WATER RESEARCH COMMISSION

KNOWLEDGE TREE REPORT 2012 | 2013

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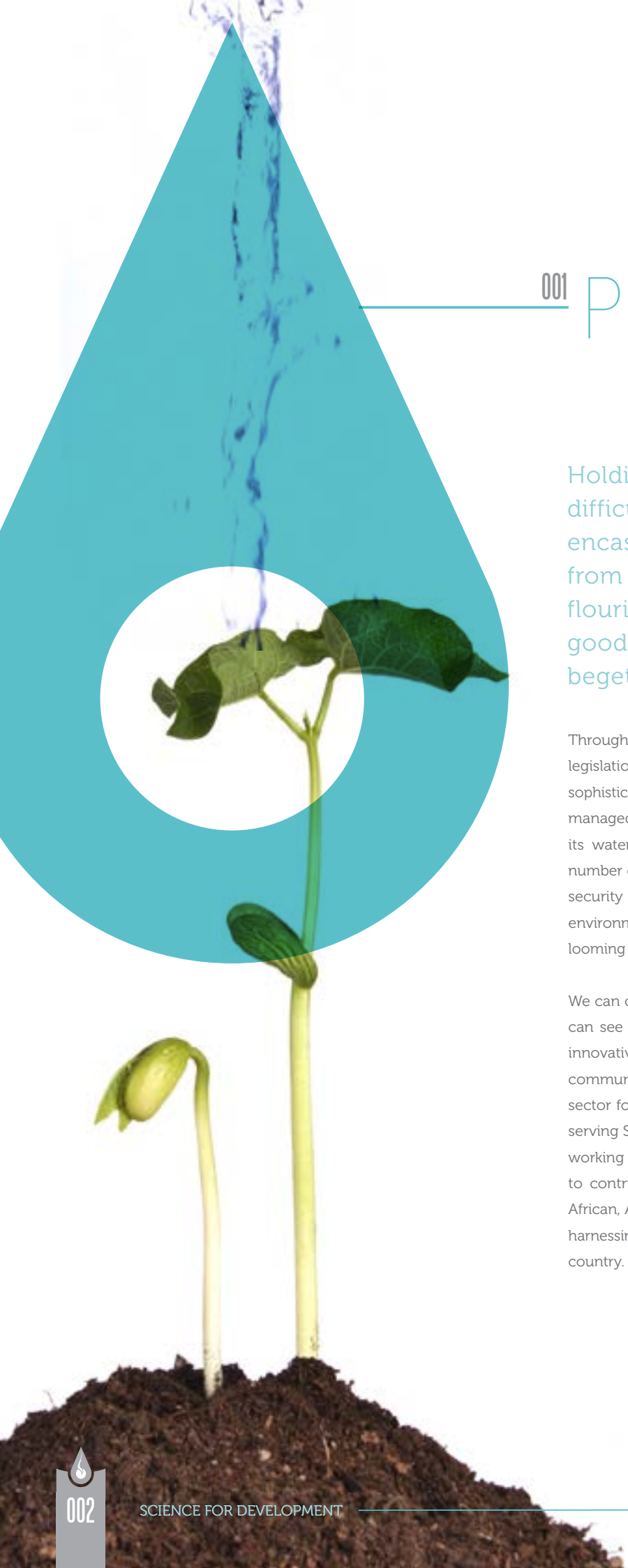


001 PREFACE

Holding the tiny seed it can be difficult to picture the mighty tree encased within it. To free the tree from its casing and allow it to flourish requires more than merely good soil and nourishment. Water begets the growth of all things.

Through its internationally recognised water policies and legislation, founded on a strong scientific base, in addition to a sophisticated infrastructure network, South Africa has historically managed to achieve consistent growth despite the scarcity of its water resources. Going forward, the country is facing a number of water challenges and concerns, including continued security of supply amid a growing population and economy, environmental degradation and resource pollution, as well as looming threats as a result of climate change.

We can choose to be overwhelmed by these challenges or we can see them as an opportunity - an opportunity to provide innovative, world-class solutions that will not only allow our communities to thrive but can propel the South African water sector forward on the world scene. Now in its fifth decade of serving South Africa, the Water Research Commission (WRC) is working with its governmental and non-governmental partners to contribute new water knowledge and solutions to South African, African and global water challenges by developing and harnessing the water research and development capability in the country.

The WRC recognises that adapting and responding to a changing, dynamic environment and providing South Africa with value for the money invested in water research and development is an immense challenge. The WRC's five-year strategy, launched during the year under review, seeks to ensure that the Commission remains proactive in addressing society's current and future needs for water-related problem-solving initiatives.

An important concept in meeting this goal is the WRC Knowledge Tree. This expression of the WRC strategy symbolises the diversification of focus that the Commission has undergone from an almost exclusive focus on knowledge generation towards investment in the 'multiplier effect'. In addition to the knowledge products and publications from the WRC research portfolio, the WRC is using that knowledge to inform policy and decision-making, contribute to sustainable development solutions, develop products and services for the real economy, actively contribute to human capital development, directly empower communities, and enable the national transformation project.

In principle, each WRC-funded project is striving to achieve as many of the Knowledge Tree outcomes as possible. So the WRC is ensuring that the knowledge generated through its funded research has meaning, and that this knowledge is converted into a series of products and services that have a direct impact on how people are living in South Africa.

The next few pages highlight the WRC's greatest achievements during 2012/13 in achieving this goal.

Dhesigen Naidoo
Chief Executive Officer

The WRC Knowledge Tree

INFORMING POLICY AND DECISION MAKING 002

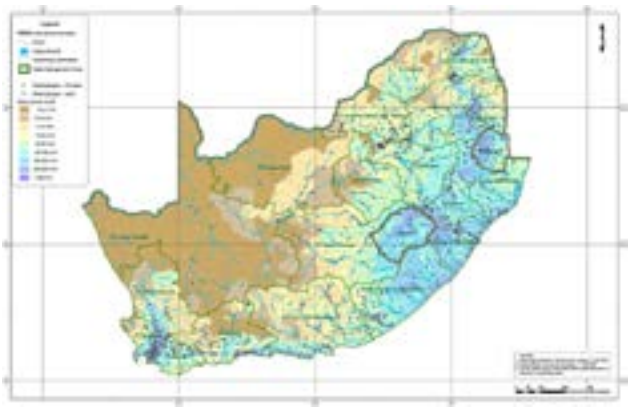
The effective management of South Africa's water resources requires an informed and reliable scientific foundation to provide appropriate evidence-based information to guide decision-making. Through its funded research, the WRC provides this foundation, aiming to ensure that the country's water resources are managed sustainably.

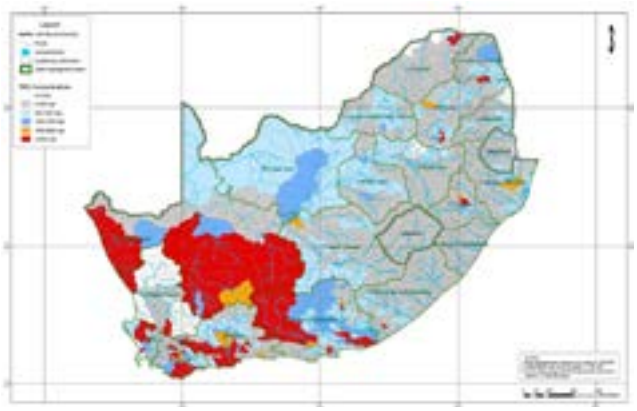
The WRC recognises the need for the status of South Africa's water to be elevated to the core of the public agenda and that advanced management practices should be applied and implemented to address the increasingly complex business of water resource development and management. During 2012/13, the WRC reinforced its efforts to fund appropriate research projects aimed at actively informing both policy development by Government partners and decision-making by all parties in the water sector.

The Water Resources 2012 (WR2012) study

It is well known that water is South Africa's scarcest resource, and that the country counts among the world's 30 most parched. With an average annual rainfall of only 465 mm a year and a concomitant high evaporation rate, South Africa has a mean annual runoff of less than 50 000 million m^3/annum. This is equal to only 50% of the mean annual flow of the Zambezi River. As a result of this inherent scarcity, the country walks a constant tightrope between development and protection of its water resources. This makes quantifying exactly how much water the country has one of the most important tasks to be undertaken in the local water sector. Undertaking regular water resource quantification assessments not only informs the country of its available water resources, but helps to augment decision-makers' and specialists' understanding of how the natural hydrological cycle behaves.

The WR2012 study, which was launched in 2012, is the sixth comprehensive national water resource assessment to be undertaken in South Africa since the first study was completed in 1952. The objective of the study is to assist decision-makers at all levels of Government to make informed choices about all policies concerning South Africa's water resources.

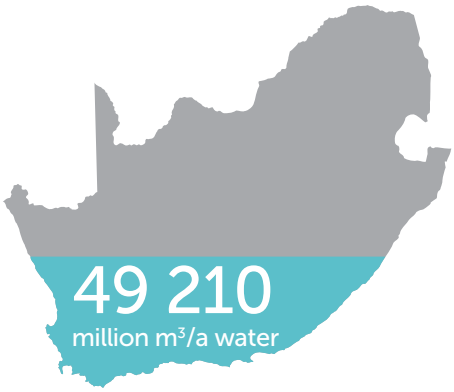


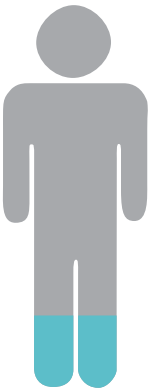


Each water resource assessment study builds on the technology and knowledge gained from the study before. A significant factor has been the exponential growth in computing power over recent decades.

This has made it possible to develop better hydrological tools using increasingly powerful computer power, resulting in more reliability and confidence in the results.

South Africa's Total Surface Water Resources:





THIS IS LESS THAN

1 000 m³/person/year

WR2012 will be the most accurate assessment of South Africa's water resources yet. The assessment study includes updates of all hydrological data up to 2010, further enhancements to hydrological models, revised groundwater data, and a monthly time series of present-day flow, among others. The project is also in the process of creating a publicly-accessible, Web-based and interactive reporting system to continually quantify both the surface and groundwater resources of South Africa.

With each consequent study it has been found that South Africa actually has less water resources available than previously thought. This is not due to climate change, but is actually the result of more precise and accurate assessment. The latest figures put South Africa's surface water resources at 49 210 million m³/annum.

WR2012 is also addressing the challenge of the declining availability of streamflow and rainfall data, which is currently being experienced in South Africa. Spatially representative, long-term consistent records of rainfall and streamflow data are essential for achieving a high level of understanding about water resources. Rainfall is the primary input to hydrological computer models, not only to determine streamflow, but also irrigation requirements and net evaporation from reservoirs. On the other hand, information on streamflow is necessary to calibrate the hydrological models to ensure South Africa gets the most accurate determination of its water resources.

The number of useful streamflow gauges in South Africa has showed steady decline from a peak of 450 in the late 1980s to less than 350 in 2004. In terms of rain gauges, the country now has roughly the same number of rainfall stations it had in 1920. Several discussions regards the challenges around data were organised by the WRC with stakeholders during the year under review. In the meantime the WR2012 assessment is determining what level of monitoring the country simply cannot do without if it is to understand and effectively manage its water resources. WR2012 will be completed in 2016.

INFORMING POLICY AND DECISION MAKING

Strengthening South Africa's climate change armoury

South Africa's water resources, already subjected to high hydro-climatic variability both over space and time, are a key constraint to the country's continued economic development and the sustainable livelihood of its people. With further projected changes in global climates into the future, changes in the South African water sector will be inevitable, especially since the regional climate in South Africa is dependent on global climate, both today and in the future. No one knows exactly how the future global climate will develop and what the resultant consequences in South Africa will be. However, South Africa lies in one of the regions of the world that is most vulnerable to climate variability and change.

Accounting for and adapting to potential effects of climate change in South Africa's water sector are therefore seen as imperative – indeed, non-consideration of potential effects of climate change and adaptation of the country's water sector should be viewed as an error. During the year under the review the WRC concluded a three-year, multidisciplinary, multi-organisational study which evaluated the sensitivity of socio-economic activities to climate change in climatically divergent South African catchments. The research consortium was led by the University of KwaZulu-Natal.

With the impacts of climate change being potentially disastrous on a regional scale and with the knock-on effects possibly having serious implications for the national economy, with vulnerable communities likely to be most seriously affected, a major goal of this project was to take current knowledge on climate change in South Africa to a new level, updating it and making it more relevant as well as usable for water managers within their decision-making processes. In so doing, the project was tasked with making use of output from state-of-the-art general circulation models to make projections at a finer scale than previous studies, of possible changes to the South African water sector associated with anticipated global climate change, and then to use those scenarios to evaluate the sensitivity and adaptability of current socio-economic activities and the likely socio-economic impacts resulting from expected climate change. The main outcome of the project was the publication, *A perspective on climate change and the South African water sector.*

The study confirms that climate change poses new challenges to water resource managers in South Africa. Some areas are likely to become 'winners' for certain projected changes and new water-related opportunities will arise, while other areas are likely to become 'losers' in the sense that more water-related stresses will be experienced. Hotspots of concern were confirmed to be the southwest of the country, the west coast and, to a lesser extent, the extreme north of South Africa.

In general, the results showed an increase in the year-to-year variability of hydrological responses into the future, often a quite substantial increase, especially when inter-annual variability was expressed in absolute terms by the standard deviation. The increase in variability also tended to be higher into the more distant future than between the intermediate future and present. Where both the standard deviation and the coefficient of variation were shown to increase, those areas were considered to be particularly sensitive to climate change. Examples of increases in variability included changes in rainfall, to stormflows, accumulated streamflows and to sediment yields.

Some components of the hydrological system were found to be more sensitive to climate change than others. Examples include changes to baseflows, hydrological droughts and surface runoff losses from irrigated lands. From an engineering perspective, an important finding was that projected spatial changes to design rainfall and design streamflows vary with return periods rather than with critical duration, and this should be factored into future hydraulic designs.

Determining the vulnerability of communities to climate change

A WRC-funded project investigated how research could assist in identifying vulnerable communities, which should be primary targets for adaptation strategies. The project aimed to, firstly, identify which communities are most sensitive to climate change due to their socio-economic status; secondly, investigate how able those communities are to respond to the risks imposed on them; and thirdly, define what the risks are that these communities are most exposed to.

Two divergent catchments were selected to test the project team's methodology: the uMgeni catchment, in KwaZulu-Natal, where a projected increase in annual rainfall is predicted; and the Berg catchment, in the Western Cape, where decreases in annual rainfall are predicted.

The results showed far higher levels of vulnerability in the uMgeni than the Berg catchment. This is based mainly on low income and education levels as well as high population densities in the Mgeni catchment. However, each catchment presents a different set of challenges to municipal managers and different adaptation plans will be required. Especially in the uMgeni catchment challenges will arise from a rather dispersed picture of vulnerable communities with divergent characteristics. The research also underlined the importance of basic levels of service, not only to improve people's daily lives but to make them less vulnerable to the onslaughts of climate change.

By identifying which communities are vulnerable to climate change, researchers can provide planners with a starting point on which to focus specific adaptation options and offer insight into which adaptation strategies are most viable for each location. By improving our understanding of the different dimensions of vulnerability, earlier action can be taken. This will greatly enhance the safety of our society, environment and economy to the potential onslaught of climate change.

INFORMING POLICY AND DECISION MAKING

Improving the state of non-revenue water

The WRC, together with the DWA, has undertaken the most comprehensive and detailed assessment of South Africa's non-revenue water to date. The study p rovides a clear indication of the current status of non-revenue water in South Africa, more specifically what the actual water losses are and how they are split between physical leakage (real losses) and commercial losses (apparent losses).

The study is in line with government policy towards improved water resource management. The Draft Second National Water Resource Strategy (NWRS2) has identified the implementation of water use efficiency, conservation and water demand management as a core strategy to ensure sufficient water to meet South Africa's needs going into the future.

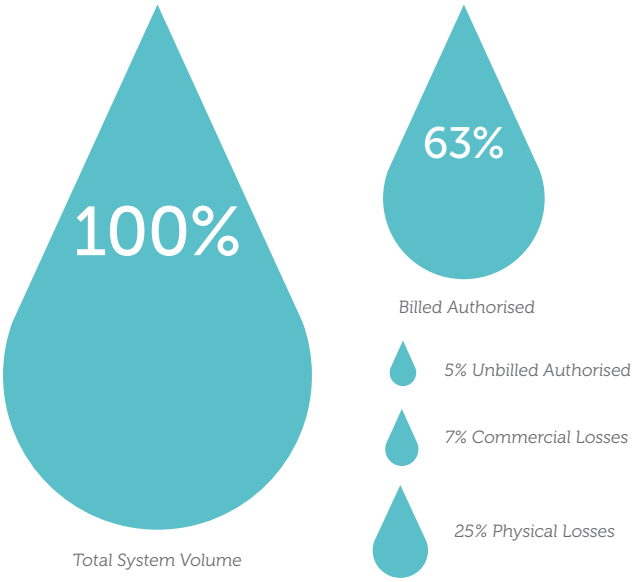
Non-revenue water can potentially have a significant impact on water supply and, in some areas, high levels of lost water have already forced the commissioning of new water transfer schemes. Non-revenue water should be viewed as a source of water as it represents a significant opportunity for municipalities to save water. Moreover, in areas that typically experience high levels of unemployment, water demand management measures can create significant energy savings, particularly in systems where water is pumped at some point in the supply cycle.

Data were gathered from 132 municipalities throughout South Africa, representing over 75% of the total volume of municipal water supply. The study follows on from similar WRC assessments undertaken in 2001, 2005 and 2007. **This is the first time the country has a single, representative estimate of non-revenue water as opposed to various estimates in previous years.**

The results indicate that South Africa's present level of non-revenue water is in the order of 37%, which is virtually at the world average of 36,6%. Of this, a quarter is considered to be losses through physical leakage.

The current volume of non-revenue water is around 1 580 million m^3/annum. At a nominal production cost of R4,5/m^3, this loss represents about R7,2-billion annually. South Africa still has a relatively high per capita water use (around 273 litres per person per day) which is an indication that the average

The National Water Balance



The issue of non-revenue water is now receiving increasing attention at municipal level. All of South Africa's large cities and towns are now monitoring their water use and attempting to establish a proper and reliable water balance in line with international recommendations. Water losses remain problematic in small constituencies, where an average non-revenue water percentage of 72,5% was reported.

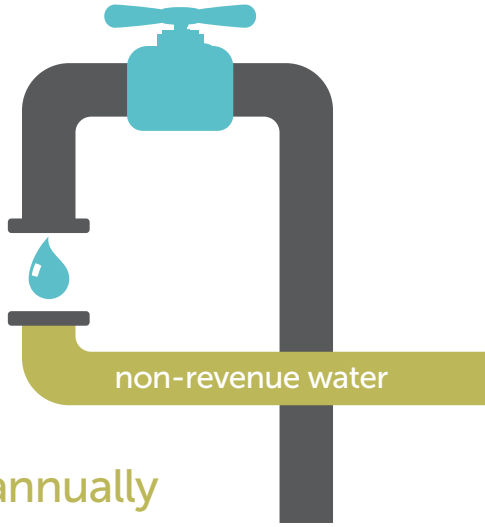
The investigation confirmed that non-revenue water remains the product of many factors, including poor planning, limited financial resources to implement the necessary programmes, poor infrastructure asset maintenance and lack of capacity. However, several additional key problem areas were also identified. One of the greatest inhibitors to the introduction of successful water

demand management in many municipalities is the lack of proper auditing and documentation of the various interventions.

Another important aspect of non-revenue water reduction is effective billing and metering. Revenue recovery is essential in order for municipalities to provide a sustainable good quality service and as such should be decisively implemented across the country, where practicable. Ultimately, local authorities have a mandate to generate revenue and to operate in a self-sustaining manner. This can only be achieved through proper monitoring of water supply systems in the form of metering, and creating a culture of payment for services to enable sound maintenance activities and a high standard of consumer service. Furthermore, the report emphasised the importance of proper planning,

South Africa's
non-revenue water=

1 580
million m^3
per year

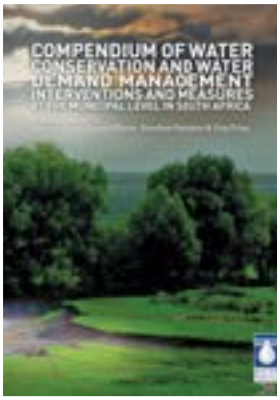


This loss represents about

R7.2bn annually

Water conservation/water demand management compendium of interventions

In an effort to improve water conservation/water demand management (WC/WDM) in South African municipalities, the WRC has published a compendium of WC/WDM measures.



The compendium documents a number of interventions, programmes and projects initiated by local and provincial government to reduce the demand for water in their constituencies. A total of 40 case studies are presented in an anecdotal, easy-to-read format. The presented case studies highlight not only best practice in the industry, but also less effective approaches that can potentially achieve greater effectiveness through improved management and implementation.

The publication notes that a key challenge in planning for future economic growth and social upliftment in South Africa is ensuring efficient use of water supplies and reducing water consumption through improved management of the demand for water. This notion also recognises that eradication of poverty cannot take place without water.

The case studies documented in this compendium abundantly demonstrate that it is possible to reduce water demand of municipal customers through carefully managed interventions, and in so doing also achieve greater financial efficiency, reduce non-revenue water and improve operation and maintenance procedures.

INFORMING POLICY AND DECISION MAKING

Growing knowledge towards better wastewater technology selection

Over the past decade, much attention has been devoted to the engineering, science and technological aspects of wastewater treatment in South Africa. More recently, attention has been redirected to assess the performance and compliance status of wastewater treatment facilities, and to identify the challenges and root causes that underpin poor performance.

The inception of the DWA wastewater services regulation programme has identified and highlighted the need for innovative approaches and appropriate technologies to ensure that sustainable choices are made by municipal decision-makers. However, equally important is that the sector takes cognisance of its responsibility to contribute to a municipal environment where it is possible and within reach to achieve improved effluent quality and optimal management performance with distinctive impact and lasting endurance.

The predominant focus in the wastewater services domain has recently shifted from that of design and construction to that of wastewater operations, maintenance and management. While the importance of these issues cannot be overstated, a number of other aspects related to plant performance are of great importance in the planning, design and management of wastewater treatment facilities. These aspects would encompass:

- the need for technology which would treat a broader range of constituents;
- the need to comply with more stringent effluent discharge limits; and
- the reality that the natural resource base is in recoil and demands 'not-to-exceed' values and standards which are prescribed and regulated by DWA.

The WRC funded a high-level assessment of 18 scientifically selected municipal cases across the country regarding appropriateness of the technological choices in relation to the current ability of the municipality to implement and administer such choices, and the legislative environment within which these choices are overseen.

Several factors affecting the choice of wastewater treatment technology were identified, most notably an over-reliance on consulting engineers, particularly in lower-capacity municipalities. A focus on price rather than technical proficiency or experience in supply-chain management policies often forces bidding firms to cut price by using existing designs that are not tailored around the specific municipal circumstance.

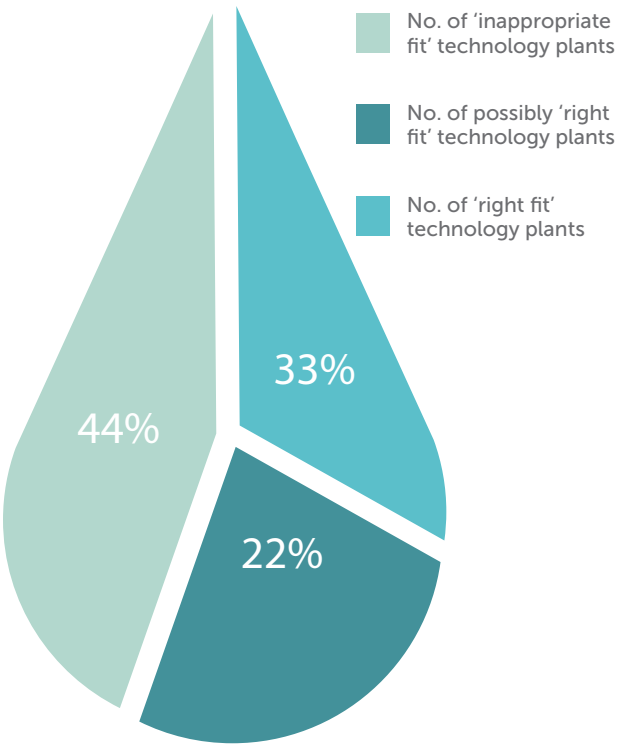
The more complex and potentially costly level of technology (medium) was found to enjoy higher preference to the low- to medium-level technologies. Although this could be ascribed to factors such as effluent treatment requirement a higher level of technology, land availability, initial cost of expansion and repairs of existing versus capital cost of new system, etc. it was observed that this is not always the case.

The study found that sustainable low- to medium-level alternatives, or the long-term cost implication of high-level technology is rarely investigated. As a result, sustainability of higher-level technologies may not always be within reach of some municipalities. Furthermore, it would appear that in terms of demand growth, the trend is not to extend the existing plant

and maintain the technology level, but to upgrade to a higher technology level. The concern is that not all municipalities are necessarily equipped to sustainably manage such a change in circumstances, especially with regard to skills and financial resource availability.

The assessment indicated that 44% (8 plants) may have opted for less suitable (inappropriate) technologies when considering their resource base, capacity to manage and effluent quality requirements. When applying the 44% statistic to a comparative national base (consisting of 850 municipal plants), it would translate to approximately 374 plants that potentially have unsuitable technologies in place.

Appropriateness of wastewater treatment technology choices in municipalities studied



Measuring rising temperatures in SA's rivers

Climate change is likely to have a range of impacts on South Africa's freshwater resources, causing a ripple effect of socio-economic consequences and putting the country's already stressed systems under increasing strain. The main repercussion of climate change worldwide is anticipated to be increased air temperatures and shifts in rainfall patterns. In South Africa, higher air temperatures are predicted for the entire country, while rainfall is expected to increase in the east and decrease in the west.

The combination of rising air temperatures and lower rainfall in some regions will in all likelihood result in elevated water temperatures in riverine ecosystems, as one of the many side-effects of climate change. Other anthropogenic factors that affect water temperature in riverine ecosystems are thermal discharges from industrial plants, flow modification due to river impoundment, inter-basin water transfers, and modification to riparian vegetation, which provides shade from direct solar radiation.

The WRC identified a need for fundamental research on water temperature and biotic response, not only to understand and predict the impacts of climate change, but also to incorporate water temperature guidelines into the ecological Reserve. The four-year study, led by the University of Cape Town, was concluded during 2012/13.

The main aims of the project were to collect baseline water temperature data in a range of rivers in the Western, Southern and Eastern Cape; develop a generic water temperature model for South Africa; develop an understanding of the response of aquatic organisms to water temperature regimes in South African rivers; identify a suite of suitable aquatic macroinvertebrates for use as bio-indicators of thermal change; develop preliminary guidelines for the water temperature component of the ecological Reserve; as well as develop scenarios of the potential biotic responses to

changes in water temperature regimes as a result of climatic and hydrological changes.

Baseline water temperature data were collected from 92 sites on 62 rivers and streams in the Eastern, Southern and Western Cape. Collaboration with other research projects allowed data to be sourced from a further 50 sites. The collection of hourly water temperatures at a spread of seemingly unrelated sites was integrated into a broader context to illustrate how water temperature time series can be linked to biotic responses, and integrated into a spatial framework. This research thus provided a foundation for including water temperatures in a regional approach to managing river systems.

In addition, studies from this research showed that water temperature regimes have a measurable impact on aquatic macroinvertebrate life histories and lifecycles. Life histories of three target macroinvertebrate species were shown to have different degrees of flexibility in life history responses – from subtle changes in the timing of emergence and egg hatching to more extreme differences involving the production of additional generations within a year, given differing environmental conditions. These responses were primarily related to water temperature and flow. At a community level, the level of thermal variability in a river system affects aquatic macroinvertebrate community structure.

Studies from this research showed that water temperature regimes have a measurable impact on aquatic macroinvertebrate life histories and lifecycles.

The body of research in this project represents a considerable advancement in understanding thermal patterns in South African rivers, and how biota (individual species and aquatic macroinvertebrate communities) respond to thermal variability and stress. Understanding spatio-temporal thermal patterns in the Eastern and Western Cape provinces requires a multi-scale approach. The collection and/or modelling of sub-daily temperatures (mean, minimum and maximum values) is fundamental to describing thermal regimes relative to timing, frequency, duration and magnitude of thermal events. Any ecological Reserve determinations in South Africa would be incomplete unless thermographs are considered together with hydrological assessments. This research project has gone a considerable way toward providing the tools for accomplishing this.

EMPOWERING COMMUNITIES

003

Poverty and inequality remain significant challenges in South Africa's development. The WRC recognises that the role of water is pivotal in guiding communities onto the path towards economic and social prosperity. Commission-funded research is not only aimed at improving the lives of South African communities and helping them to thrive in the South African economy, but to equip them with the necessary water-related knowledge to adapt to future challenges, such as those brought on by climate change.

During the year under review the WRC with its partners continued to accelerate the development of its portfolio of projects that have a direct impact on the lives and livelihoods of communities through water-related interventions. Interventions included, but were not limited to, guiding communities towards improved food security and nutrition, exploring the fishing potential of dams, improving water and sanitation service provision, to improving food safety and reducing community vulnerability to the potential impacts of climate change.

Improving household food security

In South Africa, poor households are particularly vulnerable to hunger and malnutrition (including overnutrition and undernutrition). The current economic climate and rising food prices are making it difficult for people to achieve a balanced diet. Healthy food seems to be unaffordable for many South Africans and it appears that, in general, nutrient-rich foods tend to have sharper price rises relative to less nutritious foods.

It has been recognised that the home-production of specific foods among rural communities should be based on scientific evidence, taking not only current best practice in agricultural and human nutrition into account, but also the socio-cultural context within which the interventions are to take place. Internationally, it is accepted that better understanding of the links between agriculture, nutrition and health is a priority. Thus, before researching water use and nutritional productivity of crops, it is essential to know what food is consumed by poor people, what the nutrient content is of these food products, and which of these foods can be produced by household members, either in homestead gardens or communal croplands.

These arguments motivated the initiation of a WRC-funded scoping study to investigate what we know about the current food intake of rural communities in South Africa. The project also investigated the nutritional water productivity of several food crops. While several food- and nutrition-related studies have been undertaken in South Africa, the WRC study found that

available information cannot be taken as being representative of the food intake of poor South Africans. National studies are rare and did not generally distinguish between rural and urban poor; with food data in smaller studies often not comparable.

The nature of food intake is determined by a range of factors. These include individual, household, cultural and ethnic group preferences, location, season, income and affordability, historical factors, knowledge and education, and social networks. An understanding of the reasons for food choices is important as these factors influence food and nutrition security of households and individuals. The WRC study found that the reasons for food intake were not considered in many studies. None of the national food surveys reviewed considered seasonal difference in food availability and accessibility and how this may impact on food choices. In addition, despite the importance of basic service factors such as access to basic water, sanitation and healthcare, these were not generally considered in any detail in the studies reviewed.

From the findings it does appear that poor, rural households lack dietary variety. Diets have generally been found to be monotonous and cereal-based, with a low intake of fruit, vegetables and food of animal origin. Although not conclusive, it seems that most poor people are buying and not growing the food that they are eating. At the same time it is of major concern that natural resources (water, soil, plants etc) are under utilised. This is despite the fact that 40% of the population (i.e. 20 million people) is hungry and under nourished. At the national level, South Africans' main food-related purchases are maize, wheat, bread and salt.

Food prices were found to be higher in rural than in urban areas while wages were lower in rural areas. As a result, the regularity with which food products are purchased largely depends on income quantity and frequency. In addition, variety is generally less in rural areas, even within supermarket chains, and many rural consumers are heavily reliant on general dealers, spaza shops, and what they can purchase from local informal markets, hawkers and producers.

Access to electricity and refrigerators is also a factor when it comes to storing food. Consumption of non-home prepared foods seems to be on the rise in line with international trends.

While this study has identified many challenges to food security and nutrition in South Africa, it has also identified opportunities. During the year under review, the WRC had already commissioned a follow-up study focusing on rain-fed and irrigated production of food crops and their potential to meet the all-year nutritional requirements of rural poor people in South Africa. The provinces of North West, Limpopo, KwaZulu-Natal and the Eastern Cape have been prioritised, as this is where the majority of South Africa's rural poor live and produce crops under rain-fed and irrigated conditions.

4 out of every 10
people in South Africa are hungry and under nourished

EMPOWERING COMMUNITIES

South Africa's first production guidelines for African leafy vegetables

The potential value for food security and rural development of gathering wild foods, growing locally adapted species and eating from the local ecosystem is recognised internationally.

Traditional African leafy vegetables have important advantages over exotic vegetable species. They are generally easier to produce and usually require fewer resources (such as water), while being rich sources of micronutrients, iron and Vitamin A. Regular consumption of African leafy vegetables can assist in balancing diets by adding essential macronutrients, particularly beta-carotene and iron.

As part of the WRC's ongoing investment into traditional vegetables, the first South African production guidelines have been produced for African leafy vegetables. The guidelines focus on amaranth, Jew's mallow, Chinese cabbage, spider flower, pumpkin, tsamma melon and cowpea.

Among others, the study preceding the development of the production guidelines confirmed that African leafy vegetables can be grown in home gardens using local resources. The indigenous vegetables selected were shown to be more drought- and heat-tolerant than introduced exotic vegetables, such as Swiss chard. This could prove significant in the context of projected climate change.

The guidelines not only provide previously unrecorded information on production practices such as seed selection, fertilisation, pest control and water use in relation to environmental variables at localities where these crops are growing, but aims to raise the status of these traditional food plants in South Africa by pointing out the valuable contribution these plants could make to the food security and, hence, nutrition security, of South African households. The guidelines are already being actively used by non-profit organisations focusing on food security and home gardens.

The WRC is continuing its investment in these traditional food plants, with research being undertaken on water requirements, fertilisation and nutritional productivity of African leafy vegetables and yellow-fleshed sweet potatoes, including the modelling of water use of these crops.

Investigating the fishing potential of dams

It is often stated that inland fisheries can provide an essential contribution to local and regional economies as well as sustain livelihoods. Throughout Africa natural and artificial inland water bodies are regarded as valuable and integral parts of the lives and incomes of many people. While South Africa has few natural lakes, its man-made reservoirs contain fish that can potentially be utilised as a source of food.

The Nandoni Dam, which lies 16 km southeast of Thohoyandou, in Limpopo, is part of the Luvuvhu River Government Water Scheme. Surrounded by poor, rural communities, the dam has a surface area of 1 650 ha and a gross storage capacity of 164 million m^3. Based on its size and geographical position Nandoni Dam is ideally situated to allow for both commercial fish harvesting and aquaculture. Recognising the need for sustainable utilisation based on sound knowledge of the fishery potential of the impoundment, the Limpopo Department of Economic Development, Environment & Tourism requested the research project, which was funded by the WRC and led by the University of Venda. To determine whether fish can be harvested sustainably, an assessment was undertaken to determine the status of the resource and to establish safe levels for sustainable exploitation.

Study sites were selected in the main body of the impoundment, at the inflow into the impoundment and upstream in the rivers that flow into the impoundment. The sites in the impoundment were used to investigate the limnology, establish the water quality and collect samples of fish as well as zoo- and phytoplankton. Water samples were collected and analysed in the laboratory to determine nutrient concentrations.

Fish sampling was undertaken using fleets of experimental gill nets, traps and electro-fishing. From the collected data the biodiversity, population structure, catch per unit effort and potential yield were determined. Specimens, in particular of the dominant species, were retained to investigate their reproductive and feeding biology.

Study results indicate that Lake Nandoni provides excellent habitat for fish. Not only are most of the water quality characteristics within anticipated parameters, but the upper levels of the water throughout the main body of the water are sufficiently oxygenated. Some concern has been expressed over levels of pollution recorded at the inflow sites, which could lead to the dam becoming eutrophic in future if no remedial action is taken.

Fish catches were dominated by silver catfish *(Schilbe intermedius)*, large-scale yellowfish *(Labeobarbus marequensis)*, and Mozambique tilapia *(Oreochromis mossambicus)*, the latter species being targeted by local fishermen. The population structure of the dominant species was natural, with both juveniles and adults present. Results show that the potential yield of Nandoni Dam is higher than similar water bodies in adjacent areas and suggest that a sustainable harvest should be in the region of 26 kg/hectare.

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Fortifying urban communities against extreme events

The risk that climate change poses to water supply and demand is growing both globally and locally. Incorporating climate change projections and their implications into municipal management is gaining support in cities around the world although, generally, it is not yet high on the agenda of local municipal managers as they grapple with existing complex water management issues.

Improving the understanding of current storm risks is not purely for the benefit of the science-policy dialogue, but for affected communities. Efforts also need to be made to understand how flood risk is framed and perceived by those most affected by such storms.

As a result of these needs the WRC funded a study aimed at evaluating the impact projected climate change is likely to have on water services management for a local authority, with Ekurhuleni Metropolitan Municipality, on the East Rand, selected as a case study. This was done by modelling future climate scenarios for South and southern Africa; identifying the risks associated with the expected consequences of the predicted changes in climate; evaluating the impact on water management using a hydrological model; identifying challenges and limitations of current water management practices as experienced by communities in Ekurhuleni; and assessing the awareness of water sector managers in the municipality of the risks posed by climate change.

The analysis of climate projections indicates that significant increases in the annual frequency of extreme rainfall events are plausible over the mountainous regions of eastern South Africa – including the Highveld regions of Mpumalanga and Gauteng. Rising temperatures are projected to increase the frequency of occurrence of extreme rainfall events over the Highveld region, which could result in flash flooding. Many urban poor live in informal settlements within flash flood prone areas, which exacerbates the vulnerability of communities within these regions. The introduction of infrastructure such as roads, roofs and buildings that are already prone to flash-flooding hazards tends to enhance the impact of the hazard by reducing infiltration and channelling surface run-off. This increases the chance of raging torrents, leading to higher degrees of devastation.

The hydrological analysis was based on the application of a 140-mm rainfall event to the current design storm profile for Atlasville, a suburb of Ekurhuleni, and to the storm profile adjusted for the year 2071 to 2100 time slabs. The future storm profile has an increased rainfall intensity, by 5%, but the greater area of difference lies in the recession limb of the storm profile where intensities are close to double the present-day design storm intensities. This increased intensity is also seen to have an effect on storm volumes and in runoff response times that need to be considered in the design of attenuation facilities. The significance of this is likely to increase with catchment size.

This outcome also pointed to how infiltration drainage facilities will need to be designed under a changing climate. Increasing infiltration at source and within the catchment is central to sustainable urban drainage systems, and the infiltration surfaces will need to have the capacity for higher intensities.

The study showed that the potential for an increase in high-intensity short duration storms will have significant flooding impact on stormwater, sewerage and drainage infrastructure which, in turn, will affect roads, housing and water resources. The importance of municipal water services sector putting in place priority action plans to mitigate against these future climate factors

was highlighted. The poorest sectors of the population will be most vulnerable to these incidences.

Ensuring the safety of irrigated produce

There is growing concern over the 'safety status' of South African agricultural produce. If these products are contaminated they could impact the health of the final consumer. This will immediately impact both the national and international 'trading status' and may cause a suspension of exports. In certain areas of the country warnings have already been issued by the European Union over fresh produce watered from polluted rivers.

Consumer trends are also changing, with an increasing preference for raw, unpeeled and minimally and/or unprocessed products to enhance health. Internationally, this trend has led to an increase in foodborne outbreaks directly associated with the consumption of fresh produce. In many cases, the source of contamination of agricultural products has been identified as irrigation water that had been contaminated before irrigation took place. The health risks associated with the use of contaminated irrigation water on agricultural products are therefore of increasing concern.

To date, little has been known on a national level regarding the contribution of irrigation water and the associated, potentially contaminated raw produce, to the burden of disease. To obtain a clearer understanding of the problem in order to provide input for policy formulation and regulation to reduce contamination of irrigation water, a WRC study was commissioned, in collaboration with the Department of Agriculture, Forestry & Fisheries, to undertake a quantitative investigation into the link between irrigation water quality and food safety.

Several studies formed part of this undertaking, namely:

- A baseline study on the extent of contamination found in South African river water that is used specifically for irrigation purposes at selected sites;
- A baseline study on the extent (types and quantities) of contamination found on the irrigated raw produce (fruit and vegetables) at-harvest; post-harvest and at-retail;
- An investigation on the impact of environmental parameters on the growth kinetics of contaminants; and
- An investigation to establish links between water quality and safety of fresh produce.

The baseline study on the extent of contamination in South African river water showed high concentrations of faecal indicators, in many cases exceeding permissible guidelines. The presence of indicator organisms not only indicated unsanitary conditions, but also the presence of other potential health-affecting pathogens, including *E.coli*, among others. This indicates that water from some of South Africa's rivers is unsafe for irrigation of fresh produce. There is a high risk of exposure to human pathogens when water from such rivers is used to irrigate produce that is consumed raw or without any further processing steps. The presence of pathogens in contaminated water sources is therefore a serious concern in view of irrigating fresh produce.

At harvest the produce irrigated with water from the polluted rivers showed microbial counts far exceeding acceptable levels (in some cases >88% WHO standards). Of notable concern is the fact that pathogenic *E.coli* strains were also found on some produce from subsistence farming areas. There is no doubt that irrigating with contaminated water leads to contamination of the produce. Where the produce was inspected at retail, more acceptable levels of microbial levels were found, and there were no pathogenic strains of *E.coli* on the produce sold at retail.

Based on the results from this research project, the microbial pollution levels of rivers and fresh produce monitored at selected sites were found to be of an unacceptable microbiological standard and did not meet either the international or national guidelines for safe irrigation or human consumption. Other

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potential waterborne bacterial, virus and protozoan pathogens were frequently recovered from both the water and the produce. It was concluded that there is a high risk of exposure to pathogens when water from these rivers is used to irrigate produce that is consumed raw or without any further processing steps. It has been recommended that systems be put in place to prevent risk of infection from contaminated fresh produce.

Measuring social vulnerability and risk in SA communities

Intensive efforts to mainstream disaster risk reduction into development have been underway internationally since 2005. The focus of this study was a meeting between water resource management and disaster risk reduction at the local level. The study aimed to, firstly, propose a straightforward methodology for understanding vulnerability and resilience to hazards that negatively impact the supply of potable water at the community level. Secondly, the study aimed to identify opportunities to mainstream disaster risk reduction into aspects of water services, thereby improving the sustainability of all water service provision and increasing the resilience of communities to water-related hazards. This was undertaken through three case studies in Cala, a rural town in the Eastern Cape; Kayamandi, an urban township in the Western Cape, and Wonderfonteinspruit, a mining town in Gauteng.

The study was concerned with those behaviours and factors that influence the ability of socially vulnerable communities to make good risk management decisions in relation to water resources and infrastructure. The purpose was to explore communities' strengths and weaknesses.

Cala's population is especially vulnerable due to the widespread nature of the HIV/AIDS epidemic, drought and a lack of water services, as well as the presence of social protection mechanisms for issues related to drought. The community was found to experience seasonal water scarcity and drought, a lack of water services, food security issues and social problems. Ineffective governance by local and regional leaders and limited service delivery in general also contribute to the problems experienced by the Cala community. A dispersed settlement pattern made access to basic infrastructure and services more costly for the local municipality.

In turn, Kayamandi, outside Stellenbosch, was selected because of poor water and sanitation service delivery, flood potential and a highly vulnerable population due to impaired immune systems exposure to water contaminated by human and domestic waste. The study confirmed that these challenges are increasing the social vulnerability and risk faced by the Kayamandi community.

The Wonderfonteinspruit catchment area is dominated by risks associated with acid mine drainage, which affects water quality and availability. Gold-mining in the area affects water resources in two ways, namely water availability (quantity hazard) and water pollution (quality hazard). With respect to water availability, gold-mining reduces the water resources of the catchment via dewatering. Water quality in the area is affected by both onsite and offsite sources, with numerous studies indicating significant contamination problems as a result of historic gold-mining. The HIV infection rates in the area are among the highest in the world. Poor water and sanitation service delivery compound the vulnerability.

Measurement of vulnerability and risk at a local scale is an important tool for improving understanding of the capacity of communities to overcome disasters. Working towards improving this understanding, a community-level risk index was developed through the identification of indicators for Social Vulnerability and Coping Capacity. The case study research informed the selection of a list of indicators and associated scoring system, based on available data and relevant contextual information. Individual scores were calculated and averaged across the indicators. Several recommendations emanate from the study

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The WRC continues to focus on research that helps to promote development through the reduction of poverty and inequality in South Africa. Of special interest is the role that water may play in achieving social transformation and justice in the context of deepening democratic practices, the extension of water services and redressing the wrongs of the past.

This is further complicated by the country's commitment to ecological sustainability, and addressing the effects of climate change, HIV/AIDS and the daily realities of households living in poverty. Where appropriate, the WRC includes a social perspective in aspects of water research. This includes issues of gender, class, disability, urban and rural location, culture and religion.

Commission-funded research integrates a variety of methodologies to provide a holistic view while emphasising respect for people's rights, and encourages participation in monitoring and decision-making as entrenched in South Africa's Constitution. Research projects in this domain are aimed at developing a greater understanding of social dynamics in the water sector and people's needs for and views on water; encouraging people's participation in water management and decisions about water; and searching for ways to use water for transformation and social justice.

Irrigation guidelines for the training of extension officers

The advancement and expansion of South Africa's agricultural base – particularly small-scale agriculture – remains an important objective of national Government. It is an aim that requires improving and extending skills development and training in the agricultural sector, including entrepreneurship training. This includes the training of a new corps of extension officers that will respond effectively to the needs of smallholder farmers and contribute to their successful integration into the food value chain.

There are around 390 extension officers currently serving small-scale and commercial irrigation farmers. The extension services offered include advisory services for sustainable income generation; providing and facilitating access to

agricultural information for improved planning and decision-making; facilitating access to technology; providing and facilitating access to advice on sustainable agricultural production and skills development; and strengthening institutional arrangements.

Functional irrigation equipment is but one requirement of successful irrigation farming. The science of irrigation management is complex and comprehensive, and therefore the irrigation extension officer requires comprehensive technical knowledge and skills in irrigation management, as well as appropriate knowledge and understanding regarding human behaviour, in order to serve his farming community effectively.

To strengthen and improve the current level of training presented to extension workers for the tasks they have to perform on irrigation schemes, the WRC funded the development of learning material for eight learning areas identified to form the 'knowledge profile' of the extension officer. This training material covers the main elements which directly or indirectly inform irrigation water management. Knowledge about these issues will provide the necessary confidence for extension officers to respond to enquiries by farmers and to correctly refer questions to subject matter specialists.

The aim of the learning material is to support tertiary training organisations, such as agricultural colleges and universities of technology, offering agricultural programmes on a NQF Level 5, as well as to support training providers offering short courses in irrigation management. The project was co-funded by the Department of Agriculture, Forestry & Fisheries. A total of 93 learning modules were included in the material, which have been divided into technical- and extension-related modules.

The learning package covers the entire spectrum of irrigation water management, starting with a brief overview of the soil-plant-atmosphere continuum, then moving on to agri-climatology, irrigation water management, irrigation engineering, and the irrigation legislative context and irrigation economics. The package also covers irrigation crop and fodder production as well as general skills required for productive agricultural extension. This research output fills a major knowledge gap by making comprehensive training modules available for in-service training of extension officers.

Empowering women in rural villages

Women are strategic users of water. They manage the use of water for preparing food, for drinking, bathing and washing, for irrigating home gardens and watering livestock. Thus their participation in development programmes should be given priority.

This WRC study was focused on implementation of water legislation and policies on the ground, evaluating whether the intentions of the Water for Growth and Development Framework, to bring water services and water resources together in support of women as strategic users of water and, in particular, rural women's use of water for their emerging productive activities, are met in reality. Among others, the study explored the multiple water use strategies of rural women in two different rural villages; tested the adequacy of current policies and practices against the reality and aspirations of women and their families in two rural villages; and examined whether both water services and resources needed by women in rural villages are made available or could be made available to them.

The study further examined the extent to which local authorities meet their developmental mandate to promote local economic development by supporting rural women in multiple uses of water. The study demonstrates rural women's strategies for multiple uses of water and ways in which policies and their implementation at national and, in particular, at local level, can better support them.

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A literature review component was followed by field research in the villages of Apel and Strydkraal, to interact with rural women involved in emerging productive use of water, officials and other resource holders, such as the tribal authority directly or indirectly providing support to the women's groups. To ensure meaningful participation, the study used participatory methodologies such as transect walks, mapping, and visioning exercises in order to hear first-hand from women involved in these activities regarding their sources of water, their use of water, and the vision they have for the activities they are involved in.

There is a strong Government intention in national policies to affect redress in terms of appropriate water allocation to women-led activities such as emerging productive uses. Gender equality and main-streaming are pronounced in legislation and policies as cross-cutting for all the services of government departments. However, the study revealed an isolation of these services and lack of capacity in departments responsible for them. The study revealed very limited interaction and support by government structures to rural women's groups involved in emerging productive uses of water. There was no evidence of cooperation between different government departments that could strengthen the activities of women's groups and make a contribution to women's agency in the two researched villages. In absence of support structures, women in the two villages studied resorted to using water intended for domestic purposes as well as canal water for their emerging productive purposes.

The study revealed a strong sense of women's agency in the two villages as women organise themselves, and provide support to one another – mostly at household level and to an extent at community level - through various projects they are involved in. Further strengthening of this voice, particularly in the community's socio-political structures, is needed in order for these women to use their collective strength to engage authorities and secure support in terms of accessing water for emerging productive uses. Several recommendations are made to improve rural women's ability to engage in and support themselves through activities involving productive uses of water.

Strengthening water value chains in emerging agriculture

Despite the commitment from Government and the investments made to assist emerging farmers from smallholder irrigation schemes to be integrated into commercial agri-food chains, actual achievement of this, where emerging farmers are successfully operating in commercial agri-food chains, is scarce.

The small number of success stories means that the objective to allow farmers to improve their livelihoods through irrigated agriculture is not met. Access to agricultural water plays a necessary role in increasing productivity, but access to water alone is not a sufficient condition to enhance productivity and alleviate poverty. Farmers have to generate sufficient levels of income from their irrigation activities in order to alleviate poverty.

The general objective of this WRC-funded research project was to apply value-chain analysis for optimising economically beneficial water use in agriculture and towards integrating commercial and emerging farmers in the mainstream of the economy. The point of departure of the study was a comprehensive literature review in order to develop a conceptual framework that could be used to analyse the value chains within which emerging farmers could be integrated.

Given the scope of the analysis that was required to meet the objectives of this study, the conceptual framework that was used consists of a problem tree analysis and an integrated New Institutional Economics (NIE) and Structure-Conduct-Performance (SCP) analysis of the three levels (micro, macro and meso) that comprise the value chain within which the emerging farmers are participating. The nature of the conceptual framework requires both qualitative and quantitative analyses. Qualitative analyses were conducted in the application of the problem tree analyses and the NIE framework to analyse the social environment (levels of social embeddedness) and institutional environment within which the farmers operate, and the optimal degree of vertical coordination (governance structures) that will minimise the transaction costs they face.

Within the application of the SCP framework, qualitative analyses were used to investigate the physical environment (structure) within which the farmers operate, the way they behave in the physical environment (conduct), and the level of performance in terms of production volumes and income generated. The analysis of the resource allocation level within the NIE framework consists of quantitative analyses of the levels of efficiency with which production inputs are used to generate income. The integrated NIE and SCP framework was applied to three case studies: the case of raisin producers from Eksteenskuil in the Northern Cape Province, the case of vegetable producers from Zanyokwe Irrigation Scheme, and the case of maize and vegetable producers from Thabina Irrigation Scheme.

The results from the analyses of the distribution of water use along the value chains show that the bulk of all of the water that is used along the value chain is used at farm level to produce food products. Efforts to increase the efficiency with which water is used along the value chain should thus focus attention on water use at farm level. A comprehensive analysis of the value chain is required to determine the degree of accessibility of the different marketing channels that are available in the value chain. The attributes of the product (i.e. quality) are the major determinant by which the different marketing channels can be accessed. While emerging farmers who use marketing channels other than the high-paying channels (i.e. hawkers and retail stores) may seem to make sub-optimal decisions, the attributes of their products may mean that they do not have access to the high-paying options. In such a scenario the seemingly sub-optimal decision may actually be the optimal choice. A comprehensive understanding of the attributes of the product and the requirements of the different marketing channels is thus necessary before advising the farmers in terms of the specific marketing channels to target to ensure that the advice will result in the optimal outcome.

The results from this study show that the obstacles that contribute to the exclusion of emerging farmers from participating in commercial agri-food chains are very much integrated. Efforts to overcome one or two stumbling blocks at a time may not have the desired outcome. A coordinated approach has to be followed to overcome the obstacles.

Based on the findings from the three case studies, recommendations are made for emerging farmers to enhance their ability to successfully participate in commercial agri-food chains, for policy-makers to formulate new policies and to adjust some of the existing policies to enhance the successful participation of emerging farmers in commercial agri-food chains, and for future research that needs to be conducted to contribute to the topic of the optimisation of economic beneficial water use by the integration of emerging farmers into the mainstream economy.

NEW PRODUCTS AND SERVICES FOR ECONOMIC DEVELOPMENT 005

Science and technology continue to revolutionise the way goods and services are produced and traded. Government's National Development Plan recognises that South Africa needs to sharpen its innovative edge and persistently contribute to global scientific and technological advancement.

At the same time, given the limited availability of freshwater resources in South Africa, new innovative approaches are required to reconcile demand and supply, particularly in the most water-stressed catchments and areas of development, so as to ensure that South Africa's growth is not negatively impacted. The WRC has recognised that in order to meet these objectives, greater investment in research and development to facilitate innovation is required.

During the 2012/13 financial year, several innovative developments – some with commercial properties – have been funded by the WRC. The Commission also continued work with partner organisations to facilitate the transfer of WRC innovation along the water knowledge value chain to further stages of technology development, commercialisation and uptake.

Taking the pinch out of table-olive wastewater

Olives are exceedingly bitter and need to be cured to make them palatable before consumption. The curing process involves placing the olives in a brine solution whereupon a spontaneous lactic acid and/or yeast fermentation takes place. The brining process takes from 3 to 12 months, depending on cultivar and type, and is associated with various washing and rinsing steps. This results in noxious, darkly coloured and acidic wastewaters with a high organic load, high phenolic content and high salinity (three times more than seawater). It is a water-intensive process, with up to 10 kilolitres of water being consumed per ton of olives processed. The wastewaters generated present an environmental disposal problem, as they are not amenable to biological treatment, and cannot be disposed of in municipal sewage systems or the environment for toxicity reasons. They are generally disposed of in evaporation ponds.

The wastewaters do, however, contain valuable components, in particular low molecular weight (monomeric) phenolic compounds with powerful antioxidant activity and numerous other beneficial effects on human health. Of particular interest is recovery of the naturally occurring antioxidant hydroxytyrosol or HT, which has been

shown to have antimicrobial and antiviral activity, among others. This antioxidant can be used in the pharmaceutical, personal care product, and cosmetic sectors, as an active ingredient, or in the food and beverage industries as a natural alternative to currently used synthetic antioxidants and preservatives.

Based on previous laboratory research, a comprehensive treatment system was designed in order to recover the HT and simultaneously recover purified brine that can be re-used for table olive production, while minimising the amount of waste for disposal to the evaporation ponds. In this manner, the cost of wastewater treatment can be offset by the recovery of value-added products that can be commercially exploited.

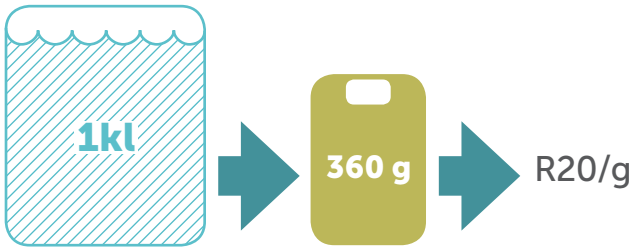
In a project funded by the WRC and executed by the University of Cape Town, a modular, containerised wastewater treatment system was developed for piloting at an olive farm and processing factory. Wastewater batches from the factory were diverted into a holding tank for temporary storage. From there 1 kilolitre batches of the discharge were processed through two sequential unit processes. Firstly, fine ultrafiltration was performed to remove lignins and tannins for disposal to waste, with the membrane permeate stream then containing antioxidants, salt, organic acids and some other minor components. Secondly, this permeate stream was passed through a chromatography column containing a selectively adsorbent resin. This allows a purified brine stream to exit the column while it retains the other substances in the water.

When the column becomes fully loaded and can adsorb no more, it is rinsed and an ethanol solution is then distilled to obtain a crude antioxidant extract, and the ethanol is recovered for re-use. The ethanol also regenerates the column and, after rinsing, it is ready for the next loading cycle. The purified brine stream can be sent for recycling, while retaining the antioxidants for recovery.

The pilot-scale system was operated for six months, during which data was collected and analysed, yields and productivity of the process were established, and the economics of the treatment process evaluated. Operation of the pilot plant has demonstrated that the technology is effective for treating such highly-polluted brine wastewaters. While relatively small-scale equipment was used for the pilot plant, it was possible, on average, to process a one kilolitre batch of wastewater per week. Up to 75% of this feed could be recovered as purified brine for recycling, while an additional 300 litres of freshwater was used for backwashing the membrane system and processing the chromatography column.

An average of 360 g of antioxidant was produced per 1 kilolitre batch of wastewater processed. The operation cost of production at the current level was around R20 per gram of antioxidant in the form of a crude extract, with a corresponding zero-cost for the treatment and recovery of the wastewater. With refinement and further modification throughout, yield and productivity can be improved further.

For every Kilolitre batch of wastewater processed, 360 g of antioxidant was produced at an average cost of R20/g



The intention is to develop the process further and scale up for commercial application through the creation of a spin-out business that will exploit the intellectual property generated during the project. The proprietors of the olive farm are continuing operation of the pilot plant and have expressed interest in seeing plans for further development.

NEW PRODUCTS AND SERVICES FOR ECONOMIC DEVELOPMENT

Determining the cost of water treatment

While considerable information is available on technical aspects of water treatment technologies, there is a lack of information about costs, in particular life-cycle costs, which are used in the comparison and selection of these technologies. This includes both capital and operating costs.

In this regard, the escalating cost of energy is becoming a factor deserving of increasing recognition. Both municipalities and consultants have scant comparative costing information for drinking water treatment system options on which to base their decisions for new water treatment schemes, resulting in incomplete planning and inadequate budgeting for these systems.

During a previous WRC-funded project all the existing and emerging water treatment technologies were evaluated and technology information sheets drawn up. The sheets contain a description and purpose of the technology, flow diagrams, performance limitations, operating requirements and maintenance requirements, whereby technologies can be compared with the view of selecting the most appropriate technology for a particular application. While some qualitative costing is presented in the sheets, there was a significant lack of available costing information, which demonstrated the need for further research to obtain accurate costing information for small-scale water treatment systems.

The latest project, concluded during the 2012/13 financial year, thus developed a **user-friendly costing model for establishing and predicting the cost-efficiency of a range of small-scale water treatment technologies** that are used in water supply schemes, as well as providing decision support for the selection of decentralised versus centralised water supply. This allows economic comparison between different water treatment and supply options being considered for water supply schemes. It also allows costing reports for existing water treatment systems to be created, which assists with budgeting and asset management.

The WATCOST Model is aligned with the DWA Costing Model, so that the two can be integrated. In addition, a manual was created to accompany the costing model. The aim of the manual is two-fold: firstly, it can be used as a reference document for information on costing data for water-supply projects, with actual costing figures that can be obtained from the tables and graphs in the document. Secondly, the manual is also an aid to using the WATCOST Model to obtain costing data for water-supply projects, either in total or for specific components in the drinking-water supply cycle.

The manual is intended for use by decision-makers, consultants, engineers, planners, water-supply authorities, and DWA, to estimate costs of new water-supply systems, costs for upgrading or refurbishing existing systems, and also to determine approximate values of existing water-supply and water treatment assets.

Bringing scientists closer to aquatic life

For the past four years the WRC has been funding a series of studies which have led to the development of a locally produced biotelemetry system to monitor the behaviour of aquatic organisms. Through collaborative efforts between the Water Research Group at North West University (WRG-NWU), the Centre for Aquatic Research at the University of Johannesburg, Scientific Services at South African National Parks, E Oppenheimer and Son and biotelemetry system specialists Wireless Wildlife International, the technology was successfully developed and tested in the field.

Biotelemetry methods are internationally recognised as one of the most effective ways of acquiring behavioural information on fishes and other aquatic animals over extended periods within their natural environments. This information regarding behaviour is, in turn, applied to develop an understanding of their biology and ecology and then to evaluate the impact of changing environmental variables, such as water quality, quantity or flows and habitat, on animal behaviour. Management guidelines can then be established for these environmental variables, which will contribute to the conservation of species.

The locally-produced biotelemetry system makes use of remote and manual tracking or monitoring systems as well as smart tags or transceivers. The latter is attached to the organism being monitored. Once tagged the animals (in the case of the study, fish and crocodiles) are released to re-establish their normal behavioural patterns. With remote and manual monitoring systems researchers now monitor the continuous behaviour of the animal for at least a year.

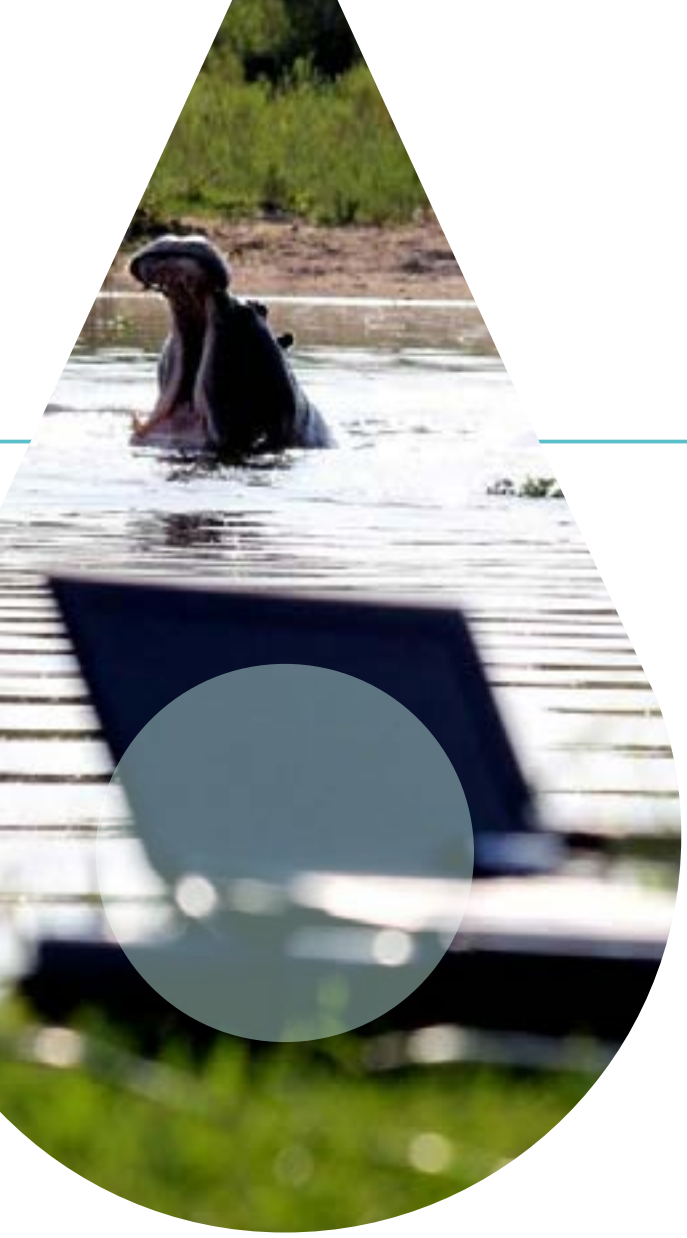
The remote monitoring systems include the use of 'listening stations' or receivers that are deployed in the study area. These record and transmit information from the tags at ten-minute intervals to an Internet-based data management system. The researchers can log onto the data management system at any time from any computer with Internet access, and download real-time behavioural data from the tagged animal. In turn, manual monitoring systems involve the use of directional antennae and hand-held receivers which are used to locate and download behavioural data from any tagged animal in the field.

Behavioural aspects of the aquatic organisms that can be monitored include the location of the animal, movement and activity, as well as some environmental variables, including the depth of the animal in the water, as well as the temperature. In addition, by monitoring the location, movement and activity of the animal over extended periods of time, the team is able to evaluate the response of the animal to changing habitat variables, flows, water quality components and weather variables, such as atmospheric pressure.

Data collected on a monthly basis can miss the short-term water resource quality changes that can affect aquatic life, making real-time data monitoring all the more important. The kind of technology developed through this research allows authorities to react more quickly, not only protecting our biodiversity but also affording a greater chance to apprehend polluters.

The Crocodile River, which forms the southern boundary of the Kruger National Park, was selected to carry out an experimental behavioural ecology study to test the locally manufactured biotelemetry equipment. Seven Lowveld large-scale yellowfish *(Labeobarbus marequensis)*, twelve tigerfish *(Hydrocynus vittaus)* and one Nile crocodile *(Crocodylus niloticus)* were captured and tagged. The animals were then released and monitored for eight months.

Behavioural data, including home range, habitat use, daily and seasonal movement patterns, daily activity patterns, as well as the response of the animals to changing environmental variables (flows, water quality and habitat availability) were described and statistically analysed. Despite some early challenges with regards to the development of the local biotelemetry system, it has proven to work well in the field.



In addition to the KNP project, team members have already made noticeable contributions to the conservation of threatened or protected yellowfish in the Vaal River and tigerfish in man-made dams in southern Africa through the use of biotelemetry. Wireless Wildlife together with the WRG-NWU now offer biotelemetry monitoring services using the locally-developed technology. Further developments in remote and manual biotelemetry monitoring methods and analysis techniques are continuing. It is hoped that this technology will go a long way towards the conservation of South Africa's rich aquatic biodiversity.

Generating safe drinking water through wave energy

In recent decades, South Africa has witnessed a rapid shift from scattered inland populations to concentrated coastal development. In 20 years some estimate that more than half the population will live within 10 km of the shore. This zone is already the most water-stressed and ecologically fragile strip in the country, pushing groundwater pumping and surface storage to costly and dangerous limits.

This project developed a prototype of an alternative water supply technology that works with nature rather than against it. Called the Wave Energy Reverse Osmosis Pump, or WEROP, it uses wave energy to desalinate seawater for domestic use. **The system is potentially unique in the world**, while the know-how around operating it is totally novel.

Primary research was carried out on site, around the Cape Peninsula, where the WEROP was assembled, launched and tested in order to improve its operation and design. Despite difficult working conditions, the model unit proved to be relatively straightforward to assemble, deploy and operate. Over several months it remained extremely durable, with little corrosion despite the lack of paint, and with little maintenance required.

The unit was tested to 90 bars, which is far higher than the 62 bars required for reverse osmosis. It was shown that, in theory, this could be pushed to an average of 2 500 litres/day in an average sea with a wave height of 0.5 meters and a period of 8 seconds. This is rather conservative, as the average period of wind chop is around 4 seconds, thus doubling production. A wave height of 0.5 meters is also very modest, as the waves found in the target area are on average over a meter in height.

In 20 years some estimate that more than half the population will live within 10 km of the shore.

Treating contaminated water through nanotechnology

Technological drives to push current boundaries and intrinsic needs to overcome modern problems associated with sustainable economic growth, along with associated environmental problems, provided the momentum for this WRC-funded project, which undertook experimental work to ascertain the effectiveness of integrating selected nanomaterials into six different remediation strategies for the treatment of model and real contaminated water samples.

The work was undertaken over a period of three years in a collaborative effort between researchers at the universities of the Western Cape, Stellenbosch, KwaZulu-Natal and the Cape Peninsula University of Technology. Research focused on the removal of several inorganic and selected organic contaminants, with an emphasis on polluted water. Specifics included acid mine drainage from various mines in Gauteng and Mpumalanga, industrial brine effluents, and dye- and bacteria-laden water. From a technical point of view, the work was subdivided into three tasks, whereby a selected technology, process or adsorbant was adapted and implemented to remediate a specific type of polluted water.

Firstly, natural adsorbents, clays and zeolites were selected as a low-cost material for the treatment of contaminated water. After the natural zeolite underwent mild activation steps it was shown to be effective in removal of ammonia from model solutions and in reducing the salinity of industrial brines, with some minor leaching of undesirable heavy metals. The inhomogeneity of the natural mineral deposit could affect its adsorption capacity.

This was followed by novel research into whether zero-valent nano-iron could be used to treat acid mine drainage. The research produced positive results, which indicated that not only could zero-valent nano-iron successfully treat the heavily contaminated water, but a one-step process (where the acid mine drainage is the source of iron) was the most effective treatment option. It was also shown that ordered mesoporous carbons were very effective as mercury sorbents after being modified with suitable functional groups.

In addition, an electrohydraulic discharge reactor that can incorporate supported titanium dioxide nanofibres was shown to be extremely effective in the complete demineralisation of dyes, and complete disinfection of *E.coli* spiked waters. This work has been patented and the invention relates to a water treatment apparatus that employs ultraviolet radiation and ozone for the purpose of directly and indirectly killing potentially harmful biological species in the water. UV radiation emanating from the electrohydraulic discharge electrode impinges on the photocatalyst to activate it, thus promoting photocatalytic reactions within the water, leading to the formation of OH radicals that attack organic pollutants, and breaking them down into water and carbon dioxide.

Finally, a chemical vapour deposition method was used to synthesize titanium dioxide nanoparticles supported on carbon nanotubes. The results show that silver nanoparticles deposited on the titanium dioxide act as electron acceptors, thereby enhancing the charge separation of the electrons and holes. This leads, in turn, to a transfer of the trapped electrons to the adsorbed oxygen during UV radiation.

In summary, zero-valent nano-iron, zeolites, ordered mesoporous carbons, electro-deionization, an electrohydraulic discharge reactor and chemical vapour deposition were investigated and each was found to show great potential as an effective means to treat select industrial wastes. Some of the technologies were general oxidation processes and others were excellent for specific pollutants.

SUSTAINABLE DEVELOPMENT SOLUTIONS

006

Water underpins all socio-economic development in South Africa. A reliable supply of water in sufficient quantities at the desired quality is critical for economic growth, social development and job creation.

Sustainable development remains a core principle of all WRC projects and activities. Consistent with the WRC's vision, there is specific focus on sustainable development solutions. This is undertaken by addressing enabling principles of sustainable development, namely, protection of water resources, optimal water use, equity between generations, current equitable access, environmental integration and good governance.

Developing water-friendly cities

Water-sensitive urban design is an internationally accepted approach to ensure urban development is planned, designed, constructed and maintained in a way that will help reduce negative impacts on the natural water cycle and protect aquatic ecosystems.

Sustainable urban drainage systems – commonly known as SUDS – are a component of water-sensitive urban design focused on stormwater management. This approach attempts to replicate natural drainage rather than carrying stormwater away in pipes and canals as quickly as possible. By dealing with runoff and pollution on-site, SUDS can help lower flow rates, improve water quality, increase groundwater recharge and create a 'greener' environment for wildlife and local residents. This is achieved with permeable surfaces such as gravel, kernel or wood chip; infiltration devices that drain water directly into the ground; filter strips and swales – vegetated slopes and channels that slow the flow of runoff, as well as detention ponds and artificial wetlands containing reeds and other riparian plants.

A WRC-funded project concluded during 2012/13 aimed to identify, develop and evaluate new and appropriate guidelines for the use of alternative stormwater technology in South Africa. The project forms part of the WRC's Lighthouse Programme focusing on water-sensitive urban design. The project resulted in, among others, the first South African Guideline for Sustainable Drainage Systems. The Guideline introduces the notion of sustainable drainage and describes important design

and management concepts associated with SUDS; describes the basic design approach; and presents 12 general SUDS options and technologies in the categories of 'source controls', 'local controls' and 'regional controls'.

SUDS generally embrace a number of options that are arranged in a treatment train. In other words, stormwater is managed through a series of unit processes in much the same way as, for example, wastewater is treated in a treatment works through a number of unit processes. Each of the 12 general SUDS options described incorporates a variety of treatment processes with considerable overlap. The selection of any particular option is determined by the unique characteristics of the site. It is important that the advantages and limitations of each option should be identified during the planning and design phases.

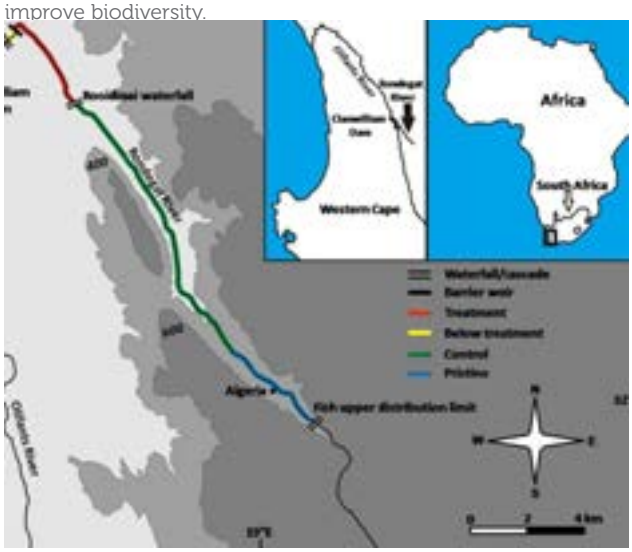
The Guideline is intended for use by all practitioners working in the field of stormwater management, and promotes the notion of interdisciplinary partnerships at all levels and phases of development. It is anticipated that the guidelines and associated products will go a long way towards changing thinking and improving practices in managing the drainage of surface water in South African cities.

Ensuring the safe eradication of alien invasive fish species

Alien invasive fish pose the greatest threat to the survival of native fish in the Cape Floristic Region of South Africa. While the majority of invasive fish are now too widely spread to be eradicated, targeted removal of these fish from key reaches where re-invasion can be prevented offers a near-term way to improve the survival of some threatened fish populations.

Almost a decade of investigations into alternative removal methods led to the launch of a joint project between the Western Cape Government and civil society organisations. CapeNature was the implementing agent for the project, which involved the use of the piscicide rotenone. Several priority streams were identified where alien invasive fish could be targeted for permanent removal, the first being the small Rondegat River, where the invasion by smallmouth bass (Micropterus dolomieu) resulted in the extinction of several native fish species in the lower reaches of the river.

To monitor the project, the WRC funded independent surveys covering the fish, invertebrate and amphibian populations, which were carried out before and after chemical treatment of the river. The surveys, led by the South African Institute for Aquatic Biodiversity, were conducted over a two-year period from May 2010 to May 2012. The project formed part of a key thrust of the WRC, which is focused on reducing threats to indigenous species, thereby restoring ecosystem functions and processes to improve biodiversity.



To ensure that all species present in the river were detected, the project teams used a combination of electrofishing, mask-and-snorkel surveys and underwater video analysis in all zones of the river. In the case of the frog study, aural encounter searches were also employed, with the bioassessment method SASS 5 and species-level assessments being used to survey invertebrates. Food-web effects were also measured by assessing algal

production on stone surfaces.

Prior to rotenone operations, a fish rescue operation was conducted to remove significant proportions of the yellowfish and bass populations from the stream. The remaining fish were all apparently killed by the rotenone operations, and no live bass were found during the fish surveys conducted following treatment. Native juvenile yellowfish (Labeobarbus capensis) were recorded in the first pool of the treatment area just three days after the operation. Two months later both yellowfish and redfin minnow (Barbus callidus) were recorded (the latter for the first time in 70 years) as far as 200 m downstream of the bass barrier, indicating recolonisation of the treatment area by native fish was underway. This indicates that the re-establishment of the 4 km-stretch of treated river was not only successful but fairly rapid.

While initial concern was expressed over the potential impact of rotenone on other (indigenous) aquatic species, results of the monitoring and surveying of the Rondegat River following the application of the natural chemical indicated that these concerns were unfounded. No significant changes in ecosystem health could be attributed to the rotenone operations, and the fundamental conclusion of the monitoring programme was that the river rehabilitation was a success, in that all bass appeared to have been removed from the treatment area without any significant long-term damage being accrued to other wildlife of the river.

Guiding on-farm and on-scheme irrigation water measurement

According to the National Water Resource Strategy, national water conservation and demand management (WC & DM) strategies are being developed.

The strategy for irrigated agriculture, the largest user of water in South Africa, provides a framework of regulatory support and incentives to improve efficiency, with a plan of action towards delivering, amongst others, the following outputs:

- implement measures that reduce wastage;
- convince users to progressively modernise their water conveyance infrastructure and irrigation equipment.

The Water Conservation and Water Demand Management Conditions for Water Use Sector Authorisation published by the DWA impose a duty to measure and record aspects of water use and requires that 'the licensee shall measure the amount of water supplied to each farm or user on a monthly basis using an appropriate flow measurement device'. The WRC has published reports and guidelines for the direct and indirect measurement of water on irrigation schemes in response to the practical need to measure and manage water effectively and efficiently. However, in most cases the water-management system currently in operation does not incentivise water measurement, and consequently measurement of water use and volumetric charging is not widely practised.

This project facilitated a process towards effective implementation of water measurement at river, irrigation scheme and farm level in South Africa. In order to achieve this, end users of water-measurement technology were made aware and convinced to adopt the technology. Specific attention was given to technical constraints and financial justification for implementation of the technologies for water measurement. This required purposeful capacity building and training of end-users such as farmers, while using the model of 'train-the-trainer', which has been found to be most successful.

Emerging trends suggest that water meters are becoming increasingly important, as they provide irrigators with vital information to help improve or protect profits. The cost of water meters is easily quantified, with the capital cost of a meter usually insignificant compared with the capital cost of the pumps, pipes, filters and other components that comprise the irrigation system itself. It is difficult to quantify the benefits of metering as clearly as the costs; however, water meters can and do offer significant value to irrigators in South Africa.

Due to rapidly rising electricity costs and the threat of curtailments to existing lawful water use in over-allocated catchments, there is

significant pressure on irrigators to improve their irrigation practices. Decision support may be required and measuring devices have a role to play in helping irrigators remain financially viable.

In this process a common understanding of the practical requirements of water measurement by water users, water managers and regulators had to be reached. Therefore it was necessary to obtain support of the DAFF and DWA on training for adoption of water measurement.

Since water user associations (WUAs) will increasingly provide an advisory role, the managers of WUAs, and leader farmers whom they serve, were targeted in order to achieve sustainable implementation of water measurement. The intention was to interact with these stakeholders as part of the preparatory phase; determine the incentives for water measurement as part of the analysis phase; and practically demonstrate how to undertake effective water management in the implementation phase. The final output of this technology transfer project is an overarching report that documents the implementation process, the lessons learned and guidelines towards general implementation of water measurement.

Counting frogs in the Kruger National Park

They may not count among the traditional big five, but this does not make the conservation of frogs in the KNP any less important. Like many freshwater species, frog populations are declining globally. In South Africa, 25 species of amphibians are classified as threatened or as near threatened, more than 20% of the total number of species. There are many factors that threaten their survival, including habit destruction and pollution.

Even animals living within the confines of national parks are not safe from these influences. About 10% of the KNP's frogs and toads live in the park's rivers, while the remainder converge at smaller, seasonal wetlands during breeding season. These habitats are especially vulnerable to air and water pollution.

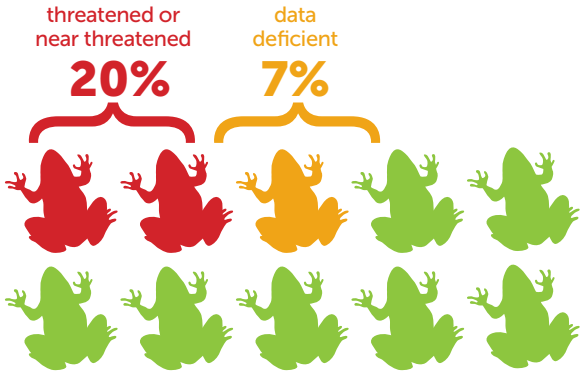
During the year under review, the WRC concluded the first in-depth study of amphibian populations of the KNP. The study assessed the biodiversity of frogs associated with the major pans and rivers of South Africa's most iconic nature reserve, as well as the physical and chemical factors affecting their distribution. Frogs were either physically identified and counted or identified through their calls.

The study confirmed the high biodiversity of frog species in the KNP. Up to 35 species of frogs were recorded per survey. This included several new records and voucher specimens collected for several species. It is no surprise that water was confirmed to be the main factor influencing amphibian biodiversity in the park. Rainfall is critical for the survival of the majority of frog species in the KNP as most frogs breed in shallow seasonal water bodies, such as temporary and seasonal pans, inundated grasslands and seasonal pools within rivers and streams. Another important factor for frog biodiversity is temperature.

Since water pollution and acid rain are already being experienced inside the KNP, another aspect of the amphibian study was to determine factors that may influence amphibian biology, distribution and population sizes. This part of the study focused specifically on the possible effect of decreasing pH levels (as a result of acid rain) on frog biology and ecology. It also determined how the presence of metals and organic pollutants could influence these amphibians. The latter was determined through histopathological, bioaccumulation and biomarker studies. Acid tolerance bioassays were undertaken with eggs as well as tadpoles of four frog species, using survival and development as endpoints.

Among others, the project highlighted the need for an ongoing frog monitoring project in the KNP to ensure the future of these amhibians in the national park. The study contributed significantly to ensuring that South Africa's most famous national park continues providing a sanctuary for all creatures no matter how great or small.

SUSTAINABLE DEVELOPMENT SOLUTIONS



A total of 25 species of amphibians are classified as threatened or as near threatened in SA, more than 20% of the total number of species. Another 7% are regarded as 'data deficient'.

Monitoring groundwater resources from space

DWA's series of reconciliation studies indicates that groundwater could be the answer for many municipalities facing water shortages, but good long-term monitoring and management are vital. The Overstrand Municipality of the Greater Hermanus Area has embarked on groundwater development to augment the water supply.

As a foundation for sustainable management of the groundwater resource, a detailed monitoring programme was developed for a better understanding of the hydraulic system, and of the interconnections between surface water, the shallow primary aquifer and the remarkable, deep, fractured-rock aquifer of the Table Mountain Group (TMG), which underlies a large part of the Western Cape. Several boreholes were drilled into a confined quarzitic aquifer, the Peninsula Formation, in the TMG. One of the production wells was found, on initial testing, to be one of the highest yielding of its kind in the Western Cape, producing more than 100 litres a second during a short air-lift blow test by the driller. Further drilling established two additional production boreholes.

The Hermanus groundwater project provided a unique opportunity to link the municipality's groundwater-monitoring system to an experiment where regional, space-based monitoring and continuous assessment was undertaken of the deep groundwater resource, augmenting the conventional methods of water-resource monitoring. The aims of the WRC-funded project were to demonstrate the use of high-precision global navigation satellite system (GNSS) technology as a tool for groundwater resource monitoring and assessment; to develop the methodology for relating GNSS measurements of aquifer behaviour; and to build South African capacity to establish the hydro-geodectic technical infrastructure and implement the data-processing methods required for groundwater resource monitoring.

Much of the benefit of this project came in the learning-by-doing experience. Considerable effort went into development of the methodology in order to build local capacity in the area of hydro-geodetic analysis, with a secondary focus on the analysis and interpretation of results in the study area.

This study, through its involvement in particular aspects of GNSS technology related to water resources, contributes substantially to a broadening of the vision towards enhanced earth observation capacities through the full spectrum of geosphere levels, from lithosphere to hydrosphere, atmosphere and ionosphere. From this local experiment, an innovative methodology is expected to emerge for regional, space-based monitoring and continuous assessment of deep groundwater resources, augmenting the conventional methods of water-resource monitoring.

HUMAN CAPITAL DEVELOPMENT IN THE WATER SCIENCE SECTOR

007

It is widely recognised that capacity building and sustainable knowledge transfer are critical concerns for several sectors in South Africa, and the water sector is no different. The loss of intellectual assets is a major threat to effective water management, particularly in water-scarce countries such as South Africa where the onus has traditionally been on the scientific community to find technological solutions for sectoral challenges.

South Africa's young water professionals are challenged with developing their skills and finding mentors to help them do so. Building skills and capacity is an integral part of all WRC-funded research. All the Commission's projects are encouraged to have a component of student participation where possible. The majority of WRC projects are able to comply.

Building a strong core of new generation water scientists

A cornerstone to water security in South Africa is to have a ready pool of skilled talent. Having good knowledgeable people at all levels of water value chain management is critical. This is an area of great challenge for South Africa. In the science and technology domain, the WRC is managing to support the training of some 500 post-graduate (Masters and Doctorate) students in its projects each year. Our research portfolio is also adjusting to train and mentor new research leaders.

During the year under review, the WRC continued to place strong emphasis on building research capacity in South Africa as well as supporting a number of related capacity-building initiatives. In many areas of research supported by the WRC, it is evident that students who participated in earlier WRC projects are now leading WRC-funded research projects and/or are serving as members of steering committees as well as reviewers of new proposals.

Number of post-graduate students involved in WRC-funded projects :

494
2012/13

In addition to its support for the training of students, the WRC initiated and supported a number of national capacity-building initiatives. These included support to national and local government as well as the development of new training material for different levels of learners and for academic institutions.

WRC 101 for project leaders

In the 2009/10 year the WRC developed an informative one-day course/workshop for aspiring and new project leaders to understand the WRC research cycle. The course shows participants the research priorities of the WRC and the fund allocation for each of the priorities; how to prepare a comprehensive proposal, with tips provided to improve the chances of success; and how to manage the technical, administrative and financial aspects of a WRC project. It also provides an understanding of the contractual and financial audit requirements and also the resources available to enhance the success of the project. Four regional courses were held in the year under review.

Techno Girls Programme

The WRC 'adopted' four girl learners during the year as part of Government's Techno Girls Initiative. The initiative identifies high-achieving 15- to 18-year-old school girls from previously disadvantaged communities. The girls are placed in corporate mentorship and skills development programmes. The girl learners are provided with access to the world of work, to enable them to take up scarce-skills careers guided by the South African economy. The programme maintains an exclusive focus on careers in the science-related fields. During the year under review, the WRC Techno Girls were exposed to various career paths and options through job shadowing of role models.

SAICE Aqualibrium Schools Water Competition

During 2012/13 the WRC became the main sponsor of the Aqualibrium Schools Water Competition, hosted by the South African Institution of Civil Engineering. The competition, which celebrated its ninth year in 2012, tasks school teams to design a model water distribution network to distribute three litres of water equally between three points on a grid using two different diameter pipes and connection pieces. Teams are then judged on how well they execute the task – working on a penalty system. This year's winners were the all-girl team from Domino Servite School in Richards Bay. Apart from raising learners' awareness of water issues in general, the competition strengthens government initiatives aimed at encouraging learners to take mathematics and science at school and to pursue a career in the water sector.


WATER
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