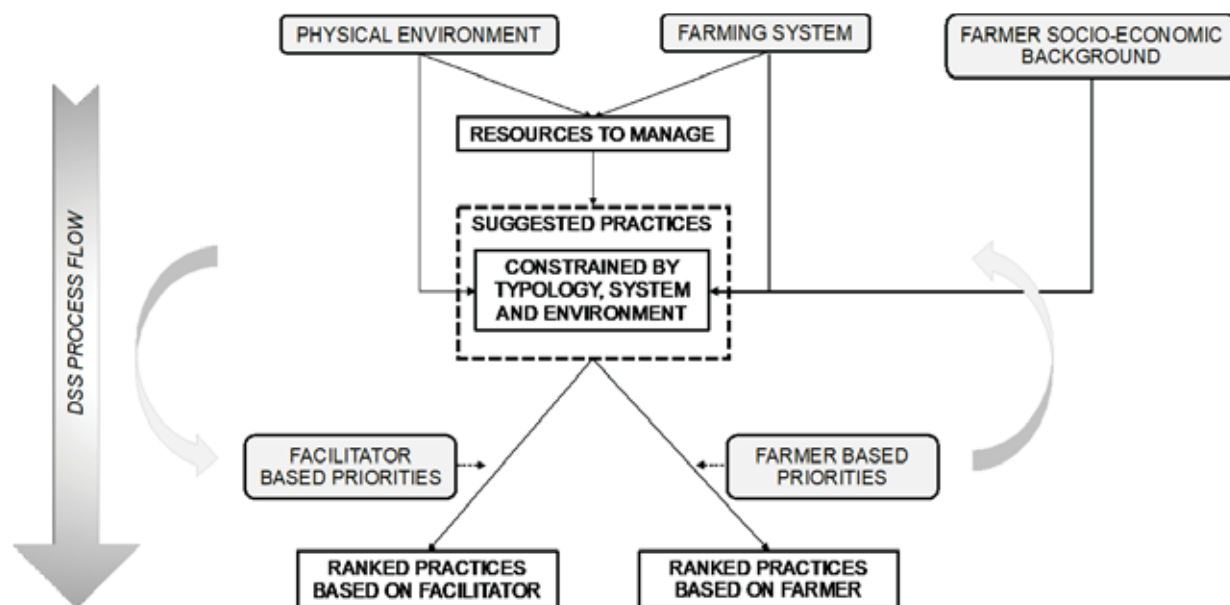


Figure 3: The computer-based model for the smallholder DSS.

In our case the set of criteria (proxies used as indicators for the complex reality) that helps to make informed decisions on management practices are:

- The current farming systems; gardening, field cropping, livestock production and natural resource management (NRM) (including trees),
- The physical environment: agroecological zone, soil texture, slope and organic soil carbon and
- The socio-economic background of the farmer; demographic information (gender HH head, age, dependency ratio), level of education, sources of income (unemployment vs. external employment, own business, grants, farm, etc.), total income, access to services, infrastructure, technology (Electricity, water (tap, borehole, rainwater harvesting, etc.), irrigation (buckets, standpipes, etc.), fencing and farming tools (hand vs traction/other), social organisation, market access (formal vs. informal), farm size and farming purpose (food vs. selling).

Besides this, the resources and related management strategies as well as a list of practices need to be provided as input to the system. All information, except the physical environment; i.e. climate, soil and topography, and the resources and management strategies, are derived through the use of a range of participatory processes. Data on the physical environmental conditions have been taken from datasets freely available online. This information can however be customised by the DSS user, in case more appropriate information is available for the specific farmer concerned.

For the Facilitator-Farmer DSS the resources and related management strategies are discussed and negotiated in the participatory process. For the computer based or Individual Farmer DSS these are provided as an input into the model using the following framework:

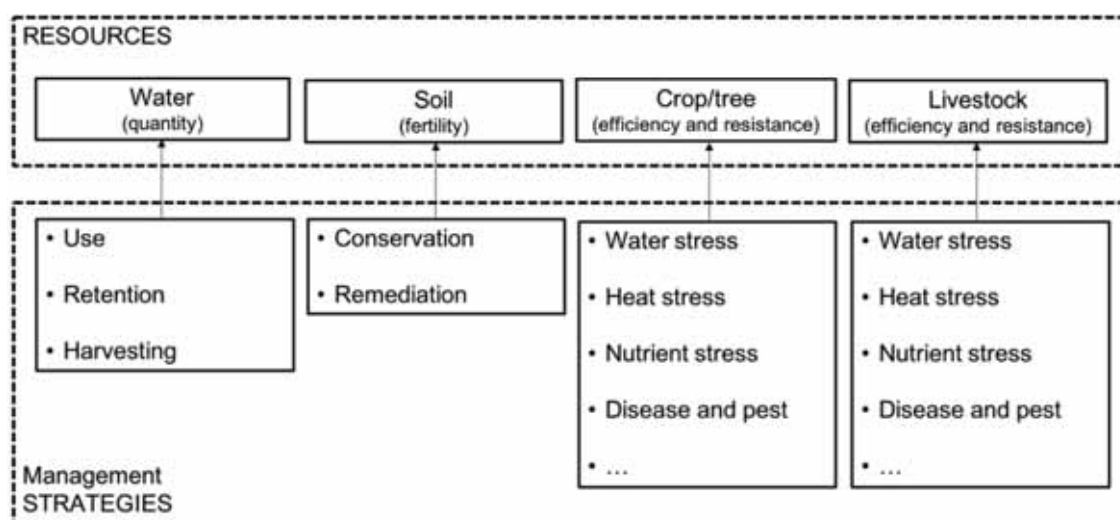


Figure 4: Resources to manage and their associated management strategies.

Once all the information is inputted into the model an initial list of practices is suggested for each individual farmer. The model has been tested and refined, through comparison of this computed based process with the participatory process and assessing how closely these two processes are aligned.

Below is an example for 1 farmer in each of the three provinces where the model has been tested.

Table 1: Basket/list of practices recommended for version 2 of the DSS

Province	KZN	Limpopo	EC
Village	Ezibomvini	Sekororo	Mxumbu
Name and Surname	Phumelele Hlongwane	Chenne Mailula	Xolisa Dwane
Drip irrigation	0	0	0
Bucket drip kits	0	0	0
Furrows and ridges/ furrow irrigation	0	0	0
Greywater management	1	1	0
Shade cloth tunnels	1	1	0
Mulching	1	1	0
Improved organic matter (manure and crop residues)	1	1	1
Diversion ditches	1	0	0
Grass water ways	0	0	0
Infiltration pits / banana circles	1	1	0
Zai pits	1	0	0
Rain water harvesting storage	1	1	1
Tied ridges	0	0	0
Half- moon basins	0	0	1
Small dams	0	0	0
Contours; ploughing and planting	1	0	0
Gabions	0	0	1
Stone bunds	0	0	0
Check dams	0	0	1
Cut off drains / swales	0	0	1
Terraces	0	0	0
Stone packs	1	0	0
Strip cropping	1	0	0
Pitting	1	1	0
Woodlots for soil reclamation	1	0	0
Targeted application of small quantities of fertilizer, lime etc	1	0	0
Liquid manures	1	1	0
Woody hedgerows for browse, mulch, green manure, soil conservation	1	0	0
Conservation Agriculture	1	0	0
Planting legumes, manure, green manures	1	0	0
Mixed cropping	1	0	0
Planting herbs and multifunctional plants	1	0	0
Agroforestry (trees + agriculture)	1	0	0
Trench beds/ eco circles	1	1	0
push-pull technology	1	0	0
Natural pest and disease control	1	0	0

Province	KZN	Limpopo	EC
Village	Ezibomvini	Sekororo	Mxumbu
Name and Surname	Phumelele Hlongwane	Chenne Mailula	Xolisa Dwane
Integrated weed management	1	1	1
Breeding improved varieties (early maturing, drought tolerant, improved nutrient utilization),	1	1	1
Seed production / saving / storing	1	1	1
Crop rotation	1	1	1
Stall feeding and haymaking	0	0	0
Creep feeding and supplementation	1	0	0
Rotational grazing	1	0	1
De-bushing and over sowing	1	0	1
Rangeland reinforcement	1	0	1
Bioturbation	1	1	1
Tower garden	1	1	0
Keyhole beds	1	1	0
No of practices recommended	35	16	14

For the KwaZulu-Natal participant, this means that around 88% of the full list of practices have been recommended for her. She has a wide range of recommendations being a farmer in Typology B (fewer restrictions) and engaging in gardening, cropping and livestock production. Although this is quite high, it is understood that the farmer level ranking is still to take place and these practices can then be prioritised and narrowed down further. For the Limpopo and EC participants, around a third of

practices have been recommended in their basket of options.

Ranking can be undertaken first by the facilitator or can be done directly by the farmer depending on the circumstances. Below is the ranking exercise undertaken for Phumelele Hlongwane (Ezibomvini, KwaZulu-Natal). The practices shown in green are those that Phumelele are already implementing. This ranked list then provides options for inclusion of further ideas and practices.

Table 2: Ranking of CRA practices recommended for Phumelele Hlongwane

(KZN; Bergville)Phumelele Hlongwane: List of practices scored by facilitator				
Practices	Field cropping	Vegetable gardening	Livestock	Natural resources and trees
Shade cloth tunnels		8		
Mulching		9		
Improved organic matter	11	11		11
Diversion ditches	9	9		9
Infiltration pits		10		
Zai pits	10	10		
RWH storage	9	9	9	9
Stone packs	9	9		9
Strip cropping	11			
Pitting	11		11	11
Woodlots for soil reclamation	9		9	9
Targeted fertilizer application	8			
Liquid manure		7		
Woody hedge rows	10		10	10
Conservation agriculture	11	11	11	11
Planting legumes, manure, green manures	8	8		8
Mixed cropping	9	9		
Planting herbs and multifunctional plants	9	9		

(KZN; Bergville)Phumelele Hlongwane: List of practices scored by facilitator				
Practices	Field cropping	Vegetable gardening	Livestock	Natural resources and trees
Agroforestry (trees + agriculture)	11	11	11	11
Trench beds/ eco circles		9		
push-pull technology	7			
Natural pest and disease control	7	7		7
Integrated weed management	7	7		7
Breeding improved varieties (early maturing, drought tolerant, improved nutrients),	7	7	7	7
Seed production / saving / storing	6	6		6
Crop rotation	9	9		
Stall feeding and haymaking				
Creep feeding and supplementation			7	
Rotational grazing			9	
De-bushing and over sowing			9	
Rangeland reinforcement			9	
Bioturbation	9	9	9	9
Tower garden		10		
Keyhole beds		10		

Below are a few indicative photographs of Phumelele's CRA practices.



Above clockwise from top left: A view of Phumelele Hlongwane's vegetable garden, a newly constructed tower garden, trench beds planted to a mixture of vegetables in her shade cloth tunnel, a plot of Dolichos in her CA field and a plot of summer cover crops- sunnhemp and millet.

The decision support system for climate resilient agriculture implementation by smallholder farmers is an important new innovation in the field of community-based climate change adaptation and can be scaled up as a framework in research, learning and implementation in this field.

NEW PARTNERSHIP HOPES TO BOOST ROLLOUT OF SAFE SANITATION



In November, the Water Research Commission (WRC) and its partners, the Department of Science and Innovation, Department of Water and Sanitation, the South African Bureau of Standards, and the Department of Trade and Industry with the support of the Bill and Melinda Gates Foundation, launched the South African Sanitation Demonstration Programme (SASTEP). SASTEP will support and accelerate the application and uptake of the latest cutting-edge toilets through evidence-based policy adjustments, demonstration, testing and science-based improvements towards localisation and industrialisation. This includes technologies supported by the Bill and Melinda Gates Foundation 'Reinvent the Toilet' programme. The revolutionary

toilet systems will offer water-saving or water-recycling features, be aspirational in design and, more importantly, offer dignity and convenience. To demonstrate the potential of the reinvented toilet as a sustainable solution to national sanitation challenges, the initiative will work with local communities to pilot proven and emerging technologies alongside the business and service models used to maintain the systems," noted WRC CEO, Dhesigen Naidoo. "Local innovation which fit the criteria and are designed to meet the new SABS 30500 standard for a non-sewered sanitation system could also join the programme for further support and evaluation."

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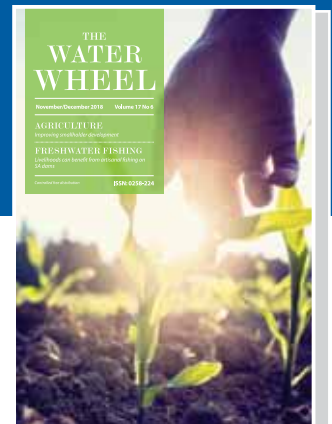
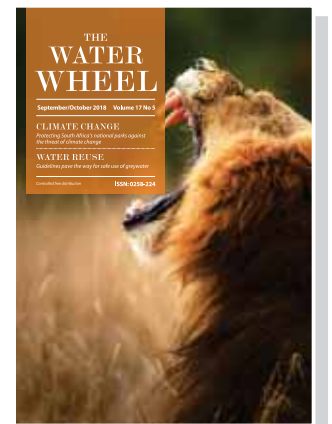
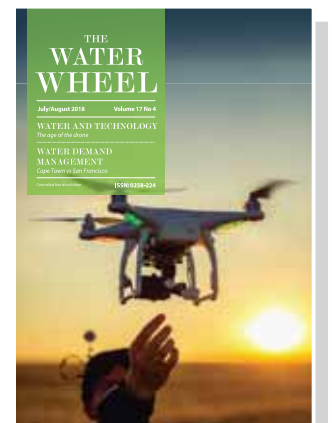
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The knowledge generated by the WRC generates new products and services for economic development, it informs policy and decision making, it provides sustainable development solutions, it contributes to transformation and redress, it empowers communities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

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